AEOD TECHNICAL REVIEW REPORT

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SUBJECT: **REVIEW OF MANUAL VALVE FAILURES**

SUMMARY

Recognizing that system unavailability could be compromised due to manual valve failures such as mispositioning or mechanical failures, a review of manual valve failures in light water reactors (LWRs) was conducted. Data on valve failures was obtained using the Nuclear Document System (NUDOCS), sequence coding and search system (SCSS) and Nuclear Plant Reliability Data System (NPRDS) databases. Data retrieved from NPRDS was generally for mechanical failures. Data retrieved using NUDOCS and SCSS included manual valve failures caused by human performance problems and design errors. Data obtained with NUDOCS and SCSS were incomplete due to problems with available search strategies.

NPRDS provided a large amount of data for physical failures of manual valves. NPRDS data consisted of approximately 6200 manual valve failures. These data were correlated with 68 LER reports which included 5 events considered important using AEOD screening criteria. Results of the review of this data indicated there were 20 plant systems with 20 or more reported failures for the same kind of manual valve.

The NUDOCS search did not retrieve any of the important LERs. The problem was caused by the available search strategies using key words. The SCSS database had similar problems in searching for manual valve failure events.

There were no events discovered in this study, including the five important events, that severely compromised plant safety. In addition trending of manual valve failures indicate, in general, that large valves (18-inches) fail by normal wearout, 6-inch valves fail due to random mechanical failures and 2-inch valves fail due to packing problems. Additional searches could be made of detailed failure categories of the manual valves; however, based on the present survey, this additional effort does not seem warranted at this time.

1. INTRODUCTION

This study is a systematic survey of manual valve failures and degradations observed in LWRs from 1985 to 1992. Manual valve failures are caused by either human performance errors or physical change resulting in mechanical failure. Both mechanical and human performance caused valve failures were reviewed. Three sources of data were used. First, the Nuclear Document System of Advance Design (NUDOCS/AD) (Reference 1) was used to obtain information from licensee event reports (LERs), preliminary notification (PN) reports, 50.72 reports, inspection reports, notice of violations and NRC internal memorandums. Second, SCSS (Reference 2) was used to obtain operational events including manual valve failures reported by LER. Third, NPRDS (Reference 3) was used to retrieve manual valve failure data reported by the operating nuclear plants. In addition to these three sources of information, technical study reports by the Office for Analysis and Evaluation of Operational Data (AEOD) were also reviewed.

The SCSS identified 656 LERs which satisfied the search conditions. The NPRDS search resulted in approximately 6200 reported manual valve failures. NPRDS records were correlated with 68 LERs where 5 were identified as important events by the AEOD review process. Finally there was one AEOD engineering evaluation report which was based on a manual valve failure (AEOD/E230, "Water in the Lube Oil Tank at Surry Power Station, Unit 2-Additional Information," Reference 4).

2. DISCUSSION

The main purpose of a manual valve is to either allow, adjust or block fluid flow through a pipe. Manual valves are used to isolate systems, block backup emergency fluids and block bypass flow. The amount of fluid flow can be controlled (throttled) by adjusting the opening of a manual valve. Hundreds of manual valves are used throughout a nuclear power plant for controlling the flow of fluids.

Some typical systems that use manual valves are feedwater systems, letdown purification system, low pressure and high pressure safety injection systems, shutdown cooling systems, chemical and volume control systems, various service water systems, steam line systems and reactor coolant systems. Manual valves used in reactor systems are usually globe valves, stop check valves, ball valves, gate valves and butterfly valves. Sizes of manual valves found in this study varied from half inch gate valve to 36-inch butterfly valves.

2.1 NUDOCS DATA

NUDOCS was used to obtain list of manual valve failure events. The manual valve failure events were obtained by searching event reports in NUDOCS which contained the key words of "manual valve" and "failure." The search resulted in finding 127 reports from 1985 to 1991. Each event report was retrieved and reviewed. A detailed review indicated only 36 of the 127 reports were actual, manual valves failures. Most of the manual valve problems were either maintenance or human performance problems such as mispositioning, failure to lock in position, inadvertent openings and switched labels. In addition, there were some manual valve problems due to design error and mechanical failures. Table 1 lists the plant, report number and the summary of the failure for the 36 events. Twenty-three of these 36 events were caused by human performance problems, 12 due to mechanical failures and 1 by design error.

The search of NUDOCS data using the combination of key words of "manual valve" and "failure" resulted in identifying 188 event reports. Using a starting date of January 1, 1985, reduced the 188 reports to 127. When the search combination of key words were changed from "manual valve" and "failure" to "manual," "valve," and "failure," the number of reports satisfying this logic increased to 2850; approximately 15 times more. Our review of some of the titles of 2850 reports indicated most were not manual valve failures.

None of the LER events retrieved with NUDOCS using key words of "manual valve" and "failure" were important events. On the other hand, an NPRDS search was correlated with 5 important LERs caused by manual valve failures. The reason why NUDOCS failed to retrieve these LERs was due to LERs not using the word "failure" in the reports. Instead of "failure," LERs used words such as: "inoperable," "declared out of service," "isolation," "leakage," and "closed." Based on this experience, NUDOCS is not an efficient method of obtaining data on manual valve failures.

2.2 SCSS DATA

Oak Ridge National Laboratory (ORNL) searched the SCSS database for LERs reporting manual valve failures. The search was limited to data between 1986 through 1991. Two sets of search conditions were used as follows:

1. Find LERs reporting valves which were found opened, closed, mispositioned, or which transferred open or closed. Of these LERs, locate those with the word "manual" in the abstract.

2. Find all other LERs reporting valves which were found opened, closed, mispositioned or which transferred open or closed due to the operation or failure of a manual valve actuators.

The search found 573 LERs for the first search condition and 83 for the second search condition. ORNL provided 656 LER abstracts which were found during the search. Comparing the LERs found with SCSS with the LER list obtained with NPRDS, found only 5 LERs were identical. Our review of the LER abstracts obtained with SCSS indicated most of the LERs had the word "manual," but very few had "manual valve failure," and the data was not complete. Only one of the 5 LERs was an important event.

ORNL has stated that events are coded based upon all information submitted in the LER, not just the information in the abstract. A mispositioned manual valve may be discussed in the LER without specific mention in the abstract. Also it is important to recognize that many valves are not clearly identified as manual valves by the licensees in the LER. Thus, many other LERs in SCSS may involve manually operated valves but are not readily identifiable. The SCSS found one important LER due to operational failure of manual valve.

2.3 NPRDS DATA

Using NPRDS, a search was made to obtain all reported manual valve failures between January 1, 1985, and June 1, 1992. Manual valve size was restricted to between 0.5 inch to 60 inches. Approximately 6200 failures were reported during this period. In addition to the failure mode, the following information was obtained from each reported failure: 1. NSSS, 2. Unit ID, 3. System, 4. Valve Manufacturer, 5. Model number and LER report number if issued. The NPRDS search found 68 LERs which reported manual valve failures including all 5 important LERs.

In order to reduce data to manageable size only manual valves with 20 or more failures were tabulated. NPRDS failure data indicated 20 operating reactor systems at 20 sites had 20 or more manual valve failures of same type valve (manufacturer and model number). A summary of these 20 systems are tabulated in Table 2. This table contains data on reactor systems, manufacturer, model number, number of failures, type of manual valves, sizes and main causes of failures.

Table 2 indicates a 6-inch manual globe valve manufactured by Consolidated Valve Corporation had 57 failures; mostly in the steam system due to mechanical adjustments and normal/abnormal wear. Table 2 also indicates another 6-inch globe valve manufactured by Industrial Valve Corporation had 78 failures mostly in the main steam system due to valves being out of calibration and set point drift.

In order to review the causes of manual valve failures, three different sizes of valves with three different types were picked from Table 2 for comparison. Description of the causes of valve failures are tabulated in Tables 3, 4, and 5. These valves consisted of

18-inch manual gate valves, 6-inch manual diaphragm valves, and 2-inch manual globe valves.

Table 3 lists the cause of failure for 18-inch manual gate valve manufactured by Crane Company. These valves had 39 failures mainly in the condensate system. The main cause of failure for this 18-inch gate valves were due to aging.

Table 4 lists the cause of failure for ITT Grinnell Company's 6-inch manual diaphragm valves. Most of the failures occurred in the service water system. Most of the failures are caused by mechanical breakdown.

Table 5 lists a failure cause for Yarway Corpora s 2-inch manual globe valves. Most of the failures were caused by worn packing. In addition to the valve packing problems, there were other mechanical problems.

Based on this review, most of the failures were age related. Trends and type of mechanical failures cannot be determined from present NPRDS cause data. Further, more detailed searches must be made to determine the trends and magnitude of various mechanical failures. Therefore no blanket general judgement can be made about failure causes from the present data.

2.4 AEOD REPORTS

There was one AEOD study which concerned a manual valve failure entitled "Water in the Fuel Oil Tank at Surry Power Station, Unit 2-Additional Information," (AEOD/E230) dated July 7, 1982. Due to inadvertent opening of manual valve, water from the fire suppression system got into the fuel oil tank at Surry Unit 2 plant. Corrective action taken by the licensee included locking and tagging the manual valve.

3.0 DESCRIPTION OF IMPORTANT EVENTS

Of the 68 manual valve failure LERs reported by NPRDS, 5 were classified as important events by the AEOD review process. These events are described briefly below.

LER 311/85-018 (Salem Unit 2) (Reference 5). "Component Cooling Water Heat Exchanger Service Water Flow Rate Below Required Value." On August 27, 1985, the "22" component cooling water (CCW) heat exchanger (HX) service water outlet valve (an 18 inch manual butterfly valve) failed to the closed position. Attempts to jack the valve open failed to adequately restore service water flow through the HX. As the redundant CCW HX "21" was out of service for maintenance at the time, Technical Specification 3.0.3 was entered, and the plant was shut down.

The malfunction of the manual butterfly valve was attributed to a vibration induced failure which eventually caused the valve actuator to separate from the valve stem. The vibration resulted from a previous removal of the cavitrol tube bundle from 22 CCW HX service water control valve, due to plugging and deterioration of the tube bundle. Subsequent investigation by the licensee revealed that operation with this tube bundle removed caused turbulence downstream of the control valve. Because of the close proximity of the control valve to the HX outlet valve, the turbulence caused the service water outlet valve to vibrate, ultimately resulting in actuator separation. The corrective action by the licensee consisted of replacing the valve actuator and installing a new cavitrol tube bundle for the HX outlet valve. The Accident Sequence Precursor (ASP) program calculated $7x10^{-6}$ conditional core damage probability for this event. The safety significance of this event was that with one CCW HX isolated and service water flow was restricted to the other, sufficient cooling could not be guaranteed for the CCW system to remove the heat from the minimum safeguards equipment during normal and accident conditions.

LER 250/86-001 (Turkey Point Unit 3) (Reference 6). "Auxiliary Feedwater System-Steam Supply Stop Check Valves." While Unit 3 and Unit 4 were at 100 percent power, auxiliary feedwater system steam supply stop check valves 3-10-119, 3-10-219 and 3-10-319 were declared out of service. Both plants (Turkey Point Units 3 and 4) were then shut down for further inspection and repair. The guide studs for the valves were found broken during a special radiography inspection of the system. Degradation of disc and disc nut assembly of the 3-inch manual stop check valves were due to prolonged low steam flow condition caused by slight leakage through a normally closed motor operated valve. The flow rate did not keep the disc of the check valve open and chattering eventually caused excessive wear to the valve internals. The valves were subsequently repaired, post maintenance tested satisfactorily and returned to power. The safety significance of this event is that with the disc studs broken, the stop check valves would open and provide full flow through them and the guide studs are only provided to insure positive seating of disc and seat ring of the stop check function during the closing cycle. A difficulty could arise from the discs not seating properly while closing the valves. This function is required to prevent backflow from an intact steam generator to a faulted steam generator. In addition there is a potential for fragmented pieces from the studs entering the auxiliary feedwater pump turbines and/or being trapped in the trip and throttle and governor valves.

LER 346/87-011(Davis-Besse Unit 1) (Reference 7). "Reactor Trip From Full Power Caused by Improper Control Rod Movement." During cooldown from a plant trip on September 6, 1987, attempts to place decay heat loop No. 2 in service resulted in a reduction of pressurizer level. A void was suspected as having formed in the low-pressure injection (LPI) system. The void was most likely caused by nitrogen coming out of solution due to leakage past 10-inch stop check valve DH76. The ASP program calculated $6x10^{-6}$ conditional core damage probability for this event.

The cause of the nitrogen gas void in the LPI system was determined to be nitrogen blanket gas from the core flood tanks. The nitrogen gas, in solution at high pressure, leaked through valve DH-76 into a system at a much lower pressure, flashing out of solution and forming the void over a long period of time. The cause of the leaking valve is suspected to be just a worn out valve. The licensee promised to refurbish DH-76 during the next refueling and until valve DH-76 could be repaired, a procedure was written to establish vent path for venting the gas before initiating decay heat removal. The safety significance of this event is that the problem caused by DH-76 could hamper the operation of decay heat removal system.

LER 414/90-002 (Catawba Unit 2) (Reference 8). "Technical Specification Violation for an Inoperable Manual Containment Isolation Valve due to Management Deficiency." A 6-inch containment isolation valve, the main steam supply to auxiliary feedwater pump, could not be closed (a manually operated gate valve). This problem was discovered during quarterly performance testing of the auxiliary feedwater pump. The licensee found the bearing assembly, for manual handwheel operator, disintegrated. Bearing failure was due to lack of proper lubrication as the handwheel bearing had not been lubricated since 1986. In addition, the valve stem had been damaged due to the bearing failure.

For corrective action, the licensee replaced the bearing assembly and stem. After functional testing, the valve was returned to service. The licensee established a preventive maintenance program to replace the bearing assembly every 36 months. The safety significance of this event is that failure to close the manually operated gate valve would have resulted in not being able to isolate steam to the turbine driven pump if required during accident conditions.

LER 281-91-005 (Surry Unit 2) (Reference 9). "Reactor Coolant System Leakage Exceeded Technical Specification Limits due to the Mechanical Failure of Isolation Valve." With the plant in hot shutdown, operations personnel discovered that the reactor coolant system loop 'C' resistance temperature device manifold isolation valve was leaking at a rate above ten gallons per minute, which is a violation of technical specification for total reactor coolant system leakage. A limiting condition for operation was entered and notification of unusual event was declared. The valve (Velan Valve Corp. 3-inch manual gate valve) was disassembled and it was discovered that the stem and disk had separated. The root cause of the fracture is thought to be wear-out and aging of stem disk assembly.

Following an engineering review by the licensee, the valve internals were removed and a blank cap was installed. This effectively removed the valve from service. The licensee made a design change to remove the resistance temperature device bypass lines and install the devices on the main reactor coolant system lines. The safety significance of this event is that leakage from the 3 inch isolation valve could have become a small break LOCA.

4. DATA RETRIEVAL AND EVALUATION

Manual valve failures are caused by either human performance errors or physical change resulting in mechanical failure. Some of the human errors are caused by shutting the valve when it should be opened or vice versa, labeling errors, tagging errors, errors in flow path alignment and design errors. Physical change of manual valves may be caused by mechanical damage to the internal structure such as a damaged stem or failed disk. Internal changes are also caused by excessive wear due to age, or debris in the fluid or degradation of valve packing. Three sources were used to obtain data on manual valve failures (NUDOCS, SCSS and NPRDS). Problems occurred with two of these sources.

In searching for manual valve failure reports using NUDOCS, problems developed because of the search scheme for the following reasons:

1. The word "manual valve" may be replaced with words such as "isolation" or "stop valves" in the text of the report without changing the meaning of the report.

2. The word "failure" may be replaced with words such as "out of service," "leakage," "closed," and "failed."

3. The number of reports increased by factor of 15 when manual and valve were separated as two words in the search. This means thousands of reports had to be read to obtain all the reports.

Failures listed in Table 1 obtained from NUDOCS are mostly for human related errors with some mechanical failures of manual valves. Twenty-three of 36 failures in Table 1 were human related where either the manual valves were left open, closed or mislabeled. The failures were evenly distributed among the plants except for Arkansas 1 and 2. Arkansas 1 had 4 failures and Arkansas 2 had 2 failures.

SCSS problems developed because SCSS searches were mainly for human related errors during plant operations. Problems with the SCSS searches also occurred because of difficulty in determining valve status from available information.

Manual valve failures were also examined using NPRDS. Since there are large numbers (approximately 6200 reported manual valve failures in NPRDS) a scheme had to be developed to evaluate the data.

A scheme required generating several sets of data which could be cross referenced. First, a table was generated which listed valve manufacturer, valve model number, type of valve, size of valve and number of valve failures from January 1, 1985, to present. Second, another table was generated which listed the plant name, system where failure occurred, valve manufacturer, valve model number and number of failures. Third, a list

of LER numbers with the failure date and the plant name was prepared. Then the failure history and description of a specific manual valve was obtained. In order to obtain the main causes of various valves listed in Table 2, descriptions and cause of failures were printed out for approximately 1000 valve failure events. This set of data gave good cross referencing for reviewing the manual valve failures.

As shown in Table 2, most of manual valve failures occurred in the main steam line, chemical and volume control system and high-pressure safety injection/low-pressure safety injection systems. The failures consisted of various sizes and types of manual valves. These valves were manufactured by various manufacturers; and there was no single manufacturer with outstanding failures. A large number of valves failed due to aging. For the purpose of this study, three sizes of valves were selected to examine in further detail. These are shown in Tables 3, 4, and 5.

Table 3 lists the cause of failure for the 18-inch manual gate valves. Inspection of the causes indicate most of the failures were due to age and wear.

Table 4 lists the 6-inch manual diaphragm valve failures. Inspection of the causes indicate failures were mainly caused by mechanical failure.

Table 5 lists the cause of failure for the 2-inch manual globe valves; most of the failures were caused by problems of packing or problems associated with packing.

5. FINDINGS AND CONCLUSIONS

Review of manual valve failures between 1985 to 1992 indicate human related problems with manual valves were evenly distributed among plants. There were no plants that appeared to have unusually high numbers of human related failures connected with manual valves. In general, mechanical failures of manual valves also appear evenly distributed among plants.

Failures tabulated in Table 3 indicate large manual valves (18-inches) fail by normal wear and aging.

Cause of failures of 6-inch manual valves was mainly due to mechanical failures as shown in Table 4. The cause of failure for smaller valves (2-inch), shown in Table 5, are mainly due to valve packing problems.

These findings show that:

- large manual valves fail due to normal wear
- 6-inch manual valves fail due to mechanical failures
- 2-inch manual valves fail mainly due to packing problems

There does not appear to be a systematic or pervasive problem associated with manual valves. Therefore, additional study does not seem warranted at this time.

REFERENCES

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3. The Institute of Nuclear Power Operation, "Nuclear Plant Reliability Data System (NPRDS)," INPO 87-024 Rev. 04, 1991.

4. Wayne D. Lanning and N. Trehan, "Water in the Lube Oil Tank at Surry Power Station, Unit 2-Additional Information," AEOD/E230, July 1982.

5. Public Service Electric & Gas Co., Licensee Event Report 50-311/85-018, Salem, Unit 2, September 9, 1985.

6. Florida Power and Light Co., Licensee Event Report 50-250/86-001, Turkey Point, Unit 3, February 14, 1986.

7. Toledo Edison Co., Licensee Event Report 50-346/87-011, Davis-Besse, Unit 1, October 6, 1987.

8. Duke Power Co., Licensee Event Report 50-414/90-002, Catawba, Unit 2, March 2, 1990.

9. Virginia Power Co., Licensee Event Report 50-281/91-005, Surry, Unit 2, June 27, 1991.

Table 1
Summary of Manual Valve Failures Reported in NUDOCS from January 1985 to July 1992

Plant Name	Type of Report	Report Number	Description of Failed Events
Arkansas 1	Inspection Report	85-027	Failure to maintain manual valve locked
Arkansas 1	Inspection Report	86-015	Failure to lock manual valve in position
Arkansas 2	Inspection Report	88-023	Failure to maintain closed
Vogtle 1	Inspection Report	[illegible]1-015	Operational problem
Palisades	LER	85-001	Wrong position
Rancho Seco	LER	85-005	Manual valve was closed
LaSalle 2	LER	85-036	Manual valve partially open
Wolf Creek	LER	85-063	Left manual valve closed
Susquehanna 1	LER	86-002	Leaky manual valve
Yankee Rowe	LER	86-010	Manual valve not shut all the way
Palisades	LER	86-017	Labels switched
Arkansas 2	LER	86-017	Mislabeled and mispositioned
Palisades	LER	86-017	Valves 1060FPC and 1060GPC transposed in drawing
Zion 2	LER	86-020	Mispositioned manual valve
Zion 1	LER	86-023	Mispositioned manual valve
Millstone 3	LER	87-046	Improper manual valve line up
Catawba 1	LER	87-048	Problem turning, stiff manual valve
McGuire 2	LER	88-004	Opened accidentally
Sequoyah 1	LER	88-021	Incorrect valve number
Arkansas 1	LER	89-008	Failure to detect design change error
Limerick 2	LER	89-008	Manual isolation valve found closed
Palisades	LER	89-012	Failure of valve yoke-nut threads
Beaver Valley 1	LER	90-001	Leaky manual valve
Catawba 2	LER	90-002	Manual valve could not be closed
Duane Arnold	LER	90-002	Personnel error during tagout
Vermont Yankee	LER	91-005	Leaky manual valve
Peach Bottom 3	LER	91-006	Mispositioning of manual valve
Maine Yankee	LER	91-007	Operational problem (locked, unlocked)

Table 1 (cont.)
Summary of Manual Valve Failures Reported in NUDOCS from January 1985 to July 1992

Plant Name	Type of Report	Report Number	Description of Failed Events
Surry 2	LER	91-010	Manual valve failure to close
Indian Point 2	LER	91-019	Diaphragm separated from stem
Peach Bottom 2	LER	92-002	Instrument air bypass manual valve open
Arkansas 2	Notice of Violation		Failure to close
Catawba 1	Notice of Violation		Failure to verify manual valve closed
Limerick 1	PNO	I-86-048	Leak on manual LPCI injection valve
Turkey Point 4	PNO	II-87-75	Mispositioned manual valve
Arkansas 1	PNO	IV-88-96	Leak occurred when valve opened (HPI)

Table 2
NPRDS Manual Valve Failure Data
Twenty or More Failures per Plant System

Reactor System (See Abbrev.)	Manufacturer	Manufacturer Number	Type of Valve	Valve Size (Inches)	Number of Failures	Main Cause of Failure
MSL	Industrial Valve Corp.	3707R	Globe	6	78	Out of calibration set point drift
LPSI	Rockwell Int/Flow Control	3624F316J	Globe	2	66	Prev. repair/installation status. Normal wear
LPSI/RCS	Rockwell Int/Flow Control	3624	Globe	2	58	Normal/abnormal wear. Aging/ cyclic fatigue
MSL	Consolidated Valve Corp.	3707R	Globe	6	57	Mechanical adjustment. Normal/abnormal wear.
MSL	Dresser Industries – Valve & Inst. Division	950W	Gate	2	54	Normal/abnormal wear
MSL	Crane Valve Prod/Crane Co.	33 1/2 XC	Gate	18	42	Abnormal stress. Aging/cyclic fatigue
CS	Crane Co.	33 1/2	Gate	18	39	Aging/cyclic fatigue
NSW	Pratt, Henry Co.	2F11	Butterfly	20	38	Aging/cyclic fatigue
SW	ITT Grinnel	SD-C-101870	Diaphragm	6	35	Mechanical binding/adj. Normal/abnormal wear
CS	Yarway Corp.	5515-BSA-105	Globe	1	35	Normal/abnormal wear
CVCS	IIT Grinnell	3X42D	Diaphragm	3	35	Aging/cyclic fatigue
CS, MFW, MSL	Yarway Corp.	5515B	Globe	2	34	Normal/abnormal wear
CVCS	Yarway Corp.	5515B	Globe	2	34	Prev. repair/installation weld related
CS	Power, William Co.	3003WE	Gate	18	32	Lubrication problem. Normal/abnormal wear
RCS	Rockwell Int/Flow Control	3624F316	Gate	2	32	Normal/abnormal wear. Aging/cyclic wear

Table 2 (cont.)
NPRDS Manual Valve Failure Data
Twenty or More Failures per Plant System

Reactor System (See Abbrev.)	Manufacturer	Manufacturer Number	Type of Valve	Valve Size (Inches)	Number of Failures	Main Cause of Failure
MSL	Pacific Valves/Mark Con	2955H	Gate	8	30	Normal/abnormal wear
LD	Velan Valve Corp.	B-12-354B-13MS	Gate	4	26	Mechanical Normal/ Abnormal wear
HPSI	Borg-Warner Corp.	CN-1500-1009J-276	Globe	1.5	26	Wearout & leaky packing
CVCS	IIT Grinnell	2-X42D	Diaphragm	2	22	Normal/abnormal wear. Aging/cyclic fatigue
RCS	Kerotest Mfg. Corp.	CN-1500-2409-502	Globe	2	22	Mechanical damage. Normal/abnormal wear

Note Abbreviation

Abbreviation	**Definition**
CS	containment spray
CVCS	chemical volume control
HPSI	high-pressure injection
LD	letdown
LPSI	low-pressure safety injection
MSL	main steam line
NSW	nuclear service water
RCSW	reactor coolant
SW	service water

Table 3

Cause of 18-Inch Manual Gate Valve Failures
Manufactured by Crane Company

Cause of Valve Failures	Number of Failures
Degradation of grease seal due to normal wearout	1
Leaking due to obstruction of inspection mirror	1
Handwheel fallen off due to wear and aging	2
Leaking through seat and disc due to normal wearout	3
Unable to open due to broken teeth on gears (wear and aging)	4
Degraded packing due to normal wear	6
Body to bonnet leak (age and wear)	22
TOTAL	39

Table 4
Cause of 6-Inch Manual Diaphragm Valve Failures
Manufactured by ITT Grinnell Company

Cause of Valve Failures	Number of Failures
Overtightened and handwheel missing	1
Handwheel separated from stem	1
Valve stem and bushing stripped due to abnormal stress	1
Normal wearout of flanged gasket	1
Broken manual actuator	1
Mechanical damage	1
Valve stem travel stop nut was out of adjustment	1
Setscrew on valve handwheel loose or broken	2
Missing stem	3
Spiral pin missing from spindle valve bonnet	1
Bonnet assembly missing finger pin	1
Pin which secures handwheel to shaft had fallen out	1
Valve stem damaged or broken	2
Stem separated from diaphragm	5
Diaphragm ruptured (damaged)	6
Leaking due to failed diaphragm (wearout)	7
TOTAL	35

Table 5
Cause of 2-Inch Manual Globe Valve Failures
Manufactured by Yarway Corporation

Cause of Valve Failures	Number of Failures
Valve stem corroded caused binding	1
Dirt in the seat area cracked valve open	1
Slight gouge in the main valve seat causing excessive internal leakage	1
Backseat bushing eroded due to normal wear	1
Disc assembly being pitted and eroded	1
Unknown	1
Normal wear and cyclic fatigue	2
Previous surveillance hydro test in putting abnormal stress on packing	3
Worn packing causes leak through the seat due to aging	23
TOTAL	34