JUN 15 1990

Mr. Bill Fitzgerald
Fisher Controls
Highway 380 East
McKinney, TX 75060

Dear Mr. Fitzgerald:

Subject: Preliminary Case Study Report on Solenoid Valve Problems at U.S. Light Water Reactors

A preliminary AEOD case study report, "Solenoid Valve Problems at U.S. Light Water Reactors," is enclosed. The study analyzes and evaluates operational experience and safety implications associated with failures and degradations of solenoid-operated valves (SOVs) at U.S. LWRs. It focuses upon the vulnerability of safety-related equipment to common-mode failures or degradations of SOVs.

The report presents information on more than 25 events in which common-mode failures or degradations of over 600 SOVs were affected, or had the potential to affect, multiple safety systems or multiple trains of individual safety systems. Although plant safety analyses do not address such common-mode failures or degradations of safety systems, operating experience presented in the report indicates that they have occurred and are continuing to occur.

A number of events in which safety systems have been adversely affected by degradations or failures of SOVs are considered significant precursors. The case study notes that SOV problems permeate almost all U.S. nuclear power plants, and that they encompass many aspects of the SOVs' design, maintenance, and operation. The case study also notes that individual SOV manufacturer's practices regarding guidance with respect to testing and maintenance contribute towards the observed problems. The report presents six recommendations which, if implemented, should reduce reactor accident risks by reducing the likelihood for common-mode failure or degradation of SOVs affecting multiple safety systems or multiple trains of individual safety systems.

In accordance with our "peer review" process, prior to the finalization and distribution of our case study reports, we are providing you and other vendors who provided input to the case study with a copy of the preliminary report for review and comment. We request that you focus your review primarily on the accuracy and completeness of the technical details (i.e., comments are being solicited on the technical accuracy of the report). The findings, conclusions, and recommendations are provided for your information in order that you may understand the significance we place on these events and, therefore, obtain a more complete picture of the total report. Changes to the findings, conclusions, and recommendations will be considered only if the underlying information concerning the details of plant design or systems operation is in error. We ask that comments be provided in writing.

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Since we wish to finalize and issue the report shortly, we ask that any comments be received by us within 30 days from receipt of this preliminary report. If you require additional time beyond that point, please let us know.

If you or your staff have any questions regarding this study, please feel free to contact me or Dr. Hal Ornstein at (301) 492-4439.

Sincerely,

Original signed by:
Thomas M. Novak
Thomas M. Novak, Director
Division of Safety Programs
Office for Analysis and Evaluation
of Operational Data

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PRELIMINARY CASE STUDY REPORT

SOLENOID VALVE PROBLEMS

AT U.S. LIGHT WATER REACTORS

June 1990

Prepared by:

Dr. Harold Ornstein

Reactor Operations Analysis Branch
Office for Analysis and Evaluation
of Operational Data
U.S. Nuclear Regulatory Commission

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EXECUTIVE SUMMARY

The study analyzes U.S. light water reactor (LWR) experience with solenoid-operated valves (SOVs). It focuses upon the vulnerability of safety-related equipment to common-mode failures or degradations of SOVs. The report presents information on over twenty events in which common-mode failures or degradations of over 600 SOVs affected, or had the potential to affect, multiple safety systems or multiple trains of individual safety systems. Although plant safety analyses do not address such common-mode failures or degradations of safety systems, operating experience presented in the report indicates that they have occurred, and are continuing to occur.

The events in which common-mode failures of SOVs have affected multiple trains of safety systems or multiple safety systems are important precursors. They indicate that actions are necessary to assure that important plant systems function as designed in accordance with plant safety analyses, and that plants are not subject to unanalyzed failure modes with the potential for serious consequences.

The report analyzes the operating experience and it outlines the root causes of common-mode failures and degradations that have been observed, and provides recommendations to significantly reduce the occurrence of common-mode SOV failures.

Analysis of operating data indicates that the underlying or root causes of many SOV failures are the users' lack of knowledge or understanding of SOVs' requirements or capabilities, such as: SOVs' intolerance to process fluid contamination; the necessity for preventive maintenance or changeout; and the propensity for rapid aging and deterioration when subjected to elevated temperatures. Compounding the problem is the fact that some SOV manufacturers do not provide the users with adequate guidance regarding proper SOV maintenance and operation. Further complicating the situation is the fact that many SOVs are "unrecognized" i.e., they are provided as piece-parts of larger components so that the end users have a restricted knowledge of the SOVs' operation and maintenance requirements, or their useful design life.

The report addresses widespread deficiencies which were found in the areas of: design/application, maintenance, surveillance testing, and feedback of failure data.

It is recommended that for safety-related applications, licensees: (1) verify the compatibility of SOV design and plant operating conditions; (2) verify the adequacy of plant maintenance programs; (3) ensure that SOVs are not subjected to fluid contamination (e.g., instrument air); (4) review SOV surveillance testing practices; and (5) verify that all SOVs which are used in safety-related applications have been manufactured, procured, installed and maintained commensurate with their safety function to assure operation consistent with plant safety analyses.

Specific technical information supporting these broad recommendations is contained throughout the report. Detailed recommendations are provided in Chapter 9.

In addition, it is recommended that an industry group such as INPO take action to improve the mechanism for feeding back SOV failure data to the manufacturers for early detection and resolution of potential generic problems.

1 INTRODUCTION

All U.S. light water reactors (LWRs) rely upon solenoid-operated valves (SOVs) to perform safety-related and non-safety-related functions. SOVs are used to operate with hydraulic and pneumatic fluids under a wide variety of conditions. They are used to control process fluid either directly, or indirectly as pilot controllers. It has been estimated that the population of SOVs in safety systems at U.S. LWRs is between 1,000 and 3,000 per plant (Ref. 1). Boiling water reactors (BWRs) usually have more SOVs than pressurized water reactors (PWRs), because of the extensive use of SOVs in BWR scram systems.

Many SOVs used in nuclear power plants are dedicated/qualified valves, which have undergone vigorous qualification testing to standards such as the Institute of Electrical and Electronics Engineers (IEEE) Standards 323, 344 and 382, and are manufactured in accordance with the Nuclear Regulatory Commission (NRC) requirements of Title 10 of the Code of Federal Regulations, Part 50 (10 CFR Part 50), Appendix B, and 10 CFR Part 21. However, we have also found many cases in which plants use commercial, nonqualified SOVs to perform safety-related functions.

This study was initiated after several licensees experienced repetitive failures of SOVs at their plants and after the simultaneous failure of four SOVs at the Brunswick 2 plant on January 2, 1988 (Ref. 2). The Brunswick event resulted in a loss of containment integrity when two sets of redundant SOVs failed to close upon demand. The NRC Office for Analysis and Evaluation of Operational Data (AEOD) has reviewed and participated in follow up work that the licensees, the NRC regional inspectors, and the valve manufacturers have performed following the SOV failures at Brunswick and several other plants.

A number of other significant operational events have occurred involving malfunctioning SOVs. Previous studies of SOV failures (Refs. 1, 3, 4, 5) discussed SOV failure rates and provided a characterization of the degradations or failures. This study addresses root causes and the generic nature of many of the observed failures.

Some of the significant events discussed in this report are:

- Emergency diesel generator (EDG) failures at Perry and Catawba
- MSIV failures at Perry, Brunswick, Grand Gulf, LaSalle and River Bend
- AFW System degradation at Calvert Cliffs and North Anna
- Losses of containment integrity at Kewaunee, North Anna, and Brunswick
- BWR scram system component failures at Susquehanna, Brunswick and Dresden
- Safety Injection System degradation at Calvert Cliffs

Chapters five and six of this study provide comprehensive reviews and evaluations of operational experience and potential safety implications associated with SOV problems at U.S. LWRs. This study provides several recommendations to address the major deficiencies which were noted during the review of the operating experience.

2 DESCRIPTION OF EQUIPMENT

There are many manufacturers and varieties of SOVs used at nuclear power plants. SOV operation is based upon changing the electrical status of the valve's electro-magnetic coil, which in turn causes a shift of the position of an internal core. The core acts to open or block the passageways inside the valve, changing the flow path within the valve. A simplified version of a two-way SOV is illustrated in Figure 1. Figures 2 through 4 illustrate other more complex SOVs which are made by three different manufacturers.

SOVs are available for use over a wide range of temperature and pressure conditions for liquid and gas service. They are available with the following formats:

- normally open or normally closed
- fail open, fail closed, fail as is
- normally energized or normally de-energized
- ac or dc power, or both ac and dc power
- two-way valves, three-way valves, four-way valves
- direct lift, pilot assist, balanced disc, gate, modulating control.

There is a wide range of sophistication and quality of SOVs. For example, mass-produced SOVs are available for home consumption for a few dollars each, whereas a limited production of high-quality SOVs are available at a much higher price. SOVs that are qualified for Class 1E nuclear service (meeting IEEE Standards 323, 344, 382, American National Standards Institute (ANSI) N45.2 and 10 CFR Part 50, Appendix B, and 10 CFR Part 21 requirements and having American Society of Mechanical Engineers (ASME) Section III "N" or "NPT" stamps) may cost several thousands of dollars.

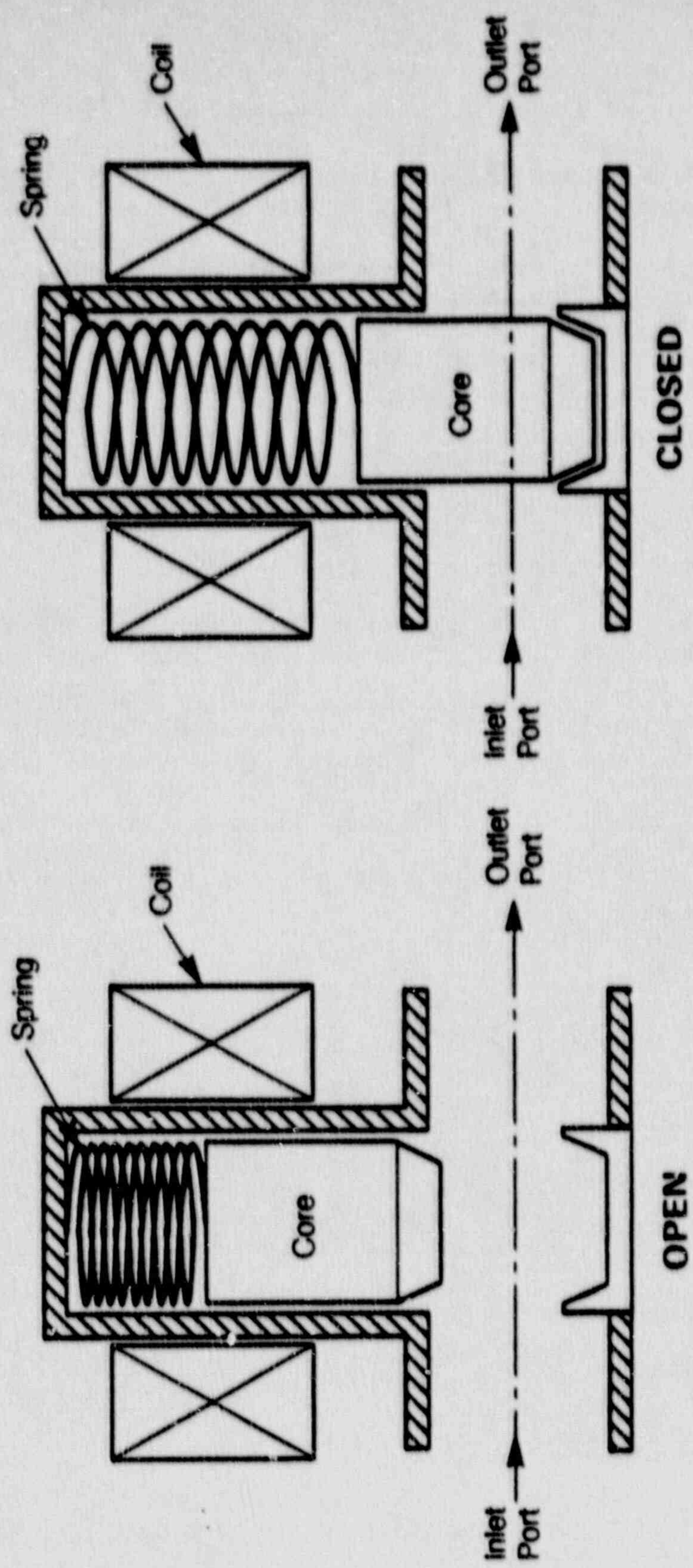

Figure 1
Simplified Diagram of a Two-Way Solenoid-Operated Valve

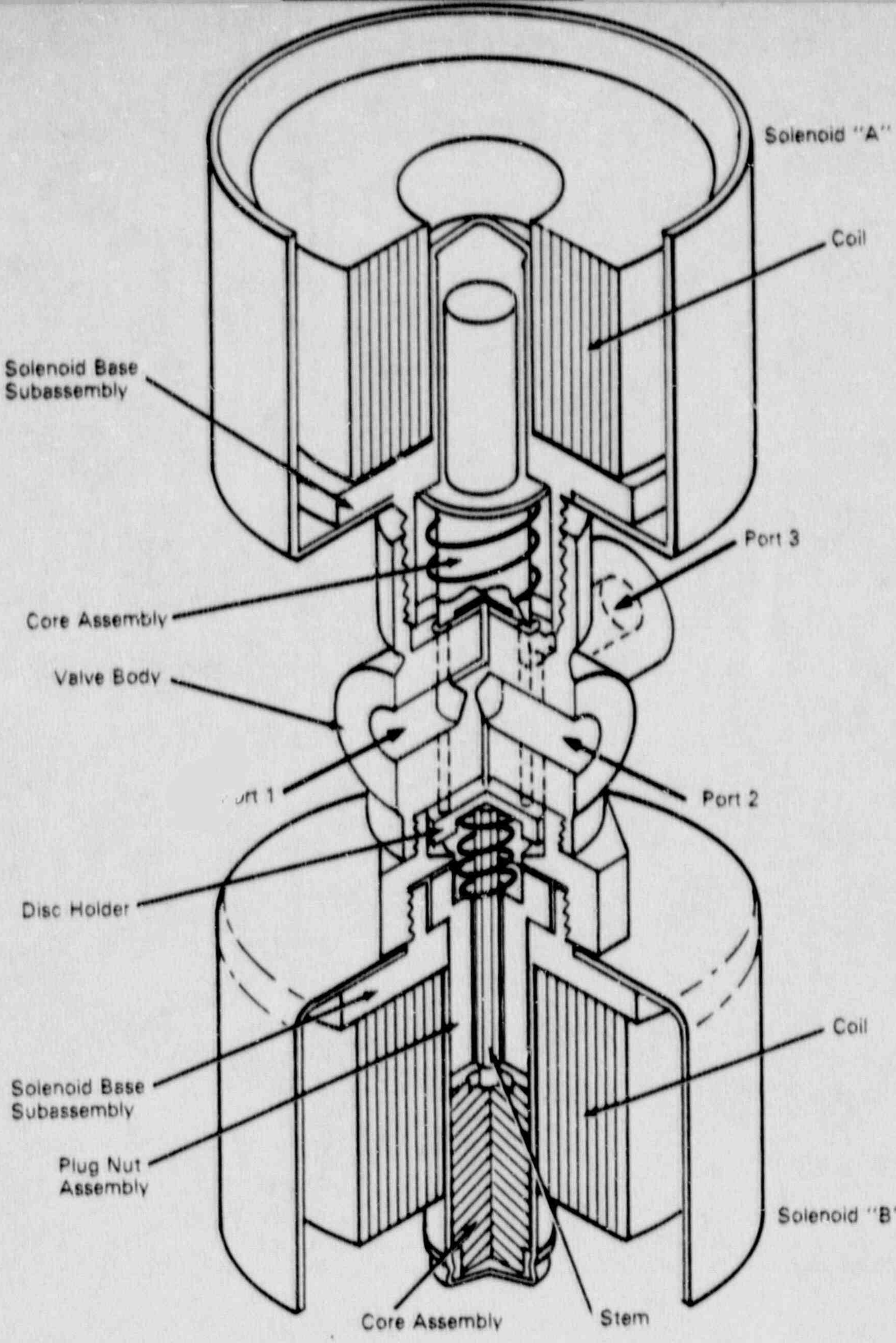

Figure 2
Isometric Drawing of ASCO Dual-Coil 8323 Solenoid-Operated Valve

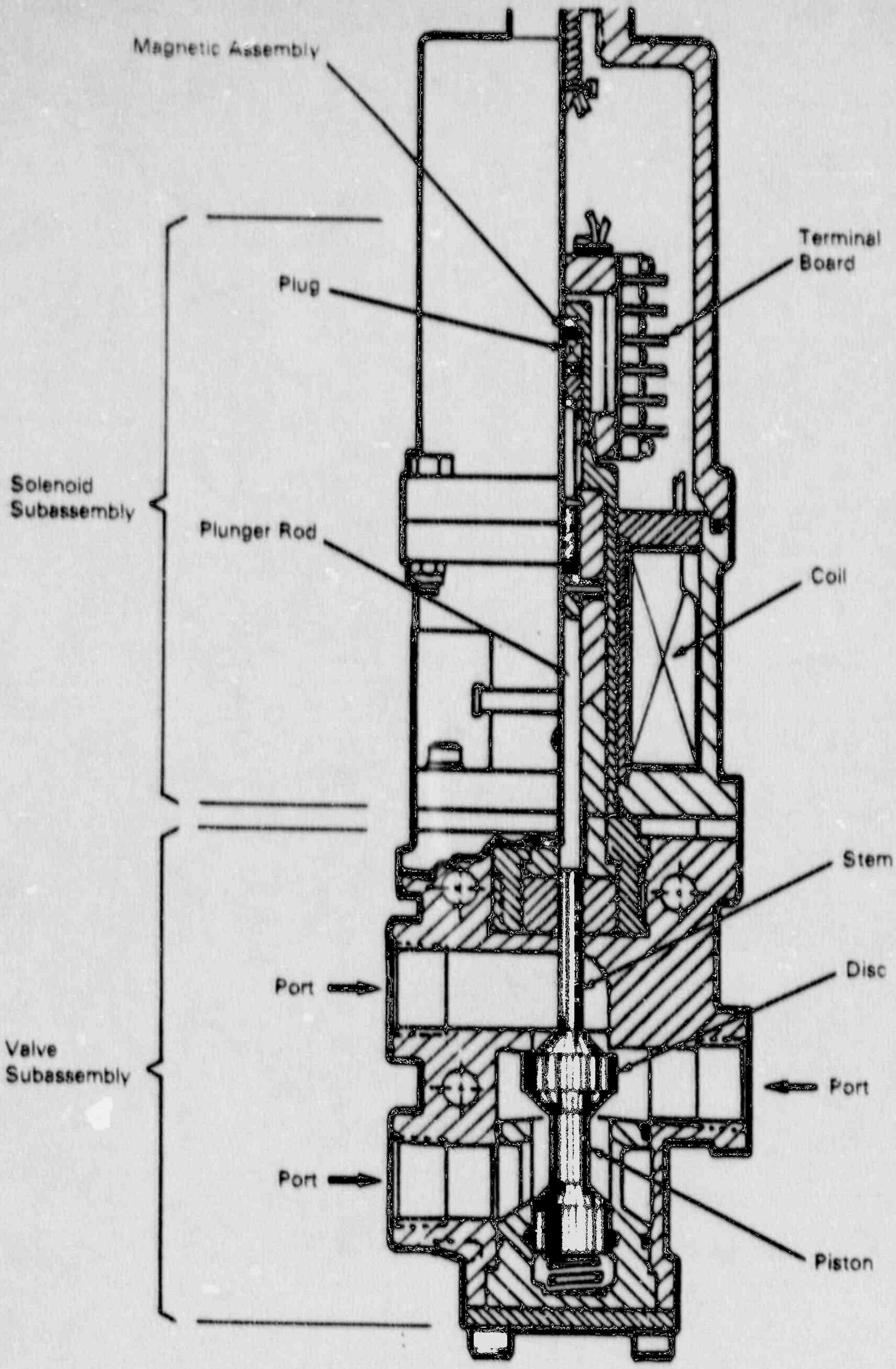

Figure 3
Schematic Drawing of a Valcor Solenoid Operated Valve

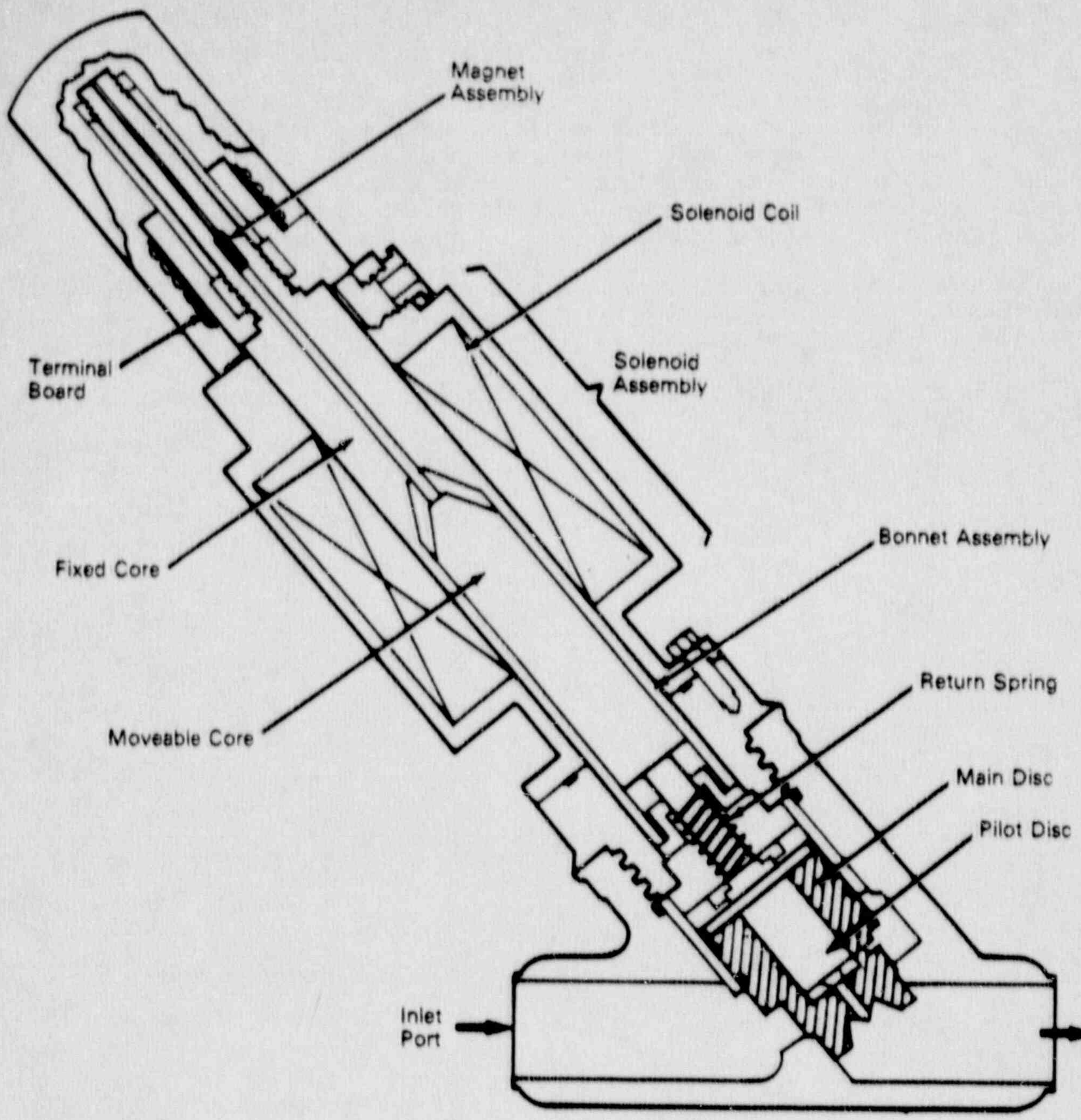

Figure 4
Schematic Drawing of a Target Rock Pilot Assisted Solenoid Operated Valve

3 USE OF SOLENOID-OPERATED VALVES

In many applications SOVs are used as alternates to motor-operated valves (MOVs). SOVs are frequently used as pilot operators to control air-operated valves (AOVs). The advantages of using SOVs instead of MOVs are that they generally have fewer moving parts, are compact and may be easier to mount. They also have low power requirements and have fast response times. Some SOV manufacturers' literature claim that SOVs have long qualified lives, have low initial and installed costs, and require low maintenance.

The use of AOVs, MOVs and SOVs is a matter of preference of application that is determined by the utility, nuclear steam system supplier, and architect engineer; their specific utilization is not a licensing requirement.

Table 1 lists many of the systems that use SOVs at U.S. LWRs.

Table 1 Systems Which Use SOVs at U.S. LWRs

1. BWR Scram
2. PWR Rod Control
3. Reactor Coolant (RCP seal)
4. Safety Injection
5. Auxiliary Feedwater
6. Primary Containment Isolation
7. High Pressure Coolant Injection/Reactor Core Isolation Cooling
8. High Pressure Injection
9. Automatic Depressurization
10. Emergency Diesel Generator
11. Instrument Air
12. Chemical Volume Control/Charging and Letdown/Boration
13. Pressurizer Control
14. Steam Generator Relief (PORVs, ADVs)
15. Low-Temperature Overpressurization Protection
16. Decay Heat Removal/Residual Heat Removal
17. Component Cooling Water
18. Service Water
19. Reactor Head Vent
20. Steam Dump
21. Reactor Cavity/Spent Fuel/Fuel Handling
22. Torus and Drywell/Vent and Vacuum
23. Emergency DC Power
24. Main Steam (Main Steam Isolation Valves/Auxiliary Boiler)
25. Reactor Building/Auxiliary Building (Ventilation and Isolation)
26. Main Feedwater
27. Condensate
28. Moisture Separation/Reheat
29. Containment Atmosphere/Containment Spray
30. Standby Gas Treatment
31. Floor/Sump Drain
32. Sampling (normal and post-accident)
33. Fire Suppression
34. Turbine/Generator
35. Reactor Building Purge
36. Containment Air Lock
37. Leak Detection
38. Radwaste

4 SOLENOID-OPERATED VALVE FAILURE MODES: APPARENT AND ROOT CAUSES

Previous studies (Refs. 1, 3, 4, 5) have noted that details of the failure mechanisms, the apparent causes, or the root causes of SOV failures were not provided in approximately half of the licensee event reports (LERs) and nuclear plant reliability data system (NPRDS) failure records for years 1978 through 1984.

Appendix A of this report provides a listing of approximately 200 LERs describing SOV failures which occurred at U.S. LWRs between 1984 and 1989. The apparent and root causes of most (approximately 75 percent) of the SOV failures reported in LERs between 1984 and 1989 are given below:

a. Coil failure or burnout that was attributed to design or manufacturing deficiencies (early failure/end of life) or an error in application (type of current, voltage level, environmental conditions). [11%]

b. Valve body failure or leakage that was attributed to design or manufacturing deficiencies, such as excessive tolerances on internal parts; excessive wear/degradation of gaskets, O-rings, seals, or springs; or foreign particulates preventing proper sealing. [13%]

c. Passageway blockage/internal binding that was attributed to contaminants such as dirt, corrosion products, desiccant, water or moisture, incorrect lubricants, excessive lubrication, or hydrocarbons. [9%]

d. Electrical malfunctions that were attributed to faulty internal wiring, reed switch shorts or external wiring with inadequate connections, splices, or grounds. [12%]

e. Design errors or misapplications that were attributed to incorrect valve configuration (normally open vs. normally closed; normally energized vs. normally de-energized); incorrect designation of "fail-safe" condition; incorrect electrical source (ac vs. dc, voltage level); incorrect designation of environmental conditions (temperature, moisture, radiation); incorrect designation of maximum operating pressure differential; incorrect material selection (incompatibility between elastomeric parts and process fluid contaminants); incorrect valve orientation (horizontal vs. vertical). [13%]

f. Installation errors that were attributed to incorrect physical orientation (backwards, upside-down), electrical source (ac vs. dc, voltage level), or inadequate electrical connections (e.g., loose connections, incorrect grounds). [7%]

g. Maintenance errors that were attributed to incorrect determination of useful life or time between overhauls; inadequate preventive maintenance or incorrect preventive maintenance. [7%]

h. Sticking that was the result of unidentified foreign substances coating valve internals, excessive use of lubricant, or foreign particulates. [5%]

5 OPERATING EXPERIENCE: SIGNIFICANT EVENTS INVOLVING COMMON-MODE FAILURES OR DEGRADATION OF SOVS

The events described below were chosen as a representative set. They should not be construed as being a complete set of common-mode failures and degradations of SOVs. Additional events are tabulated in Appendix A. Many other SOV failures fall below NRC reporting requirements, and as a result are not captured in the LER data base.

Many individual SOV failures not reported in the LER data base are reported in the Nuclear Plant Reliability Data System (NPRDS) data base. Reference 1 noted that for 1978-1984 data, all SOV failures reported in LERs were also reported in NPRDS.

5.1 <u>Design Application Errors</u>

Representative operating experience illustrating design application errors associated with high ambient temperature, internal heatup from energization, incorrect maximum operating pressure differential and incorrect valve orientation are described below. Based on this experience, findings and recommendations relevant to design application errors are provided in Sections 7.1 and 9.1 respectively.

5.1.1 Ambient Temperatures

5.1.1.1 MSIVs at Perry - Excessive Heat From Steam Leaks

On October 29, 1987, while performing stroke time testing, three of the plant's eight MSIVs failed to close within the plant Technical Specifications' allowable time of five seconds. Two of the MSIVs were in the same main steamline. During subsequent testing, each of the three valves closed within the Technical Specifications value.

Since the valves all stroked satisfactorily subsequent to their initial failures, the licensee believed that the failures were due to the presence of impurities in the air pack SOVs controlling the MSIVs, and that the impurities were apparently discharged during subsequent MSIV operation. As a result, the three MSIVs that had failed were declared operable.

These MSIV air packs consist of a single-coil 4-way SOV (ASCO NP8320), a dual-coil 3-way SOV (ASCO NP8323) and three poppet type air pilot-operated valves (2, 3, and 4-way CA Norgren Co.). A photograph of one of the Perry plant's MSIV air packs appears in Figure 5.

In response to NRC concerns, the licensee performed additional MSIV stroke testing. As a result on November 3, 1987, the inboard and outboard MSIVs in the "D" line again failed to close within the required 5 seconds (outboard MSIV closed in 2 minutes and 49 seconds and the inboard MSIV closed in 18 seconds). Additional MSIV stroke tests were performed, and both MSIV's again closed within the Technical Specification allowable times.

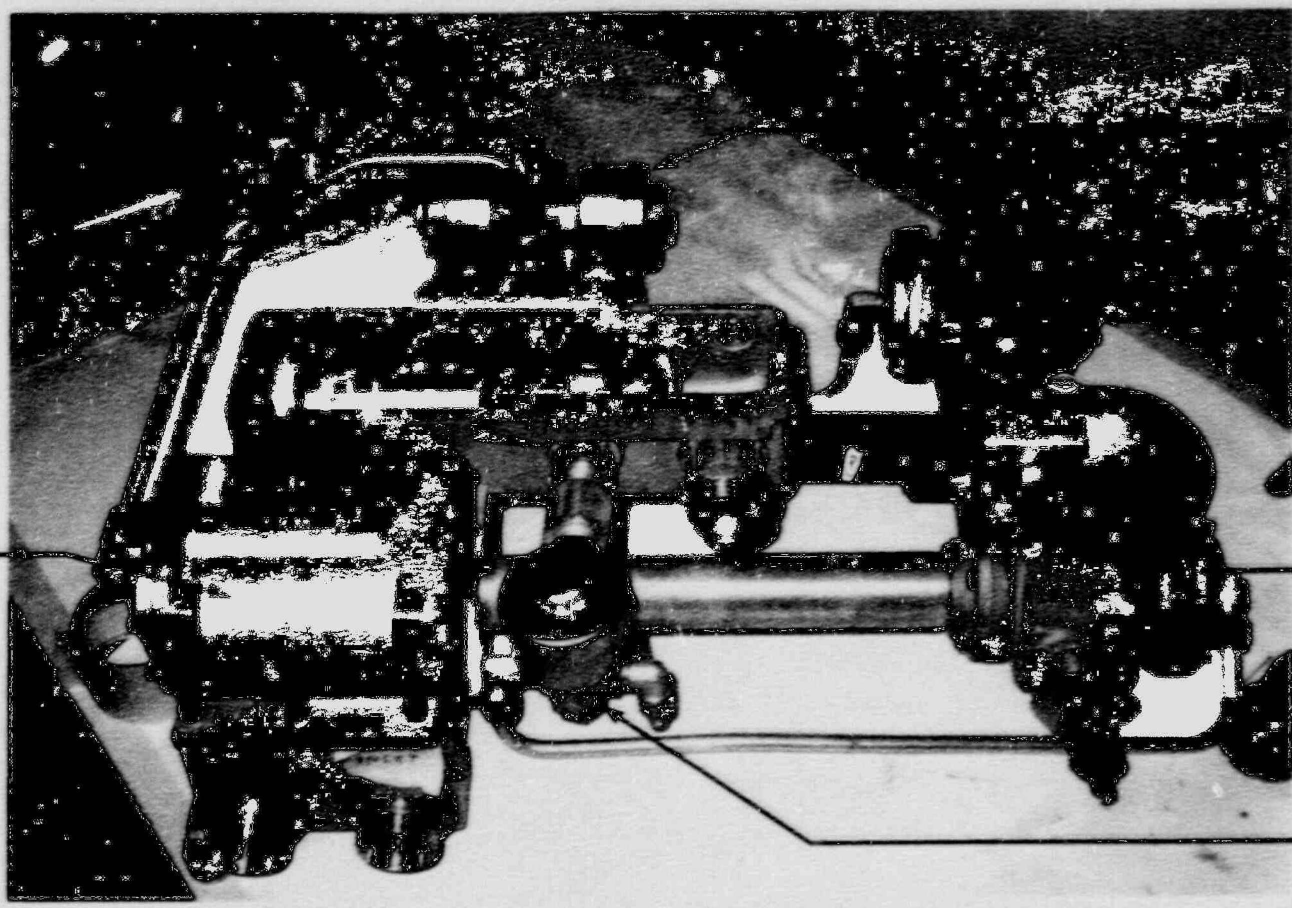

Figure 5
MSIV Air pack from Perry Nuclear Power Plant, November 1987

Because of continued NRC concerns about MSIV reliability, the licensee shut down the plant and established a plan to find the root cause of the MSIV failures (Refs. 6, 7, 8). Intense investigative efforts were conducted by the utility to determine the root cause of the MSIV failures. The failures of the MSIVs on both October 29 and November 3, 1987, were attributed to the failure of the ASCO dual-coil Model NP8323 SOVs to shift position upon de-energization. The SOVs failed to shift position because of degradation of their ethylene propylene dimer (EPDM) seats and discs. The degradation was caused by high temperatures that had existed in the vicinity of the SOVs as a result of several steam leaks. Originally, hydrocarbon intrusion was suspected as having contributed to the degradation of the EPDM seats and discs. It was not until microscopic and spectral analyses were performed at an independent laboratory a month after the event that the possibility of impurities from hydrocarbon intrusion was eliminated as a root cause of these failures (Ref. 9). However, as part of its corrective action to prevent future failures, the licensee took steps to improve the maintenance of the instrument air system. In addition, the licensee undertook an aggressive program to review the effects of all known steam leaks that could affect other safety-related equipment.

5.1.1.2 MSIVs at Crystal River 3 - Thermal Aging - Incorrect Estimation of Ambient Temperatures

In April 1989, NRC inspectors reviewed the environmental qualification of electrical equipment at the Crystal River 3 plant. Their review found that errors had been made in the licensee's determination of the service life of 16 normally de-energized SOVs that are used to pilot the plant's MSIVs (Ref. 10).

The licensee's determination of SOV service life was made assuming an ambient temperature equal to the weighted average of the temperature of the areas where the SOVs were located. The licensee's calculations did not consider the localized elevated temperatures that the SOVs were subjected to as a result of hot process piping. Recalculation of the service life of the SOVs using representative ambient temperatures reduced the estimated service life of the SOVs from 40 years to 8 years. As a result, the licensee is replacing those SOVs sooner than previously anticipated.

5.1.1.3 Millstone 2 - Thermal Aging - Localized "Hot Spots" in Containment

In November 1988, an NRC inspection report (Ref. 11) noted that Millstone 2's environmental qualification program recognized a significant shortening of the qualified lifetime of eight Valcor SOVs that are used for pressurizer and reactor vessel head vents. Originally the SOVs were calculated to have qualified lives of 40 years based upon an ambient temperature of 120°F. Although the plant's Technical Specifications require that the "primary containment average air temperature" does not exceed 120°F, the licensee found localized "hot spots" of 157°F in the vicinity of the eight SOVs. The licensee determined that the increase in ambient temperatures from 120°F to 157°F shortened the lifetime of the SOVs from 40 years to 12 years. The problem of equipment degradation due to localized hot spots is not unique to Millstone 2. Reference 12 lists several other plants that have experienced localized thermal "hot spots" inside containment. In addition, NRC Information Notice 89-30 (Ref. 13) noted that similar heating events have been reported since 1982. The information notice alerted licensees to the potential for exceeding equipment's qualification specifications when the bulk temperatures are measured by a limited number of sensors that indicate acceptably low average temperatures.

5.1.2 Heatup from Energization

5.1.2.1 Grand Gulf 1 MSIVs - Thermal Aging (Self-Heating From Energization)

On August 14, 1989, following a reactor trip, one MSIV (inboard "B" line) failed to close upon demand (Refs. 14, 15, 16). The MSIV did close about 30 minutes later. The failure of the MSIV to close was attributed to the failure of an ASCO dual-coil NP8323 SOV, a piece-part of the MSIV air pack. The licensee's investigation found a piece of EPDM from the SOV's disc on the SOV's outlet port screen. The licensee concluded that the piece had been lodged in the SOV's internals, thereby keeping the SOV from venting control air and hence keeping the MSIV from closing. It is believed that after the EPDM piece became dislodged from the internals, the MSIV closed.

Subsequent inspections by the licensee of all eight ASCO dual-coil NP8323 SOVs piloting the MSIVs disclosed that all eight had degraded seats. Initial visual inspection did not reveal the degradations, which became apparent under microscopic examination. The EPDM seats of all eight SOVs had cracks. However, on six of them, the raised portion of the seat, formed by the annular impression made by the seat of the exhaust port, was missing. It appeared that six of the eight SOVs had experienced similar sloughing of material from the seat.

The August 14, 1989 failure is believed to have been caused by a piece of the EPDM disc material which had been extruded into the SOV's exhaust port vent hole. The extruded material had separated from the disc as a result of the adhesive and frictional forces when the normally energized SOV was de-energized. The frictional and adhesive forces eventually led to the tearing off of the extruded parts of the EPDM discs.

The extrusion of EPDM discs is discussed in GE Service Information Letter (SIL) 481 (Ref. 17). SIL 481 notes that the intrusion of the disc into its exhaust port may account for previous events involving the sticking of similar EPDM dual-coil SOVs, but tearing of the discs had not been observed previously. It is believed that the tearing and overall degradation of the dual-coil SOVs' EPDM discs at Grand Gulf was symptomatic of thermal degradation resulting from the excessive time the EPDM materials were exposed to high service temperatures. The EPDM discs had been operating at elevated temperatures due to the energization of the dual coils. The local temperatures inside the SOVs near the EPDM discs were approximately 325°F inside the inboard SOVs in a 135°F drywell and 305°F inside the outboard SOV in a 125°F steam tunnel. The SOVs had been in service for approximately 4.5 years. However, the qualified lives of the degraded EPDM discs are estimated to have been 2.2 years for the inboards and 3.2 years for the outboards based upon environmental temperatures of 135°F for the inboard SOVs and 125°F for the outboard SOVs.*

The NRC issued an information notice on this event, noting the life shortening effects of self-heating from coil energization (Ref. 18). Subsequently, ASCO issued a service bulletin providing licensees with heat up data for all their nuclear qualified SOVs (NP series). (Ref. 19).

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*Other EPDM discs in the same SOV which were exposed to slightly higher temperatures were estimated to have had qualified lives of 1.58 and 2.28 years, respectively.

5.1.2.2 North Anna 1 and 2, and Surry 1 and 2 - Thermal Aging (Self Heating Due to Energization)

In December 1986, Virginia Electric & Power Co. (Vepco) requested ASCO to provide information regarding the effects of "self heating" in continuously energized SOVs. ASCO's response indicated that a significant increase in temperature would occur and that the temperature increase could result in a significant reduction in the qualified life of the SOVs. The licensee recognized that previous estimates of SOV service life did not account for the effects of self heating (Refs. 20, 21). The licensee evaluated the affected SOVs and determined that, contrary to previous analyses, 125 SOVs would require replacement at North Anna 1 and 2 between the 1987 and 1989 refueling outages (Ref. 22). The SOVs affected piloted air-operated valves, many of which served containment isolation functions. The systems affected were: Safety Injection, Reactor Coolant, Main Steam, Component Cooling Water, Containment Vacuum, Radiation Monitoring, Sampling Systems, Instrument Air, Post Accident Hydrogen Removal, Heating and Ventilation, Steam Generator Blowdown, Gaseous Vent and Aerated Drains.

The licensee recognized that Surry 1 and 2 were similarly affected, and Vepco engineering informed personnel at the Surry station of this problem. Similarly, Surry 1 and 2 required early replacement of 58 ASCO SOVs because of self heating.*

It is interesting to note that the licensee for North Anna station stated in a Deviation Report (Ref. 21) that these findings were non-reportable because: "NRC and utilities are aware of this issue to some extent." In Reference 20, the licensee noted that it had learned of this problem initially from discussions with "industry representatives" at Equipment Qualification (EQ) seminars in late 1986.

5.1.3 Maximum Operating Pressure Differential (MOPD) - Multiple Plants

Many plants have experienced conditions in which SOVs failed or could have failed to perform safety-related functions because of excessive operating pressure differentials. Figure 6 is a schematic diagram of an SOV, illustrating how an operating pressure differential in excess of its maximum operating pressure differential (MOPD) can cause an SOV to malfunction. When the SOV is in the de-energized position, pressurized fluid enters the valve at port 2 and is blocked by the core assembly. If the pressure differential between ports 2 and 3 exceeds the MOPD, the overpressure could lift the core assembly, resulting in leakage of fluid from port 2 to port 1 and port 3.

In the energized position the core assembly is raised to block the exhaust port (port 3). However, the excess pressure would act to retard or prevent the core subassembly from dropping down (shifting) upon de-energization. As a result, de-energizing the valve would not assure the valve achieved its correct de-energized position (block off port 2).

*Telecopy communication between W. Murray, Vepco, and H. L. Ornstein, USNRC, December 19, 1989.

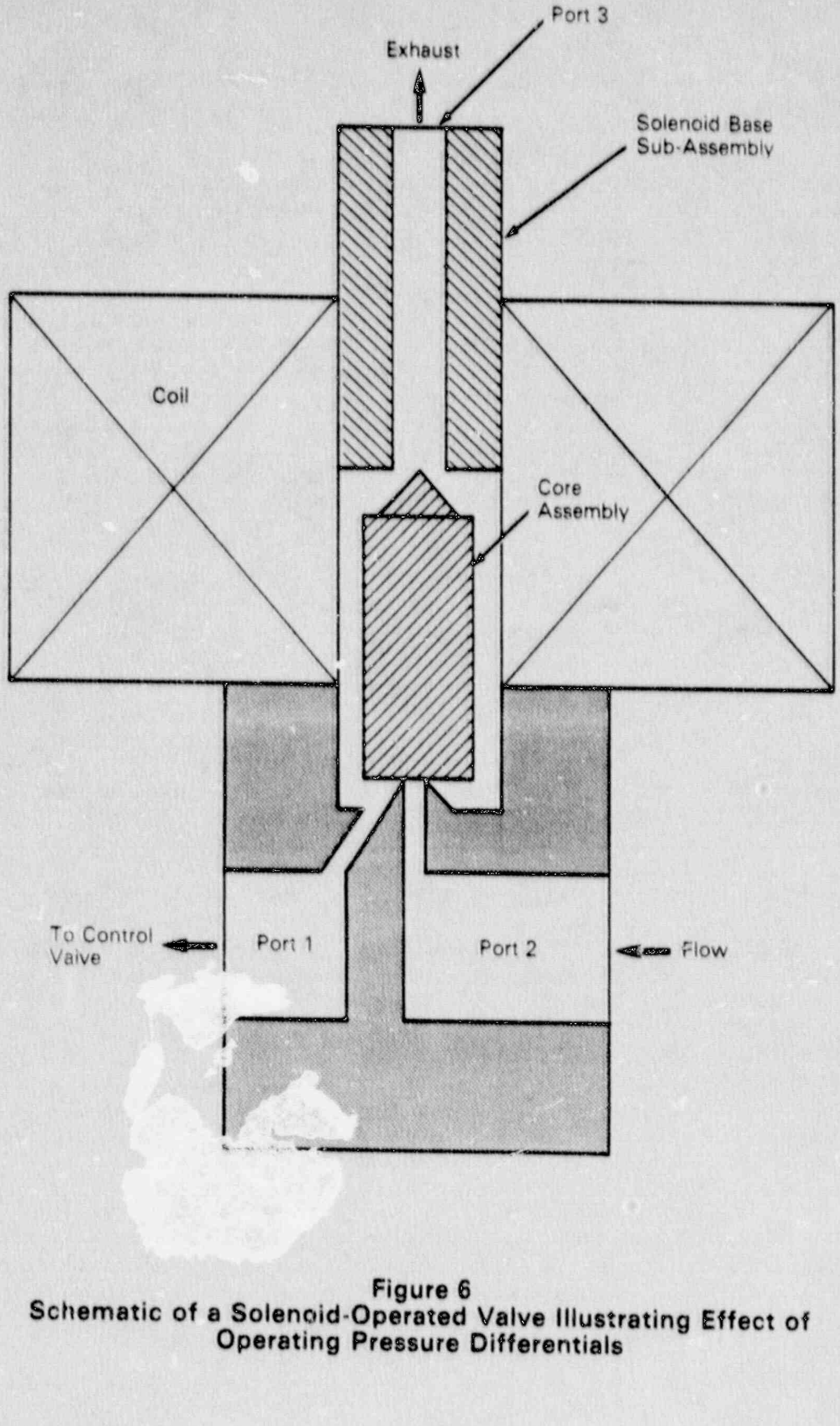

Figure 6
Schematic of a Solenoid-Operated Valve Illustrating Effect of Operating Pressure Differentials

For many SOVs, the MOPD rating does not appear on the nameplate or in the installation and maintenance instructions. Vendor catalogs need to be consulted to determine those SOVs' MOPD ratings.

In May 1988, the NRC issued Information Notice 88-24 "Failures of Air-Operated Valves Affecting Safety-Related Systems" (Ref. 23). It informed licensees of two SOV failures which were experienced at Kewaunee (Ref. 24) and of the potential for additional failures at Kewaunee and Calvert Cliffs 1 and 2 (Refs. 25-27). Subsequently, several licensees informed the NRC of similar discoveries in their plants, where the potential for overpressurizing SOVs exists, which could prevent the SOVs from performing their safety-related functions. At some plants, the task of verifying the potential for overpressurizing SOVs has been complicated by the fact that documentation is not readily available. For example, Millstone 1 and 2 (Ref. 28), Crystal River 3 (Ref. 29), have reported that documentation to identify SOVs in containment is not readily available, and that containment walkdowns are necessary for their identification.

It is not clear that Information Notice 88-24 has been effective in eliminating the potential for SOV overpressurization. Our concern is predicated upon Ref. 29 and a followup discussion in which the Crystal River 3 licensee stated that its review of the potential for SOV overpressurization assumed the proper operation of in-line pressure regulators, it did not address the consequences of pressure regulator failures.* One of the events described in Information Notice 88-24 involved the discovery at Calvert Cliffs that several safety systems were vulnerable to single failures of pressure regulators in the air supply system.

The earliest SOV overpressurization failures that we found occurred in 1980 at the Pilgrim plant. On October 7, 1980 and again on October 31, 1980, a safety relief valve (SRV) spuriously opened while the reactor was at power. On each occasion, the SRV did not reclose until the reactor was shutdown and the reactor coolant system was depressurized. The spurious valve openings were caused by excessive pneumatic (nitrogen) supply pressure to the SOV controlling the SRV. The high nitrogen pressure exceeded the SOV's MOPD, causing the SOV to shift position which caused the SRV to spuriously open.

The NRC issued an information notice and a bulletin on these events (Refs. 30, 31). Information Notice 80-40 (Ref. 30) indicated that two-stage SRVs with Target Rock SOVs are susceptible to such MOPD malfunctions, whereas older three-stage SRVs having ASCO or AVC SOVs are not. Bulletin 80-25 (Ref. 31) required licensees to review and upgrade their SRV pneumatic supply systems and/or SOVs to assure that the SOVs operate within their maximum operating pressure. The bulletin required licensees to install protective devices (such as relief valves) to protect the SOVs against excessive supply pressures.

The issue of overpressurization failures of SOVs in other systems was not addressed in the information notice or the bulletin.

The discovery of the potential for overpressurizing multiple SOVs at the Vogtle plant was reported in Reference 32. Reference 32 described a situation

*Telephone discussion between L. Kluit, Florida Power Corporation, and H. L. Ornstein, USNRC, October 10, 1989.

in which SOVs controlling the operation of all eight MSIVs could fail because of overpressurization due to overheating. The MSIV manufacturer (Rockwell) had noted that a small steam-line break in the vicinity of the plant's MSIVs could cause an increase in the hydraulic fluid pressure in excess of the SOVs' maximum operating pressure differential. These SOVs were manufactured by the Keane Company. As a result of SOV overpressurization, both MSIVs on one or more steam-lines could allow uncontrolled blowdown of more than one steam generator following a main steam or feedwater line break. Essentially, if the MSIVs' hydraulic actuator fluid heated up 12°F, a condition not bounded by the plant's safety analyses could result. The licensee's corrective action was to replace the SOVs with others having higher MOPD ratings.

In November 1987, the Kewaunee plant actually experienced two SOV failures caused by overpressurization (Ref. 24). During review of the two SOV failures, the licensee found that 58 additional SOVs could fail to perform their safety-related functions as a result of overpressurization.

In April 1988, the licensee of Calvert Cliffs 1 and 2 found that 40 SOVs could fail to perform their safety-related function as a result of overpressurization (Ref. 25)

In the case of TMI-1, (Ref. 32) the SOVs were connected to line pressures in excess of the maximum dictated by the SOVs' MOPD. In the case of Kewaunee and Calvert Cliffs 1 and 2, it was found that failure of a non-qualified pressure regulator under accident conditions could result in the SOVs being subjected to supply pressures in excess of the maximum allowed by the SOVs' MOPD.

Eight reported events in which SOVs failed, or had the potential to fail, to perform their safety-related functions as a result of excessive operating pressure differentials are briefly described below.

(1) Three Mile Island-1; October 17, 1980; (Ref. 32)

The following 11 containment isolation valves could have been prevented from achieving their safeguard positions:

- 2 makeup to core flood tanks
- 2 core flood tank sampling
- 1 reactor building vent
- 6 fan motor coolers for the reactor building cooling units.

(2) Vogtle-1; January 22, 1987; (Ref. 33)

- 8 main steam isolation valves could have failed to perform their safety function.

(3) Kewaunee; November 28, 1987; (Ref. 24)

- 2 containment isolation valves failed to close
- 1 pressurizer relief tank makeup
- 1 RCDT pump discharge (its redundant SOV had the potential for similar failure)
- 58 other SOVs in safety-related applications were also found to be subject to overpressure failure.

(4) Calvert Cliffs 1, 2; April 14, 1988; (Refs. 25, 26, 27)

The following 40 SOVs, equally distributed between Units 1 and 2, had the potential to fail:

- 8 auxiliary feedwater system
- 8 steam generator blowdown isolation system
- 6 reactor coolant pump bleedoff isolation
- 18 safety injection system (fill and vent)

(5) Pilgrim 1; July 19, 1988; (Refs. 34, 35, 36)

The following six SOVs had the potential to fail due to overpressure:

- 4 control room high efficiency air filtration system damper controls (2 in each train)
- 1 standby gas treatment system damper control
- 1 primary containment system RCS sample line isolation valve

(6) Millstone 2; October 8 1988; (Ref. 37)

One containment isolation valve failed as a result of an air pressure regulator that failed high.

(7) Millstone 1, 2 and 3; November 8, 1988; (Ref. 28)

Unit 1: The status of 16 SOVs in safety-related functions was unknown because of a lack of design information.

Unit 2: A total of 24 "harsh environment safety valves and their installed EEQ (sic) solenoid valves" could have failed as a result of overpressure (one of the 24 had failed on October 8, 1988). The licensee also noted that the status of an unspecified number of safety-related SOVs was undetermined because the "data base is incomplete as to solenoid make and model number."

Unit 3: Approximately 20 SOVs installed in "safety valve configurations" could have failed because of overpressurization.

The specific applications of these SOVs were not listed. However, the licensee indicated that there are many additional inaccessible SOVs that may also be susceptible to overpressure failure. The licensee indicated that determination of such vulnerability would be made subsequent to future walkdowns when SOV nameplate data could be obtained.

(8) Crystal River 3; November 8, 1988, January 5, 1989 and January 11, 1989: (Refs. 29, 38, 39, 40)

Five containment isolation valves had the potential to fail due to overpressure:

- 2 once through steam generator blowdown lines
- 2 once through steam generator sample lines
- 1 reactor coolant pump seal controlled bleed off line

5.1.4 Directional SOVs

We are aware of seven plants that have observed spurious operation of safety-related Target Rock angle-type SOVs due to improper valve orientation. As shown in Figure 3, upstream fluid pressure at the angle-type SOV's inlet port assists valve disc seating. However, many licensees have also learned from their own operating experiences and from followup discussions with the SOV manufacturer, that several different models of Target Rock angle-type SOVs used for isolation purposes are "uni-directional" i.e., they will experience undesired seat lifting when the backpressure (pressure at the outlet port shown in Figure 3) is only 2 to 5 psi higher than the upstream or inlet pressure. As noted in Target Rock Manual TRP 1571 (Ref. 41), the manufacturer has been aware of this problem at nuclear plants since 1978. However in the late 1970s time-frame, Target Rock developed an SOV for use as a bi-directional isolation valve (would not open spuriously due to high backpressures). Target Rock considered the spurious seat lifting to be an Architect Engineer/Licensee "application problem" --not an SOV problem.* The issue of uni-directional isolation SOVs is clearly addressed in some - but not all Target Rock SOV users manuals. For example, Reference 42 noted that the uni-directional qualities of the Target Rock angle-type SOVs are stated in Target Rock manual TRP 1571 (Ref. 41). i.e.

> "Most solenoid valves because of the nature of the operation of the valve, will stop flow in only one (1) direction. By design, upstream pressure acts on the top of the disc, forcing it onto its seat, thereby creating a tighter seal. However, if downstream pressure rises above upstream pressure, the disc will tend to lift off of its seat, thereby allowing flow."

Since Target Rock considered the spurious opening of uni-directional SOVs to be an application problem, not an SOV problem, Target Rock did not issue any field service notifications to alert owners of the affected SOVs to this problem.

Plants that have experienced spurious openings of safety-related Target Rock angle-type SOVs are:

H.B. Robinson 2 (1980)	(unspecified number of SOVs)
ANO-1 (1985)	(2 SOVs)
ANO-2 (1985)	(2 SOVS)
River Bend (1986) & (1989)	(3 SOVs) & (10 SOVs)
Harris 1 (1987)	(2 SOVs)
Hatch 2 (1988)	(12 SOVs)

The licensees' corrective actions were to re-orient the SOVs to assure that they would operate properly during accident conditions. Section 5.1.4.1 describes the most recent events which occurred at River Bend.

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*Telephone discussion between T. D. Crowley, Target Rock Corporation, and H. L. Ornstein, USNRC, January 24, 1990.

5.1.4.1 Incorrect Valve Orientation at River Bend

In April and May 1989, during testing conducted in response to NRC Generic Letters 88-14 (Ref. 43), the River Bend station found ten Target Rock SOVs used in safety-related applications which would spuriously open during accident conditions upon loss of instrument air. The opening of those uni-directional SOVs would have resulted in the blowdown of safety-related accumulators and would have prevented safety-related equipment from performing their functions as assumed in plant safety analyses (Refs. 42, 44). For example:

(1) Spurious actuation of six uni-directional SOVs upon loss of instrument air would result in bleed-down of safety-related accumulators in the control building, the auxiliary building and the fuel building. The licensee postulated that rapid depletion of accumulators in the control building (in 3.7 minutes) would prevent proper operation of building dampers and would adversely affect cooling of safety-related equipment, control room cooling, and control room air filtration. Depletion of accumulators in the auxiliary building would affect building dampers resulting in the loss of cooling of safety-related switchgear. Depletion of accumulators in the fuel building would affect building dampers and would impact air filtration and prevent the maintaining of a negative building pressure.

(2) Two uni-directional SOVs were found in the standby service water system (ultimate heat sink) which could spuriously open when subjected to accident conditions to prevent removal of heat through the ultimate heat sink.

(3) Two uni-directional SOVs were found in the instrument air system which could spuriously open upon loss of instrument air. Such opening would prevent long-term operability of all of the plant's (16) ADS/SRVs.

In Reference 42, the licensee also noted that several years earlier (1986) it had found three other Target Rock SOVs which had to be re-oriented due to spurious opening which was discovered when they were subjected to leak rate testing.

Those three SOVs had served as containment isolation valves in the containment hydrogen sampling system. The licensee did not consider that event to be reportable at that time.

5.2 Maintenance

Representative operating experience illustrating maintenance problems associated with maintenance frequency, replacement versus rebuilding, contamination, and lubrication are described below. Based on this experience, findings and recommendations relevant to maintenance problems are provided in Sections 7.2 and 9.2 respectively.

5.2.1 Maintenance Frequency

5.2.1.1 Dresden 3 - BWR Scram System - Primary System Leak Outside Primary Containment

During recovery from a reactor scram at 81 percent power on September 19, 1985, Dresden 3 experienced a leak of reactor coolant outside primary containment. The leakage path was through the scram outlet valves and the SDV vent and drain valves (Refs. 45, 46, 47). The NRC issued Information Notice 85-95 to alert licensees to the potential for reactor coolant leakage into the reactor building which could result from scram solenoid valve problems (Ref. 48). The information notice indicated that a similar event had occurred at Dresden 2 in 1972; however, the licensee did not determine the root cause of that event.

After the reactor scrammed in September 1985, the control room operators attempted to reset the reactor protection system (RPS). RPS channel A was successfully reset, but channel B could not be reset.* This channel configuration allowed the scram pilot SOVs to vent air, resulting in reduced air header pressure. The reduced air header pressure (38 psig) was sufficient to allow the SDV vent and drain valves to open (opening pressure ~8 to 15 psig), but it was not sufficient to enable the scram inlet and outlet valves to reclose (~42 psig required to close). For approximately 23 minutes, reactor coolant leaked outside primary containment into the reactor building. The high temperature reactor coolant flashed to steam. The leak resulted in elevated radiation levels on the first three floors of the reactor building.

In addition to the anomaly associated with the half scram configuration, degraded scram pilot SOVs contributed to the event. Testing showed that leaking scram pilot SOVs resulted in a combined SDV air header leak of 25 scfm. The licensee found widespread wear, aging, and hardening of the SOVs' O-rings and diaphragms. Maintenance records showed that some of the worst leaking valves had been rebuilt during the previous refueling outage.

After a reactor scram, the SDV and the scram instrument volume are in direct contact with hot pressurized reactor water. A common-mode failure of the pilot SOVs controlling the scram discharge system vent or the drain valves could result in an uncontrolled release of reactor water outside primary containment (see Figure 7) until the scram is reset. Such an event occurred at Hatch 2 in August 1982 (Ref. 49). Similarly, a sluggish SOV piloting an SDV drain valve caused a water hammer at Brunswick 1 which resulted in damaged pipe supports in the SDV drain system (Refs. 50, 51). As noted in Reference 46, a severe water hammer in the SDV system could result in an uncontrolled leak of reactor water outside the primary containment.

Discussion with GE** has indicated that since Information Notice 85-95 was issued, BWR owners have made improvements in their SDV systems so that there are redundant SDV vent and drain valves at all U.S. BWRs (vs. only one vent and one drain valve per SDV header in the early 1980's). However, it is not certain that all U.S. BWRs have manual handwheel overrides for the SDV vent and drain valves to limit reactor water leakage outside primary containment in the event of a common-mode failure of the SOVs piloting the SDV vent and drain systems.

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*Channel B remained tripped because of stuck contacts on the reactor mode switch.
**Telephone discussion between G. Strombach and E. Giebo, GE, and H. L. Ornstein, USNRC, June 23, 1989.

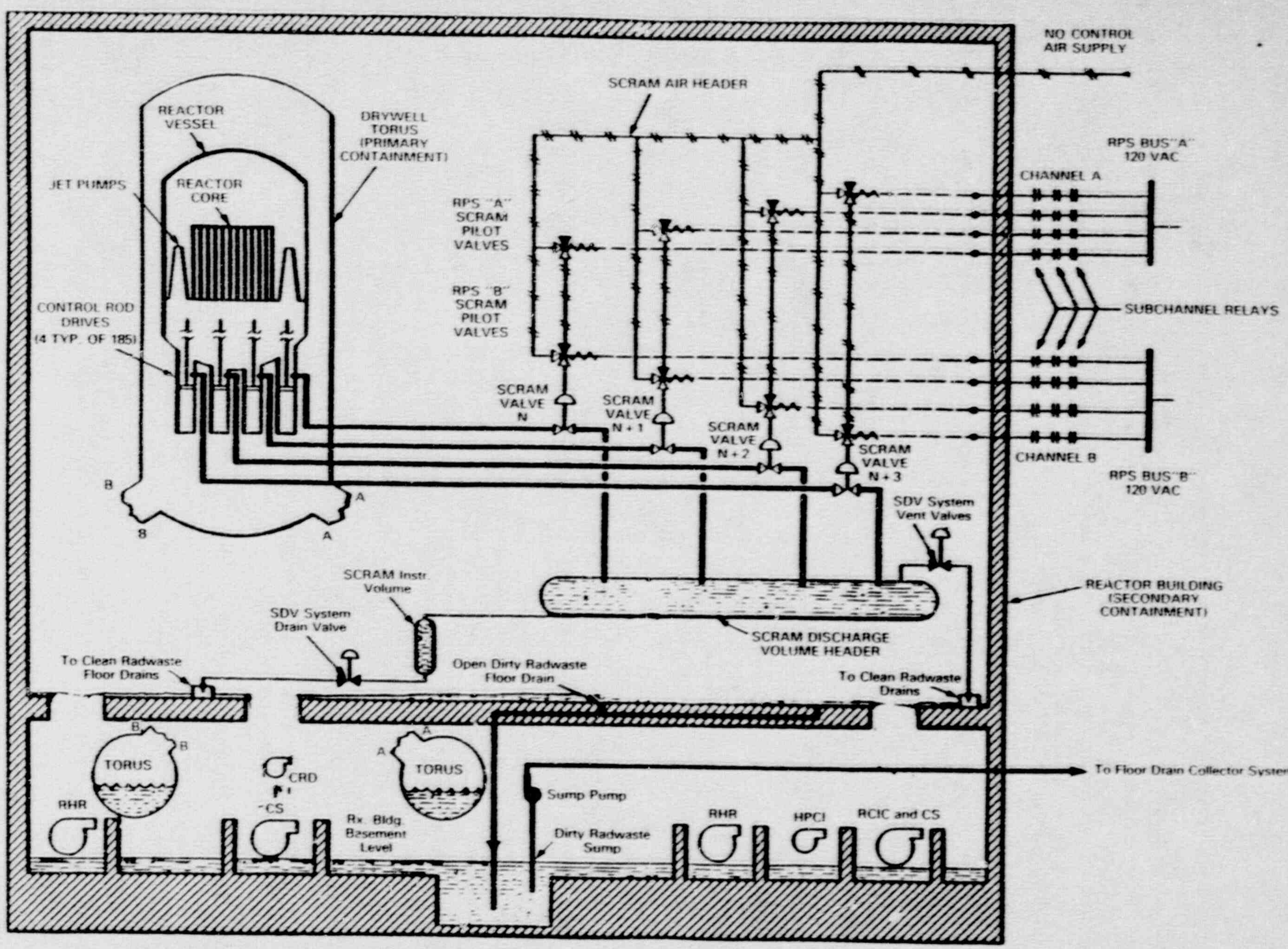

Figure 7
BWR SCRAM System-Illustrating Leak Path Outside Containment

5.2.1.2 Perry - Simultaneous Common-Mode Emergency Diesel Generator Failures

On February 27, 1987, the Perry Nuclear Plant experienced simultaneous common-mode failures of both emergency diesel generators (EDGs) (Ref. 51a). The failures were attributed to excessive air leakage through SOVs on each EDG's control panel. The SOVs were Humphrey Products Model No. TOG2E1-3-10-35 which were supplied by Delaval as EDG piece-parts. The SOVs are 3-way air control valves which are continuously energized while the EDGs are in standby.

The licensee had previously identified those SOVs for replacement due to observed air leakage. Work requests had been initiated for replacement of those SOVs but at the time of their failures, the work requests had not yet been implemented.

Discussions with the licensee* and the EDG manufacturer** revealed the following information:

1 The failed SOVs had been in service for over 10 years.
2 The analysis of the SOVs found that the elastomeric parts (Buna-N) were "dried up and cracked"
3 The failure was attributed to long-term operation at elevated temperatures
4 The Humphrey valves were purchased by Delaval as commercial valves and were upgraded/dedicated for nuclear service by Delaval. Delaval did not provide specific maintenance instructions for the SOVs.
5 The changeout frequency of the SOVs is not specified in the Delaval Operator's Manual; however, it could be implied from the manufacturer's control panel environmental qualification report.
6 Although the SOV manufacturer has stated that SOV failures have occurred because of incorrect use of lubricants on the Buna-N parts, the licensee was not provided with any such instructions.
7 The Perry plant upgraded the SOVs to ones with Viton instead of Buna-N; and more recently they replaced the SOVs with electrical relays.
8 We are uncertain about the vulnerability of other nuclear power plants having Delaval EDGs with Humphrey SOVs similar to the ones that failed at the Perry plant in February 1987.

5.2.2 Replacement Versus Rebuilding

5.2.2.1 MSIVs at Perry - Inadequate SOV Rebuild

After determining the cause of the MSIV failures of October 29 and November 3, 1987, the licensee replaced or rebuilt the ASCO SOVs on the MSIV air packs. Due to the limited availability and long lead times for replacement

*Telecon H. L. Ornstein USNRC and R. DiCola, Cleveland Illuminating Co., May 29-30, 1990.

**Telecons H. L. Ornstein and D. Pesout and S. Owyoung, Cooper Industries (formerly Delaval) May 29-30, 1990.

parts (air packs and ASCO dual-coil NP8323 SOVs), the licensee had to rebuild some (rather than replace all) of the MSIV air pack SOVs.

One entire air pack was replaced for the inboard D MSIV.

One dual-coil NP8323 SOV was replaced for the outboard D MSIV air pack.

One dual-coil NP8323 SOV was replaced for an inboard MSIV that had not failed previously. It was replaced upon inspection because it was observed to have sustained heavy damage to the electrical coils due to moisture intrusion.

Five dual-coil NP8323 SOVs were rebuilt, including the inboard B MSIV which had failed on October 29, 1987.

The licensee conducted increased surveillance and testing of the MSIVs after repairing and replacing the air pack SOVs. The licensee initiated monthly operability testing of the MSIV air pack SOVs, quarterly fast closure timing tests, and inspections of the ASCO NP8323 dual-coil SOV experiencing the highest temperatures.

On November 29, 1987, while performing operability testing, the ASCO dual-coil NP8323 SOV, controlling the inboard B MSIV, failed to change state when it was de-energized. Examination of the failed SOV found that the failure was caused by several foreign particles in the SOV. Laboratory examination confirmed that the particles were EPDM from the SOV's O-ring which had been replaced during the SOV's rebuilding process subsequent to the November 3, 1987 failure (Refs. 8, 9).

Apparently, during the original SOV rebuilding process, the licensee did not completely disassemble the ASCO dual-coil NP8323 SOV. As a result, one or more small particles remained in the valve and remained undetected until it (they) caused the SOV's failure.*

To preclude additional failures due to foreign particles remaining from the rebuilding process, as had happened on November 29, 1987, the licensee replaced all eight ASCO dual-coil NP8323 SOVs with new ones. Furthermore, the licensee stated that they were going to modify their preventive maintenance program: in the future, all Class 1E ASCO SOVs will either be replaced with new valves or undergo complete disassembly and cleanout to ensure that no particles remain or are introduced during the rebuilding process.

5.2.2.2 Brunswick 1 - Safety Relief Valves - SOV Rebuilding Error: Excess Loctite

On July 1, 1987, while attempting to control pressure following an unplanned automatic reactor trip, an SRV failed to open on demand. Following shut down, the licensee tested the SRVs that had not cycled during the trip recovery and found another SRV that did not open on demand (Refs. 52, 53).

The SRV failures were due to SOV failures. The two SOVs that had failed (Target Rock Model 1/2-SMS-A01) are used to port air to the SRVs' actuators,

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*It is believed that one particle remained in the SOV, and that the particle broke up during subsequent SOV operation.

allowing remote-manual opening of the valves. The two SRVs that failed were part of the plant's Automatic Depressurization System (ADS).

The failure of both safety relief valves to open on demand was attributed to excess Loctite RC-620, which was found in the internals of the related SOVs. Although two additional valves were found to have excess Loctite on the SOV's internals, those valves did not exhibit signs of binding.

The licensee determined, with the assistance of the SOV manufacturer, that Loctite RC-620 had been used by the SOV manufacturer's field service representative while rebuilding the SOV during a previous outage. In Reference 52, the licensee noted that the manufacturer's (Target Rock) field service representative had rebuilt all of the Brunswick 1 SOVs that actuate all eleven of the plant's SRVs (seven ADS valves and four non-ADS valves). The licensee stated that the Target Rock field service representative had done SOV refurbishment work on the valves at Brunswick 1, but he had not done similar work on any SOVs which pilot SRVs at other plants. Target Rock field representatives service the SRVs for all U.S. BWRs (except for Browns Ferry 1, 2, and 3) at Wyle Laboratories during the plants' refueling outages. Most plants send their SRVs and SOVs to Wyle for refurbishment every refueling outage, but some only send half of their SRVs and SOVs to Wyle for such refurbishment each refueling outage.

The problem encountered with Loctite RC-620 was one of excessive application. Loctite RC-620 is an anaerobic adhesive. Curing takes place in the absence of air. The SOV manufacturer's refurbishment procedure specifies that Loctite RC-620 be applied to a locknut assembly beneath the valve plunger. The procedure cautions against application of excessive amounts of the adhesive. The licensee concluded that the SOVs had excess amounts of Loctite RC-620 applied to them, and that curing did not occur until after the valves were placed in the inerted containment. The licensee believed that, prior to curing, the excess adhesive migrated to the interior of the valves, bonding the SOVs' plungers to the bodies of the valves.

The licensee concluded that even though only two ADS SOVs were found to malfunction, two other ADS SOVs had similar bonding due to excess Loctite RC-620; however, those bonds were broken during the initial removal and handling of the SOVs when they were removed from the drywell and bench tested.

The licensee's assessment of the event (Ref. 52) concluded that a common-mode failure, the inoperability of all 11 SRVs as a result of Loctite RC-620 bonding of all SOVs by one vendor field service representative, is a reasonably credible event. The occurrence of a design basis event under such conditions is beyond the bounds of the plant's final safety analysis report.

The NRC staff issued Information Notice 87-48 (Ref. 53) to notify licensees of the July 1, 1987 event. A similar SRV failure occurred on July 25, 1980 at Pilgrim (Ref. 31). A Target Rock SRV failed to open on a manual demand signal. The failure was caused by excessive Loctite RC-620, which had caused the SRV's solenoid plunger to stick to the valve's bonnet. In this case, the excessive Loctite was used during the fabrication of the SRV (as opposed to the July 1, 1987 event at Brunswick in which the excess Loctite was applied during refurbishing).

5.2.2.3 Peach Bottom 3 - Scram System - SOV Rebuilding Error: Excess Loctite

On November 17, 1983, a control rod was observed to have an excessive insertion time during a reactor scram (Refs. 54, 55). The sluggish control rod insertion was attributed to the failure of an SOV* to shift position to allow control air to be exhausted from the control rod's hydraulic control unit. As a result, the licensee replaced the scram pilot SOVs associated with the control rod that did not scram promptly and sent the scram pilot SOVs to GE for failure analyses.

On January 14, 1984, during a reactor scram, another control rod did not insert within the technical specification allowable time of 7 seconds. The second control rod had acted sluggishly during the November 17, 1983 scram. However, because it was believed to have inserted within the technical specification allowable time on November 17, 1983, no maintenance was performed on its pilot SOVs at that time.

Subsequent to the second failure (January 14, 1984), the licensee undertook an extensive investigation. That investigation revealed that, contrary to previous findings, the second control rod also had failed to meet its allowable scram insertion time limit on November 17, 1983.

Laboratory analysis of the two pairs of SOVs associated with the slow inserting control rods revealed that one valve of each pair had a yellow varnish-like foreign substance on its core assembly. One of the SOVs which was found to have the foreign substance on it exhibited sticking during subsequent bench testing. The foreign substance was originally believed to be a silicone lubricant, but it was later identified to be Loctite 242. Loctite 242 had been introduced to the SOVs during the rebuilding process, in accordance with the supplier's (GE) recommendations. In a 1978 Service Information Letter, (SIL) 128, (Ref. 56), GE had recommended that when rebuilding CRD scram pilot valves Loctite 242 adhesive/sealant should be used to secure the "acorn nut" on the solenoid housing to prevent it from loosening.

The Peach Bottom 3 failures were attributed to excess Loctite 242 which was used in the rebuilding process. It had appeared to be fully cured and the excess had not been wiped off. When the system returned to service, the Loctite 242 migrated and hardened and bonded the SOV's core plunger to its base assembly. After determining the source of the sticking, the licensee eliminated the use of Loctite 242 from its rebuilding process. Subsequently, GE issued a supplementary service information letter, SIL 128 (Ref. 57) which recommended that all BWR owners discontinue using Loctite 242 or any other chemical adhesive thread lockers on the acorn nut of the pilot SOVs.

GE had originally recommended using Loctite 242 to overcome loosening of the "acorn nut", and ASCO had agreed. Following the sticking problems at Peach Bottom 3, ASCO made a design change and replaced the acorn nut with a nylon-lined locking nut which would not require adhesive thread lockers to remain tight.**

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*ASCO Model HVA-90-405, which is built by ASCO but procured from GE, it is similar to the ASCO Model NP8316 valve.

**Telephone discussion between J. Shank, ASCO, and H. L. Ornstein, USNRC, June 19, 1989.

The common-mode failure potential for the scram system at some BWRs exists because some plants have used the same SOVs that are used to pilot the individual control rod hydraulic control units to pilot the scram discharge volume vent and drain valves. In the case of Peach Bottom 3, the potential for multiple simultaneous failure was compounded by the fact that the licensee had rebuilt all 370 control rod scram SOVs during the previous refueling outage. To reduce this common-mode failure potential, GE's SILs (Refs. 56, 57) recommended (not a binding requirement) that CRD pilot SOVs be rebuilt on a staggered basis from a "distributed checkerboard pattern."

5.2.3 Contamination

5.2.3.1 Brunswick 2 MSIVs - Excessive Heat and Poor Air Quality (Hydrocarbons and Water)

On September 27, 1985, during surveillance testing at Brunswick 2, three of the plant's eight pneumatically operated MSIVs failed to fast close (Refs. 58, 59). There are two MSIVs in series in each of four parallel steam lines. Two of the valves that failed to fast close were on the same steam line. An investigation of the failures found that the MSIVs failed to close because of disc-to-seat sticking of the MSIV air pack SOVs (ASCO dual-coil Model NP8323). The internal O-rings on the SOVs also were found to be degraded; they were brittle, and several O-rings were stuck to the valve body. Several SOV discs came apart after becoming brittle: pieces of one SOV disc became wedged in the SOV's exhaust port, one disc stuck to the exhaust port, and another SOV lost a piece of its disc.

Laboratory analysis of the three failed SOVs showed the presence of a significant amount of hydrocarbon in them. The combination of hydrocarbons and elevated temperature caused the EPDM discs to swell and fill the SOVs' exhaust ports, which blocked the discharge of air in the air actuator and increased the frictional force opposing SOV core movement. The instrument air system was believed to have been the source of the hydrocarbon contamination.

Because of the susceptibility of the SOVs' EPDM parts to hydrocarbon contamination, the licensee replaced all of the SOVs with the same model SOV having Viton discs and seals. Compared to EPDM, Viton is less susceptible to hydrocarbon contamination, but it is more susceptible to radiation damage.

This event was reported to Congress as an abnormal occurrence. The abnormal occurrence report categorized the event as one which resulted in the "loss of plant capability to perform essential safety functions such that a potential release of radioactivity in excess of 10 CFR Part 100 guidelines could result from a postulated transient or accident" (Ref. 60).

5.2.3.2 North Anna 1 and 2 - Multiple Systems - Oil and Water Intrusion

While performing maintenance operations at North Anna in the morning on April 24, 1987, an operator error resulted in a service water intrusion into the Unit 1 and 2 instrument air systems (Refs. 61-64).* The licensee quickly recognized that the service water intrusion affected SOVs and pneumatic controllers for auxiliary feedwater systems, primary and secondary pressure

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*Telephone discussions between J. Lewis and J. E. Wroniewiez, Vepco, and H. L. Ornstein, USNRC, May 1989.

control systems, and the SOVs required for containment isolation ("trip valves") for both Units 1 and 2.

At the time of the event, Unit 1 was in mid-loop operation and Unit 2 was operating at 100 percent power. The licensee's immediate response to the event was to continue operating Unit 2 and to blow down the affected instrument air lines.

About 2-1/2 hours after the intrusion occurred the licensee tested the Unit 2 "A" motor-driven AFW pump. The air-operated discharge valve and the back-pressure regulating valve for the AFW pump both malfunctioned rendering the pump inoperable. About three hours later the licensee tested pump B satisfactorily.

Throughout the evening of April 24, 1987, the licensee continued to blow down instrument air lines until no moisture was observed. The "A" AFW pump's discharge and pressure regulating valves were repaired on the evening of April 24, 1987 and were satisfactorily tested around midnight.

The cleanup procedure was not totally effective since there were low points in the instrument air system that had not or could not be drained. The residual water that remained in the low points of the instrument air system and the moisture and contaminants in the instrument air system resulted in widespread SOV failures for almost two years after the service water intrusion event. In addition to failures of "freestanding" SOVs, there were dozens of control valve failures. The bulk of the control valves that failed were Fisher control valves. Integral to each Fisher control valve is an ASCO SOV. The Fisher control valve failures were essentially failures of the ASCO SOVs which are piece-parts of the control valves. Examination of plant equipment failure records noted that between April 1987 and February 1989, there were approximately fifty Fisher control valve (ASCO SOV) failures. It appears that those failures resulted from poor quality air due to the April 24, 1987 water intrusion event and from poor maintenance of the instrument air system.

In addition to these failure records, NRC inspectors noted (Ref. 62) many ASCO SOV failures that had been observed during surveillance testing after April 24, 1987, were not reported and the SOVs were not repaired. The primary reason was that the SOVs that failed to operate during surveillance testing operated properly after being tapped ("mechanical agitation") by plant personnel. As a result of such practices, repetitive malfunctions were observed, the malfunctioning SOVs were not fixed or replaced expeditiously, and the root causes were not found or corrected on a timely basis. Characterization of the licensee's in-service testing practices regarding SOVs was cited in Reference 61 as follows:

> "The process of tapping on solenoid valves and repeated cycling of valves prior to running a satisfactory surveillance was considered an acceptable practice by the licensee."

Some of the systems that were affected by malfunctioning ASCO SOVs (freestanding or piece-parts of Fisher control valves) due to contamination of the instrument air system are listed in Table 2.

Table 2 Systems Impacted At North Anna By SOV/Control Valve Failures Due to Service Water Intrusion/Instrument Air Contamination

<u>Unit 1 and Unit 2</u>
Residual Heat Removal/Low Pressure Safety Injection
Main Steam Relief (PORVs)
Auxiliary Feedwater
Component Cooling Water
<u>Unit 2 only</u>
Containment Isolation
Containment Fan Cooling
Main Steam Isolation

In a February 10, 1988 memorandum, the Chairman of North Anna Station's Nuclear Safety and Operating Committee stated that successful stroking of the SOVs is an appropriate corrective action to remove contaminants, because "cycling the affected valves blows the contamination from the lines and returns the SOVs to operable status" (Refs. 65, 66). North Anna Station's approach to maintenance of malfunctioning SOVs contradicts the valve manufacturer's recommendations. ASCO's installation and maintenance instructions and the licensee's telephone discussions with ASCO on February 4 and 5, 1988 advised the licensee that, after SOV contamination, the NP Series SOVs should be inspected for corrosion, sediment or other contaminants, and cleaned accordingly.*

A meeting was held at NRC Region II offices on February 7, 1989 to discuss repetitive AFW system control valve failures which occurred in January 1989, due to moisture in the instrument air system (Ref. 67). At the meeting, the licensee acknowledged that widespread failures of SOVs, control valves and air-operated valves had occurred during the 21 months from the time of the service water intrusion into the instrument air system (April 1987 through January 1989). A large number of repetitive SOV and control valve failures were attributed to poor quality instrument air (oil and moisture contamination in addition to the April 1987 service water intrusion). The licensee noted that attention had been focussed on the quantity of instrument air available without paying attention to its quality and indicated that subsequent to a review of their instrument air system, a program was initiated to clean or replace the affected equipment. The licensee also provided information on steps that were being taken to improve the instrument air system to assure delivery of clean, dry, oil free instrument air.

We view the April 24, 1987 service water intrusion into the instrument air system as a significant precursor event. It resulted in widespread degradation of SOVs, controllers, and air-operated valves that had the potential for disabling many systems needed to achieve safe shutdown. If a design-basis event

*Telephone discussions between F. Maiden and W. Murray, Vepco, and K. Thomas, ASCO, February 4 and 5, 1988.

had occurred at Unit 2 on April 24, 1987, before removing the service water from the instrument air system, the operators' ability to bring the plant to a safe shutdown could have been seriously impaired. A large number of SOV and control valve failures occurred at Units 1 and 2 between April 24, 1987 and January 1989 as a result of water, corrosion products, and residue from the service water intrusion, and from impurities introduced by poor quality instrument air. This event exemplifies the necessity for providing SOVs with clean, dry, oil free air, and the need to thoroughly clean and inspect the equipment if water or other contaminant intrusions occur.

5.2.3.3 Susquehanna 1 and 2 - Scram System: Oil and Water Contamination

The Susquehanna plants have experienced common-mode failures of SOVs that resulted in multiple failures of control rods to insert, slow insertion of multiple control rods, and repetitive failures of scram discharge volume vent and drain valves. The SOV failures were linked to contaminants in the instrument air system (i.e., hydrocarbons, water, and particulates) and high temperatures.* Because both Susquehanna units share a common instrument air supply, the common-mode failure potential that existed for both unit 1 and unit 2 scram pilot SOVs also existed for the SOVs that actuate both units' backup scram valves. The backup scram valves are intended to provide diverse scram capability to protect against common-mode failures. Although Unit 1 experienced the failures, the potential for such failures also existed at Unit 2; both units' scram and diverse scram systems were vulnerable.

The Susquehanna SOV failures illustrate the potential for multi-plant common-mode failures leading to events that are beyond the plant safety analyses (i.e. failure of multiple control rods to insert and unisolated primary leak outside containment via the scram discharge volume).

A summary of the Susquehanna SOV failures are described below:

On October 6, 1984, while Susquehanna 1 was operating at 60 percent power, two control rods failed to insert during individual rod scram testing. Further scram testing revealed that a total of four rods would not insert and nine additional rods hesitated before inserting. A similar event occurred previously at Susquehanna on June 13, 1984, when several control rods hesitated momentarily before inserting (Ref. 68). Two of the control rods that failed to insert on October 6 had not met the plant Technical Specifications scram time requirements on June 13. The licensee did not become aware of the June 13 malfunctions until the October 6 failures were investigated.

The October 6 failures were attributed to common-mode contamination of the instrument air system. The combination of contaminants (oil and/or moisture) and high temperatures (140°F) caused the SOV internals to degrade and become stuck. The SOV polyurethane disc holder subassembly seats were found to be stuck to the SOV exhaust port orifice. This prevented air from the scram inlet and outlet valve operators from bleeding off through the SOV exhaust ports, which prevented the scram inlet and outlet valves from opening.

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*At Susquehanna each of the 185 control rods is piloted by one ASCO HV-176-816 SOV. Many other BWRs' control rods are piloted by other model ASCO SOVs, but two per control rod. The ASCO SOVs used in U.S. BWR scram systems are typically procured from GE.

Two independent laboratories examined the failed SOVs and concluded that the polyurethane parts degraded because of a combination of contamination in the instrument air and elevated temperature (Ref. 69). The first laboratory (Franklin Institute) cited the failure mechanism as hydrolytic decomposition of the polyurethane seats due to a combination of moisture and elevated temperatures. The second laboratory (GE) indicated that polyurethane seat failure was caused by contamination of the instrument air with a synthetic diester oil (SDO, which is a plasticizer). Both Franklin Institute and GE recommended replacing the polyurethane seats with a seat material capable of operating at higher temperatures and having an improved resistance to contaminants. The recommended material was Viton. The licensee replaced all of the SOV polyurethane seats on Units 1 and 2 control rods and all the backup scram valves. About half of the SOV discs for the Unit 2 control rods had already been replaced in 1983 with Viton discs.

The licensee's investigation found that the SOV for the scram discharge volume vent and drain valves on Unit 1 had a polyurethane disc that also was susceptible to the same type of failure. The SOVs for the vent and drain valves also were replaced with different SOVs having Viton discs.*

The October 6, 1984 scram system degradation at Susquehanna was reported to Congress as an abnormal occurrence (Ref. 70). The NRC staff concluded that the event involved a "major degradation of essential safety-related equipment," and demonstrated the plant's susceptibility to common-mode failure. The failure caused a reduction in "the required 'extremely high probability' of shutting down the reactor in the event of an anticipated operational occurrence" (Ref. 70). Another scram discharge volume (SDV) system component failure attributed to contaminated air occurred at Susquehanna 1 on December 21, 1984 (Ref. 71). During surveillance testing, an SOV that controls the SDV vent and drain line isolation valves malfunctioned as a result of particulate matter that was lodged between the SOV's disc and seat. As a result, the SDV vent and drain valves were stuck open. Since the reactor was at power, if the SOV had failed to completely close after a scram, the potential for an unisolated primary leak outside containment would have significantly increased.

5.2.4 Lubrication

5.2.4.1 Multiple Plants - Manufacturing Error: Residue-Producing Lubricant

The Kewaunee nuclear power plant experienced three SOV failures on May 28, 1988 during surveillance testing (Ref. 72). Two of the SOVs were redundant containment isolation valves piloting the reactor coolant drain tank discharge header isolation valves. The third SOV that failed served as the pilot for the pressurizer relief tank makeup isolation valve. All three failed SOVs were nuclear qualified ASCO NP8314 DC valves that piloted air-operated valves. They were normally open, normally energized, and were designed to close (fail safe) on loss of instrument air or electrical power. The failures of the SOVs to

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*The SOV chosen was a larger size, made by another manufacturer. The original Unit 1 valve was undersized and the replacement made was the same as the one on Unit 2.

shift position upon de-energization were attributed to an amber-colored residue inside the SOVs. The residue was found at the location where the SOV core assembly (plug) contacts the SOV body (solenoid base sub-assembly) see Figure 4. The failed SOVs had been in service about 18 months prior to their failure. The local ambient temperature was about 110°F. The licensee inspected two other ASCO NP8314 SOVs from the same manufacturing lot which were installed adjacent to the three SOVs that had failed. They had been installed at the same time as the ones that failed, but were operated in the de-energized mode. The de-energized SOVs had performed satisfactorily.

The licensee assisted by two independent laboratories (Wyle Laboratories and Akron Rubber Development Laboratory) and ASCO conducted an extensive investigation to determine the root cause of the failures. On the basis of the investigation, the licensee and ASCO concluded that the SOV failures were most likely caused by the degradation of a lubricant (International Products Corporation, "P-80" rubber lubricant) which had been introduced during the manufacturing process. P-80 is a water-based rubber lubricant used by ASCO personnel to facilitate SOV assembly. Although P-80 was an approved lubricant for use at ASCO's manufacturing facility, its use for the assembly of the NP8314 SOVs was not an explicitly approved procedure. P-80 product literature states that it provides "temporary slipperiness" for assembling rubber parts, and that it is absorbed into the rubber "leaving no residue or harmful effect on the rubber." Subsequent to SOV assembly (using the P-80 lubricant), the SOVs were cleaned; however, minute amounts of the P-80 lubricant remained within the internal cavities of the SOV. From the laboratory results, it was concluded that the small amount of lubricant, remaining in the SOVs, migrated subsequent to energization, and the heating, due to energization, degraded the P-80 to form the amber-colored sticky residue which caused the SOV malfunctions. The investigation discounted Dow Corning 550 lubricant as the source of the residue that had been found inside the NP8314 SOVs. ASCO has discontinued using P-80 in the assembly of SOVs as a result of the investigation.

On October 18, 1988, ASCO issued a 10 CFR Part 21 notification regarding the potential failures of NP8314 SOVs (Ref. 73). The notification accounted for 231 suspect SOVs that were sent to 17 U.S. LWRs, 76 suspect SOVs that were sent to suppliers who most likely shipped them to unspecified plants as pieceparts of other equipment between 1981 and 1988, and 9 suspect SOVs that were sent to Franklin Research Center (FRC) in 1986. The Fort Calhoun plant had received the largest number of suspect SOVs (79) in 1981. Several of those SOVs failed at Fort Calhoun in 1981 and 1982. Three of the SOVs that failed at Fort Calhoun were returned to ASCO for investigation. ASCO's investigation of those valves, incident report IR 3604 - May 1982 (see NRC Vendor Inspection Report 99900369/88-01 (Ref. 74), noted that the failures were due to sticking caused by a varnish-like residue. At that time, neither ASCO nor the Fort Calhoun licensee were able to identify the source of the "acrylate ester residue found on the plunger and sub-base assembly" of the energized NP8314 SOVs.

Fort Calhoun experienced a similar failure of another energized NP8314 SOV in March 1982. It was cleaned and returned to service (Ref. 75). The licensee stated that it would replace the internals of all the NP8314 SOVs using new spare parts kits. Subsequently, Fort Calhoun donated 10 ASCO NP8314 SOVs that had been in continuously energized service for 18 months to FRC for use in an

NRC sponsored SOV aging research program (Ref. 71). FRC also purchased nine new NP8314 SOVs from ASCO, which were shipped in April 1986, to be used in FRC's SOV aging program (those SOVs were also listed in ASCO's 10 CFR Part 21 notification). Six of FRC's purchased SOVs, which were undergoing accelerated thermal aging, failed prematurely (failure to shift position) as a result of organic deposits ("sticky substance"). After the deposits were "cleaned away" with acetone and the SOVs were reassembled, they performed successfully for the duration of FRC's testing program. FRC's report (Ref. 76) also noted that organic deposits were found in the NP8314 SOVs received from Fort Calhoun. FRC believed that the sticky deposits that had prevented the SOVs from functioning were due to an organic compound that was introduced during the assembly of the valves; however, a detailed analysis and final determination of the source of the deposits were not pursued by FRC because of budgetary restraints of the program. In the course of the FRC's SOV aging research program, ASCO had been apprised of the sticking problem, however ASCO did not find the source of the residue (P-80) until after the Kewaunee failures in 1988. The failures of the NP8314 SOVs indicate that P-80 was used to assemble the NP8314 SOVs as early as 1981 and as late as 1988.

A similar case, in which another SOV manufacturer used a lubricant to assist with SOV assembly, also resulted in subsequent SOV performance problems. As noted in Reference 77, Target Rock Corporation used castor oil as a lubricant to facilitate the assembly of its two stage safety relief valves (SRVs). After investigating several SRV failures, it was found that castor oil, which was used to lubricate silicone rubber O-rings, caused swelling and accelerated degradation of the O-rings. Subsequently, Target Rock discontinued using castor oil as a lubricant. DAG-156 lubricant (carbon particles suspended in an alcohol base) was used to replace castor oil. We are not aware of any subsequent Target Rock SRV failures that have resulted from the use of DAG-156.

Target Rock informed the author of this case study during a visit to their facility (November 1988) that, paralleling the use of P-80 at ASCO, Target Rock had used "mineral oils" to facilitate SOV assembly. This practice was discontinued in the mid-1980s and DAG-156 was chosen as a replacement for mineral oils.

5.2.4.2 Catawba: Poor Quality Air and Lubrication with Vaseline

The Catawba nuclear power plant experienced common-mode failures of EDG starting air system inlet valves (Refs. 78, 79, 80). The EDGs were manufactured by Delaval. The air start system inlet valves, model T-3618, were made by California Controls Co. (Calcon). These two-stage air-operated valves each have a solenoid pilot valve that is normally closed and requires dc power to actuate the solenoid pilot to admit starting air into the EDG.

The licensee has reported five instances of common-mode failure of these valves. The valves stuck open when a sticky, slimy substance formed inside the poppet portion of the valve. The licensee determined that the substance was the silicone lubricant Dow Corning 111 that was used on the valves. On five occasions, the licensee cleaned the valves and replaced the Dow Corning 111 with Vaseline petroleum jelly. Calcon's recommended lubricant is GE Silicone fluid G-322-L, which is significantly different from DOW Corning 111. The licensee did not check for the compatibility of Vaseline petroleum jelly with the Buna-N rubber used in the Calcon Valve. Low nitrile Buna-N rubber degrades when in contact with petroleum based products. After reviewing the EDG air start valve failures and other EDG pneumatic equipment failures (Calcon pressure sensors) the licensee concluded that the sticking was caused by moisture interacting with the Dow Corning 111 silicon lubricant. The source of the moisture was the starting air system, the root cause was inadequate dryer maintenance (the licensee's failure to changeout the spent desiccant).

Subsequently, the licensee upgraded its maintenance on the air dryers, thereby lowering the starting air moisture content. In addition, the licensee cleaned the valves and replaced the Vaseline petroleum jelly with Dow Corning 111 lubricant. These actions in conjunction with more frequent changeout of the Calcon gas valve's elastomeric parts in accordance with the Delaval owners' group plant specific recommendations appear to have eliminated the valve sticking problem.

5.2.4.3 Common-Mode Failure of 16 MSIVs at a Two Unit Station (BWRs): Incorrect Lubrication

In July 1986, the licensee of a two-unit station reported excessive stroke time of the Unit 1 "C" outboard MSIV which resulted from a failure of an Automatic Valve Corporation (AVC) SOV (model C4988-8). The failure was attributed to "poor workmanship from the factory" and "improper lubrication, which would allow the valve piston to jam at a certain place in the valve." The failed AVC valve was replaced with a new one.

Five months later (December 1986), while performing monthly closing tests, the licensee found that the Unit 2 "B" inboard MSIV did not stroke properly as a result of a failure of another AVC SOV. The licensee shut down both units from 100 percent power and inspected the SOVs piloting all 16 MSIVs. The licensee found that the AVC SOVs on all 16 MSIVs were damaged. The three-way and four-way valves and solenoid pilot valves on all 16 MSIVs had a hardened, sticky lubricant in their ports and on their O-rings. As a result, motion of all the SOVs was impaired, resulting in instrument air leakage and the inability to operate all of the MSIVs satisfactorily. The licensee also examined unused spares in the warehouse and found that the lubricant had dried out in those valves, leaving a residue. Several of the warehoused spares were bench tested. They were found to be degraded and they also leaked.

The original "approved" or "preferred" SOV lubricant (based upon equipment qualification testing) was Parker Super-O-Lube. However, later equipment qualification testing (1985) found that the Parker Super-O-Lube could cause SOVs in the MSIV air pack to malfunction. The Parker Super-O-Lube was found to break down to an adhesive, powdery substance when exposed to radiation fields greater than 1x10E6 RAD. Because of the potential for breakdown of Parker Super-O-Lube and binding of the SOVs in the air packs, the licensee changed the SOV lubricant to E. F. Houghton SAFE 620.

In separate telephone conversations the SOV manufacturer (AVC) told the AEOD staff that it had informed the utility that E. F. Houghton SAFE 620 lubricant attacks and degrades the aluminum in the AVC valves.* Nonetheless, in accordance with utility purchase orders, AVC shipped SOVs lubricated with E. F. Houghton SAFE 620 to two different utilities.

After the multiple failures occurred in December 1986, General Electric (GE) informed the licensee that the Parker Super-O-Lube is an acceptable lubricant "if it is applied in a 'thin film'." AVC and GE had concluded that the problem experienced with Parker Super-O-Lube in the 1985 qualification testing was due to "excess lubricant."

On December 19, 1986, AVC issued a 10 CFR Part 21 notification (Ref. 81). The notification indicated that Commonwealth Edison had also purchased AVC valves lubricated with E.F. Houghton SAFE 620. Commonwealth Edison told AEOD staff** that the AVC valves which contained E. F. Houghton 620 lubricant were replacements for older model AVC SOVs which had been discontinued. Before being notified by AVC of the problem with E. F. Houghton SAFE 620 and before installing the valves, Commonwealth Edison replaced the SAFE 620 with Dow Corning Molykote 55M. The licensee had recognized that Parker Super-O-Lube was the lubricant that had been used in earlier equipment qualification testing, and SAFE 620 was probably not an acceptable replacement.

Justification for the use of Molykote 55M instead of Super-O-Lube was based upon the licensee's engineering analysis that indicated the similarities between Molykote 55M and Super-O-Lube. In retrospect, a detailed examination of these two lubricants reveals they may have very different high-temperature behavior and, under similar operating conditions, the Molykote 55M would be more susceptible to dryout.*** Because of these differences, it is not clear that Molykote 55M is an acceptable "qualified" replacement for the Super-O-Lube.

With regard to problems of excessive lubricant and the application of "thin films" of lubricant, it is interesting to note that a Commonwealth Edison plant had sticking problems with a similar AVC SOV several years earlier. In that case, the sticking was attributed to not having enough lubricant applied to the AVC valve.

5.2.4.4 Grand Gulf 1, LaSalle 1, and River Bend MSIVs - Sticking SOVs - Foreign Unidentified Sticky Substance (FUSS) - Lubricant Suspected

Between February 1985 and December 1989, the Grand Gulf 1, LaSalle 1 and River Bend nuclear power plants experienced sticking of ASCO dual-coil 8323 SOVs in the MSIV air packs (Refs. 8, 82 to 88). The SOV malfunctions were attributed to a sticky substance at the contact point of the plug nut/core assembly interface (see Figure 1). The SOV malfunctions impaired or prevented the MSIVs from closing within the times specified in the plant safety analyses.

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*Telephone discussions between T. Hutchins, Automatic Valve Corporation (AVC) and USNRC (S. Israel - October 14, 1988 and H. L. Ornstein - April 12, 1989).

**Telephone discussion between M. Sievert, Commonwealth Edison Company, and H. L. Ornstein, USNRC, April 12, 1989.

***Super-O-Lube consists of high molecular weight silicones whereas Molykote 55M is a lighter weight methyl silicone oil thickened with lithium soap having a lower dropping point than Super-O-Lube (where dropping point is an indication of the temperature limit at which the lubricant dries out).

In the case of LaSalle, it was demonstrated that the cohesive/adhesive force caused by the foreign sticky substance between the plug nut and the core assembly of an ASCO dual-coil NP8323 SOV was significant and could have been the cause of its failure. After the core assembly was held vertically, the plug nut was pressed against the core assembly, and then the plug nut let go, the adhesive forces from the foreign substance between the two surfaces were able to support the weight of the plug nut to prevent it from falling.*

Because the licensee suspected the Dow Corning 550 lubricant (applied to the SOVs internals at the factory) to be the cause of the sticking, the licensee considered removing the factory installed lubricant from the 8 new NP8323 SOVs that were installed after the December 16, 1987 failure. In consideration of ASCO's concern that, without the internal lubricant, ac powered SOVs could suffer fretting damage, the licensee installed the 8 new NP8323-Viton SOVs as they were received from the manufacturer (without removing the lubricant). Those 8 replacement SOVs have operated successfully through 1989.**

Subsequent to the September 30, 1988 failures of two ASCO dual-coil NP8323 SOVs at River Bend, the licensee replaced all 8 dual-coil NP8323 SOVs with new ones. However, prior to installing the new SOVs, the licensee removed the factory coated lubricant (Dow-Corning 550) from their internal metallic parts. On December 1, 1989 two of those replacement SOVs failed due to sticking. The licensee attributed the sticking to FUSS which was believed (but not confirmed by laboratory analysis) to be Dow Corning 550 lubricant.

In following up the December 1, 1989 failures, the licensee reviewed the procedures which were used in September 1988 to remove the factory applied lubricant. The licensee's review of those procedures indicated that although the Dow Corning 550 lubricant was removed from the internal metallic parts of the SOVs, the cleaning and reassembly procedures included a step in which the elastomeric parts of the SOVs were relubricated with the same Dow Corning 550 lubricant. Because there was more FUSS on the cleaned SOVs that failed in December 1989 than on the factory assembled SOVs that had failed September 1988, the licensee believed that the root cause of the December 1989 failures was the licensee's reapplication of excessive lubricant during the SOV cleaning and reassembly process.

Subsequent to the December 1, 1989 failures the licensee's corrective action was to replace all eight NP8323 dual-coil SOVs with new ones -- after removing all the factory applied lubricant from them, without relubricating the elastomeric parts.

Table 3 summarizes events where MSIV air pack SOVs have stuck at Grand Gulf, LaSalle, and River Bend.

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*According to ASCO, the plug nut weighs about one ounce while the spring force is about two pounds. ASCO indicated that after a similar NP8323 SOV failure at WNP 2, the licensee had performed a similar demonstration. The sticky substance at WNP2 was believed to be from excess lubricant (Dow Corning 550) that had been applied by the licensee when the SOVs were rebuilt.

**Telephone discussion between R. Lanksbury (USNRC Sr. Resident Inspector at LaSalle Station) and H. L. Ornstein (USNRC), December 22, 1989.

Table 3 MSIV Air Pack SOV Failures (ASCO Dual-Coil 8323)

Plant/Event Date	Description of SOV and Corrective Action	Number of Stuck SOVs and Location	Other SOVs Having Foreign Unidentified Sticky Substance (FUSS)	Comments
Grand Gulf 1 2/10/85	ASCO HTX8323* (Viton). Replaced all 8 SOVs with ASCO NP8323 (having EPDM parts). See Section 5.2.1.1 for a discussion of the subsequent failures of the replacement valves caused by thermal aging from self-heating (August 1989)	2 outboard lines (A and C) 1 inboard (D line)	All others (5)	In subsequent testing at ASCO only 1 of 4 additional valves malfunctioned (leakage). However the failure of the outboard C-line SOV was attributed to FUSS at the plug nut/core assembly interface.
LaSalle 1 12/16/87	ASCO NP8323 (Viton). Replaced all 8 SOVs with like.	1 outboard (C-line)	All others (7)	3 of the valves that did not fail in the plant, failed during subsequent testing at ASCO, due to presence of FUSS at the plug nut/core assembly interface.
River Bend 9/30/88	ASCO NP8323 (EPDM). Replaced all 8 SOVs with like - attempted to remove the factory coated lubricant (Dow Corning. 550) from SOVs, but applied excessive amount of lubricant to O-rings while reassembling caused 2 subsequent failures (December 1989)	2 inboard lines (B and C) (1 inspected, FUSS found)	One unfailed inboard SOV inspected was found to have FUSS. Two outboard SOVs inspected found to have FUSS.**	Not all SOVs have been inspected. Some are being held for archival purposes. Two outboard SOVS were inspected at ASCO. The coil enclosures of both SOVs had had evidence of moisture intrusion, indicative of localized steam heating.**

*ASCO HTX 8323 is not a nuclear qualified SOV, it is a non-qualified commercial valve similar to the NP8323.
**Telephone discussion between J. Shank, ASCO, and H. L. Ornstein, USNRC, May 8, 1989.

Table 3 MSIV Air Pack SOV Failures (ASCO Dual-Coil 8323) (continued)

Plant/Event Date	Description of SOV and Corrective Action	Number of Stuck SOVs and Location	Other SOVs Having Foreign Unidentified Sticky Substance (FUSS)	Comments
River Bend 12/1/89	ASCO NP8323 (EPDM) Replaced all NP8323's with new ones--but removed factory installed lubricant from all internal parts of the SOVs.	2 outboard lines (A and D), FUSS found or both	1 other SOV was inspected (inboard), It also had FUSS, but less than what was found on the failed outboards	Licensee believes FUSS from was from excessive application of Dow Corning 550 which was used by the licensee when lubricating the O-rings subsequent to removing the Dow Corning 550 from the SOVs' internal metallic parts subsequent to the 9/30/88 failures.*

*Telephone discussion between V. Bacanskas, River Bend, and H. L. Ornstein, USNRC, December 12, 1989.

The inspection of the SOVs on the inboard and outboard MSIV air packs at all three plants indicated that in almost every case the SOVs, which had not failed, were degraded in a manner similar to the failed SOVs, but to a lesser degree. In each case, the licensee recognized the common-mode failure potential for compromising fast closure of inboard and outboard MSIVs on one or more steamlines and replaced all the 8323 SOVs on the inboard and outboard MSIV air packs.

The valve manufacturer and several laboratories conducted extensive inspections and tests on the 8323 SOVs which had been replaced. There are no simple explanations for these failures individually or as a group. The source(s) of the sticky substance(s) which resulted in multiple SOV failures is uncertain. There is major disagreement between the utilities, the SOV manufacturer, the reactor manufacturer and the laboratories regarding the root causes of the failures. Internal SOV lubrication (by the manufacturer and in one case by the licensee), and poor air quality are primary suspects.*

5.3 Surveillance Testing

5.3.1 Control Rod Timing Tests - Failed Scram Pilot SOVs - Perry

On July 22, 1989, during scram time testing, plant personnel observed two control rods failed to meet their scram time testing requirements on initial attempts -- however, when retested the rods operated satisfactorily. As a result, both control rods and their SOVs were declared to be operable. Subsequently, on November 25, 1989, one of those rods failed its timing test twice but was retested satisfactorily twice. As a result, it was declared operable. When the second control rod that had also failed twice on July 22, 1989, was retested on November 25, 1989, and failed, it was declared inoperable. At that time, the licensee conducted an investigation to determine the root cause of the test failures (Refs. 89, 90, 91).

The licensee's root cause analysis found that a manufacturing error had been made at ASCO (failure to upgrade polyurethane seats of the scram pilot SOVs with viton), and that the Perry Plant had not responded to a product recall notice that ASCO had sent them (Ref. 91).

It is significant that the licensee's surveillance testing program did not provide guidance to the plant staff regarding actions to be taken when unsatisfactory test results are encountered.

5.4 Use of Non-Qualified SOVs

5.4.1 Colt/Fairbanks-Morse EDGs: Repetitive Air Start Valve Failures

One plant, having Colt/Fairbanks-Morse EDGs, experienced six air start SOV failures during an 8-year period. There were five failures of one valve and one failure of an identical, redundant SOV. The SOVs were commercial grade valves, model X833-134, made by ASCO. The failures occurred from February 1, 1980,

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*Failures of ASCO NP8314 SOVs which are geometrically similar to the 8323 SOVs have been traced to an assembly error during manufacture. Conceivably, a similar error may have been introduced during the assembly of the 8323 SOVs (see Section 5.2.4.1).

through March 28, 1988, and in each case the failures involved excessive air leakage.

Four of the five failures of the same valve (DA-19B) were attributed to the SOV core and spring assembly. The first failure was attributed to wear of the core and spring assembly caused by excessive heat from the solenoid being constantly energized. The SOV was rebuilt (core and spring were replaced). The SOV's second failure was attributed to "wear of the core and spring assembly." The SOV was rebuilt again (core and spring assembly were replaced). The third malfunction of the same SOV occurred while attempting to start the diesel. The failure was attributed to "misalignment of solenoid header due to previous repairs." The licensee's corrective action was to realign the solenoid header. Three months later the same SOV was again found to be leaking air. This fourth failure was attributed to "wear of the core and spring assembly." The SOV was rebuilt again (core and spring assembly were replaced). Five months later a redundant air start SOV (DA-23B) on the same diesel was found to be leaking air. It was rebuilt (spring and core were replaced). On March 28, 1988 the same SOV that had failed four times before (DA-19B) failed again. The fifth failure was attributed to a worn seat that resulted in air leakage. The valve was replaced rather that being rebuilt. We are unaware of any subsequent failure of this replaced SOV.

Discussions with the licensee who's EDGs experienced these six failures, and other licensees with Colt/Fairbanks-Morse EDGs indicated that they have received little, if any guidance from the EDG supplier about preventive maintenance or replacement of the air start system SOVs. The SOVs that are used for the Colt/Fairbanks-Morse EDGs are commercial grade ASCOs which are supplied with limited maintenance or service life information.

6 ANALYSIS AND EVALUATION OF OPERATIONAL EXPERIENCE

6.1 Common-Mode Failures

Examination of the events discussed in Chapter 5 and many of the SOV failures included in Appendix A clearly indicate a potential exists for common-mode SOV failures that could compromise multiple trains of diverse safety systems. Such common-mode failures are not considered in plant safety analyses.

It is not practical to perform safety analyses for all combinations of common-mode SOV failures. However, it is feasible to take actions to minimize the likelihood for encountering common-mode SOV failures that could affect safety systems. Chapter 9 presents recommendations that can be effectively used to minimize the potential for common-mode SOV failures affecting safety systems.

The root causes of many common-mode SOV failures that have been observed thus far are given below.

(1) Design/Application Deficiencies

- Incorrect specification of operating parameters such as MOPD (e.g., Section 5.1.3.1) and valve orientation (e.g., Section 5.1.4.1);
- incorrect material selection such as incompatibility between SOV internal parts and fluids in contact with the SOV (e.g., Section 5.2.3.3);
- incorrect specification of ambient (non-accident) conditions (i.e., temperatures, radiation, and moisture) (e.g., Sections 5.1.1.2, 5.1.1.3);
- incorrect assessment of the life shortening effects of coil heating (e.g., Sections 5.1.2.1, 5.1.2.2).

(2) Inadequate Maintenance

- Failure to replace or rebuild limited life piece-parts of the SOVs (e.g., gaskets, seals, diaphragms, springs, and coils) on a timely basis (e.g., Sections 5.2.1.1, 5.2.1.2);
- failure to rebuild SOVs correctly (e.g., Section 5.2.2.1);
- failure to maintain clean, dry instrument air. Contaminants have caused long-term common-mode SOV degradation and failure (e.g., Sections 5.2.3.1, 5.2.3.2);
- excessive lubrication of SOV internals have contributed to SOV failures (e.g., Section 5.2.4.3).

(3) Installation Errors

- Incorrect orientation (backwards, upside-down) installation at an angle not in accordance with SOV qualification testing (e.g., Section 5.1.4.1, Appendix A);

- incorrect electric current (dc vs. ac) (e.g., Appendix A);

- inadequate terminal or junction box connections as a result of inadequate manufacturer's guidance or architect engineer's interpretation of manufacturer's guidance (e.g., Appendix A).

(4) <u>Manufacturing Defects</u>

- Lubrication errors (e.g., Section 5.2.4.1);

- defective materials - body, plug, springs, elastomers (e.g., Ref. 74);

- tolerance/assembly errors such as incorrect spring size or stiffness (e.g., Ref. 74, Appendix A);

- faulty wiring/coil defects (e.g., Appendix A).

6.2 SOV Failure Rates

It is difficult to accurately quantify SOV failure rates due to the following reasons:

(1) Not all SOV failures are documented. In many cases SOVs are viewed as expendable items, and their failures are simply viewed as end of life, and replacements are installed without any failure reports.

(2) Many SOV failures not associated with reactor trips or complete train failures of safety systems are not reported in the LER data base.

(3) Many SOVs that are subcomponents or piece-parts of other larger components or systems are not always reported as SOV failures in the nuclear plant reliability data system (NPRDS) for example, MSIVs, flow regulators, governors that fail to function properly because the related SOVs have failed are unlikely to be reported as SOV failures. Hence, an accurate estimate of SOV failure rates from NPRDS is not achievable.

Coupling the difficulties of obtaining accurate SOV failure counts with the difficulty of accurately assessing the number of successful SOV challenges or surveillance tests can, at best, lead to a crude estimate of SOV failure rates. Nonetheless, Table 4 lists SOV failure rates from several sources, including the results of this study's query of the NPRDS data for failures which occurred from January 1, 1985 through December 31, 1988.

It is significant that assuming quarterly testing of SOVs, NPRDS data, for the years 1985 through 1988, indicate failure rates of 7 to 9.5 times higher than the estimates used in WASH 1400 and in the NUREG 1150 methodology. Exemplary of item (3) above, the NPRDS failure records used for estimating SOV failure rates generally do not include the unrecognized SOVs.

It should be noted that publicly available SOV failure rate data does not distinguish between SOV size, energization mode, valve opening status, manufacturer, model, or type. In view of the wide range of SOV variations, the available failure data does not allow for accurately predicting individual SOV performance or failure rates.

Table 4 Estimates of SOV Failures to Operate

Source	Estimated failure rate
WASH 1400	1×10^{-3}/demand
This study (NPRDS data Jan 85-Dec. 88) Assuming quarterly testing	7 to 9.5×10^{-3}/demand
NUREG 1150 methodology NUREG/CR 4550 Vol. 1	1.0×10^{-3}/demand
(Seabrook PRA)	2.4×10^{-3}/demand
NUREG/CR 4550 Vol. 6 (Grand Gulf PRA)	1.6×10^{-3}/demand
NUREG/CR 4819, Vol. 1 (NPRDS data Sept 78-July 84)	7×10^{-8}/hr
This study (NPRDS data Jan 85-Dec. 88)	6.4 to 8.7×10^{-6}/hr

In view of the aforementioned problems of estimating single SOV failure rates, we find the task of estimating the risk resulting from common-mode SOV failure to be a difficult task, the results of which may have significant uncertainty. Such an undertaking is beyond the scope of the present study.

We know of no PRA which accounts for the contribution of common-mode failures of SOVs. Omission of such cross system/cross train failures lead towards nonconservative results.

6.3 Maintenance Problems

6.3.1 Maintenance Problems - SOV Manufacturers' Contributions

Review of operating experience indicates that a substantive number of SOV failures are attributed to inadequate maintenance or refurbishment. As evidenced by several of the events discussed in Chapter 5, it is clear that utilities are not fully informed of SOV maintenance requirements. The neglect or oversight of SOV maintenance oftentimes comes from the SOV manufacturers' failure to provide SOV maintenance requirements to the SOV users or second-level manufacturers--such as EDG manufacturers (ALCO, Colt/Fairbanks-Morse, General Motors, Delaval, Cooper-Bessemer), valve manufacturers (Xomox), controller manufacturers (Fisher, Masoneilan), etc. Some SOV manufacturers are more prescriptive than others. Some manufacturers provide no guidance on preventive maintenance. One manufacturer (Valcor) varies its recommendations depending on whether the purchaser bought the "full documentation package."

Examples of the variation among SOV manufacturers' maintenance recommendations are discussed below.

ASCO does not provide any specific recommendations for SOV maintenance or refurbishment. This is even true for their nuclear qualified 1E valves. Quoting ASCO's installation and maintenance bulletin for NP8323 SOVs (Ref. 92).

"Preventive Maintenance

1. Keep the medium flowing through the valve as free from dirt and foreign material as possible. Use instrument quality air, oil-free for Suffix "E."

2. While in service, operate valve periodically to insure proper opening and closing.

3. Periodic inspection (depending upon medium and service conditions) of internal valve parts for damage or excessive wear is recommended. Thoroughly clean all parts. Replace any parts that are worn or damaged.

4. The valves may require periodic replacement of the coils and all resilient parts during their installed life to maintain qualification. The exact replacement period will depend on ambient and service conditions. Spare parts kits and coils are ordered separately (see Ordering Information). Consult ASCO for specific recommendations in connection with the replacement of parts."

Valcor provides specific recommendations for maintenance or refurbishment of its N-stamped SOVs. However, it is possible to purchase the same valve without an N stamp. If it is purchased without an N stamp, it can also be purchased without any documentation. Such a "no-doc" valve would not be provided with any preventive maintenance or refurbishment recommendations.

Target Rock - All of Target Rock Corporation's SOVs appear to be supplied with specific preventive maintenance and refurbishment recommendations.

Circle Seal, Ross and an Unspecified Foreign Manufacturer - Circle Seal and Ross make SOVs which are used in several different EDG air start systems. Those valves are not supplied with any preventive maintenance or refurbishment recommendations. Lack of specific maintenance recommendations has contributed to multiple failures of a foreign manufacturer's SOVs used in the EDG air start system of a foreign plant (see Section 6.3.2.1).

Skinner Electric - SOVs manufactured by Skinner Electric Company which are used in Woodward Governors on BWR HPCI turbines are not provided with any preventive maintenance or refurbishment recommendations.

Sperry-Vickers - SOV's manufactured by Sperry-Vickers which are used in the hydraulic controllers used for BWR recirculation pumps and main turbine-trip systems are not provided with preventive maintenance or refurbishment recommendations.

6.3.2 Maintenance Problems - Contribution of the Unrecognized SOVs

In many cases plant maintenance and operations personnel are unaware of the presence of, or maintenance requirements of SOVs. This situation is common because there are many cases in which SOVs represent only a small portion of a larger system or component, and the information available to plant staff does not identify the care required by the SOV which is "unrecognized" within the "overall system". Examples that we have observed are:

Emergency diesel generators: air start systems, governors, and cooling water control systems. Auxiliary feedwater and main feedwater systems: flow control regulators. BWR high pressure cooling injection systems: remote shutoff controls, governors. Instrument air dryers: desiccant column regeneration and cycling control systems.

6.3.2.1 Unrecognized SOVs in Emergency Diesel Generators

The operation and maintenance manuals for the plants diesel engines, and operator and maintenance personnel training are heavily weighted by the engine manufacturer's literature which, at best, includes minimal information regarding the SOVs used in the EDG's auxiliary systems. Specific examples observed included:

A foreign reactor site where the air start SOVs were not on any preventive maintenance program. Failure of one SOV due to aging of a Buna-N diaphram was undetected until its redundant backup failed from the same cause. As a result, the station added refurbishment or changeout of such resilient parts to all its EDG air start systems. Similar failures have been observed at numerous U.S. plants, e.g., Three Mile Island 1* (Refs. 93, 94), Ginna (Refs. 95, 96, 97), Duane Arnold (Ref. 98).

During a trip to the Duane Arnold plant in reviewing SOV experience, AEOD staff learned that subsequent to the July 1982 failure (Ref. 98), the Duane Arnold staff recognized the SOV's limited lifetime and the need for SOV refurbishment or replacement. As a result the Duane Arnold staff added SOV changeout to their preventive maintenance program. However, several years later, plant maintenance personnel made a decision to eliminate changeout of that SOV from their preventive maintenance program. The rationale for dropping such preventive maintenance was that the SOV was cycled only 7 seconds a month, and such limited use did not seem to require maintenance. The basis for implementing the SOV's preventive maintenance and the previous failure, which resulted from age related degradation, appeared to have been forgotten. Subsequently, the licensee stated that preventive maintenance on the aforementioned SOVs would be reinstated.

As a student in a recent TVA EDG training course applicable to seven plants, (Browns Ferry 1, 2, 3, Sequoyah 1, 2, Watts Bar 1, 2) the case study author learned that maintenance literature for the General Motors Electro-Motive Division (GM-EMD) diesel engine supplied by Morris-Knudsen, does not provide the licensee with any instructions for refurbishment or changeout of the SOVs in the EDGs' air start and governor control systems.

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*Telephone discussion, M. Schaefer, General Public Utilities, and H. L. Ornstein, USNRC, February 16, 1989.

6.3.2.2 Unrecognized SOVs in Auxiliary and Main Feedwater Systems

As noted in Section 5.2.3.2, a review of failure data at North Anna Units 1 and 2 showed that poor quality air was the root of the SOV/control valve failures. As a result, the licensee initiated a program for repairing and replacing the SOVs and control valves, as well as upgrading the air system quality and enhancing plant personnel training and maintenance practices.

6.3.2.3 Unrecognized SOVs in BWR High Pressure Coolant Injection Systems

In Reference 99 the Duane Arnold plant's licensee reported the failure of the remote shutoff control system which is part of the HPCI turbine's governor system. Discussion with plant personnel and the turbine manufacturer indicated a lack of communication between them regarding the potential for undetected failures of the SOVs. The licensee's report noted that the failure was caused by aging of the elastomeric parts of the SOV. Such an undetected failure could result in failure to start the HPCI system. Apparently information provided by the turbine manufacturer (Dresser-Rand, formerly Terry Turbine) did not provide adequate maintenance information about the SOV that is supplied as an internal part to the Woodward Governor (the SOV was manufactured by Skinner Electric Co.). The Skinner Electric maintenance instructions do not address preventive maintenance or service life requirements for the SOV. The Woodward Governor service manual does not address SOV preventive maintenance, or service life. The service information letters (SILs) provided by the NSSS vendor (GE) did address other aspects of HPCI turbine service, performance and maintenance, but discussion with plant personnel and GE personnel indicated that maintenance, refurbishment or replacement of the SOVs are not addressed in any of GE's SILS.

6.3.2.4 Unrecognized SOVs in Instrument Air Driers

Review of a leading instrument air drier manufacturer's operation and maintenance manual indicated minimal guidance with regard to SOV maintenance. The SOVs are required to cycle every five minutes to ensure that the air flows through the correct desiccant stack to assure proper air drying and acceptable outlet dew points. Failure of the SOVs could result in undetected high instrument air moisture content which could lead to degradation and malfunction of equipment utilizing instrument air, including other SOVs that perform safety-related functions.

6.3.3 Maintenance Problems - Contributions of Utility Programs and Practices

Review of SOV failure reports and follow up discussions with plant personnel, NRC inspectors, and SOV manufacturers showed that shortcomings in many utilities' SOV maintenance programs and practices were a major source of SOV failures. For example:

(1) Reference 100 indicated that Brunswick plant staff stated that ASCO Class 1E SOVs with 30-year qualified lives did not require any preventive maintenance for 30 years. The licensee did not recognize the fact that the resilient, or elastomeric parts of the SOVs require more frequent replacement.

(2) After finding that SOVs would not shift their position on demand during surveillance testing, it was common practice for Brunswick and North Anna Stations' plant personnel to tap the SOVs ("mechanical agitation"). If a SOV would change position when tested after the mechanical agitation, no further maintenance would be performed, and the SOV would be declared operable (Refs. 100, 101).

(3) ASCO's valve engineering department product engineering manager visited the Susquehanna plant to assist the utility in finding the root cause of the failure of a rebuilt ASCO SOV which failed after being returned to service. The ASCO manager's discussions with plant personnel revealed that subsequent to rebuilding the SOV, plant personnel bench tested the SOV with poor quality service air instead of clean, dry instrument air. Inspection of the SOV revealed that oil from the service air system had caused the SOV's second failure.*

(4) The Calvert Cliffs 1 and 2 plants' SOV maintenance is tracked by the station's reliability centered maintenance (RCM) program. The RCM program has found that instrument air dryer SOVs have a mean time between failure of 10 months, but the plants' maintenance program replaces such SOVs on an annual basis.** The failure of the instrument air dryer SOVs can cause serious instrument air system degradation leading to common-mode failures of many other SOVs, including those that perform safety-related functions.

6.3.4 Rebuilding vs. Replacement

Review of SOV failure data indicates that inadequate rebuilding of SOVs has been a significant cause of SOV failures. There is a broad range of complexity associated with rebuilding SOVs, depending upon individual SOV manufacturer and model number. To further complicate the issue, there are variations among SOV manufacturers with regard to providing test apparatus to check the soundness of rebuilt SOVs; for example, Target Rock Corporation has marketed a test fixture for licensees to test their rebuilt SOVs.

Although some manufacturers provide values of acceptable coil voltages, leakage rates, etc., to enable users to check the conditions of their SOVs, some other manufacturers do not make such information available. Serious questions arise about the acceptability of new SOVs if acceptance criteria are not available.

In Reference 102, ASCO notified licensees that it has discontinued selling rebuild kits for its nuclear power plant SOVs (NP series). However, ASCO is continuing to sell rebuild kits for commercial SOVs and SOVs used in BWR scram systems (purchased through GE).

As noted in Chapter 5, there have been several events in which common-mode failures resulted from incorrect rebuilding of SOVs. The potential for common-mode SOV failure resulting from rebuilding errors may be minimized by staggering

*Telephone discussion, J. Shank, ASCO, and H. L. Ornstein, USNRC, May 11, 1989.
**Telephone discussion, J. Osborne, Baltimore Gas and Electric Co., and H. L. Ornstein, USNRC, April 21, 1989.

the rebuilding (if possible), or by limiting the amount of SOV rebuilding done by any one individual (see Sections 5.2.2.2, 5.2.2.3).

In addition to focussing attention on the useful life of SOVs being governed by the elastomeric parts, attention should be focused on the shelf life and on the actual manufacturing date of the elastomeric parts in the rebuild kits. For example, because of elastomeric (Buna-N) degradation observed in SOVs used in BWR scram systems, GE recommended (Ref. 56) that BWR scram system SOVs having Buna-N parts be rebuilt periodically. The frequency of rebuilding should be governed by the "useful life" of the elastomer ("useful life" being defined as the sum of shelf life and in-service life). Controlled by the Buna-N parts, GE recommended a "useful life" of seven years for scram system SOVs. The seven years being from the time of kit manufacture (not from the time of rebuild).

7.0 FINDINGS

The root causes of most SOV problems are traceable to the lack of understanding of the capabilities and requirements of SOVs. Oftentimes plant operations and maintenance programs do not address the short lifetimes of the resilient elastomeric piece-parts of the SOVs (gaskets, seals, diaphragms, etc.). Maintenance programs also fail to address the low tolerance SOVs have for operating under adverse conditions that are significantly different than those of the controlled laboratory environment under which they were originally tested. In many cases, the manufacturers have not provided the end users with a full understanding of the sensitive nature of certain parts of the SOVs. Many users have learned after using certain SOVs that they are unforgiving and finicky with regard to contaminants and local environmental conditions.

Deficiencies in selection, operation, and maintenance of SOVs have resulted in hundreds of SOV failures, many of which were common-mode failures that cut across multiple trains of safety systems. Our major findings regarding the root causes of common-mode SOV failures are described below.

7.1 Design Application Errors

7.1.1 Ambient Temperatures

Many common-mode SOV failures have resulted from subjecting SOVs to ambient temperatures in excess of their original design envelope. Such common-mode failures have resulted from localized steam leaks (see Section 5.1.1.1), incorrect estimates of ambient temperatures (see Sections 5.1.1.2, 5.1.1.3), and failure to account for ventilation system malfunctions (Ref. 103). Because the useful qualified lives of the short lived parts of SOVs are halved by every 18°F temperature rise (Arrhenius theory - Refs. 104, 105), seemingly minor increases in ambient temperatures above those considered in the SOV design cannot be allowed to prevail for extended time periods without running the risk of sustaining "seemingly" premature failures.

7.1.2 Heatup from Energization

Many common-mode SOV failures have occurred because the estimated service lives did not properly include the life-shortening effects of heatup due to continuous coil energization (see Sections 5.1.2.1, 5.1.2.2). Many licensees have been unaware of this situation. For example, by incorrectly using the certificates of compliance provided with ASCO's NP-1 nuclear qualified valves, licensees have overpredicted the service life of continuously energized SOVs. Use of appropriate SOV heatup data in conjunction with Arrhenius theory (Refs. 104, 105) has been found to be an acceptable (but not a 100 percent accurate) method for predicting SOV life.

7.1.3 Maximum Operating Pressure Differential

Many licensees have found misapplications in which SOVs could be or were subjected to operating pressure differentials that could or did prevent them from operating. Although NRC issued Information Notice 88-24 (Ref. 23) about this problem, as noted in Section 5.1.3.1, it is not clear that all the licensees have addressed the issue, of over-pressure which could result from pressure regulator failures.

7.1.4 Unrecognized SOVs Used as Piece-Parts

Many SOVs used in safety-related equipment are not given prominent attention because they are used as piece-parts of larger equipment. Specific preventative maintenance requirements are not readily available for them. Many SOV failures have occurred as a result of the lack of maintenance or replacement of such unrecognized SOVs (see Section 6.3.2).

7.1.5 Directional SOVs

Six plants have reported experiencing undesirable spurious openings of safety-related SOVs due to high backpressure. The licensees did not recognize or were not aware of the directional requirements of the valves (see Section 5.1.4.1). In addition to reports of SOV malfunctions which occurred because they were installed backwards, there are also reports of SOVs which were installed upside-down, or at improper angles (see Appendix A).

7.2 Maintenance

Operating experience has confirmed that SOV maintenance deficiencies can incapacitate multiple safety systems. The pervasiveness of maintenance deficiencies highlight the need for implementing aggressive SOV maintenance programs to prevent widespread common-mode failures. Specific maintenance problem areas are discussed below.

7.2.1 Maintenance Frequency

Lack of timely preventive maintenance (complete SOV replacement or rebuilding of short-lived piece-parts of SOVs) has resulted in many SOV failures (see Sections 5.1.2.1, 5.2.1.2, 6.3.2.1). Many SOV manufacturers have failed to provide the users with definitive information on the useful lifetime of the SOVs internal diaphragms, gaskets, O-rings, coils, etc. Some manufacturers indicate that periodically changing the elastomeric parts is necessary, without specifying the frequency of changes. Other manufacturers do not even mention that any changing is necessary. Similarly, there are wide variations among manufacturers with regard to specifying (or not specifying) the allowable shelf lives of their SOVs and SOV rebuild kits (see Sections 6.3.1, 6.3.3, 6.3.4).

Because of the limited lives of their elastomeric or resilient parts, SOVs should be replaced or refurbished in accordance with the manufacturers' recommendations. In the absence of specific manufacturers' recommendations, and in absence of applicable failure data, changeout of short-lived elastomeric and resilient materials (or complete valve replacement) should be done on the basis of material shelf life, manufacture date and installation date. However, changeout of elastomeric parts or complete SOV replacement should be done more frequently if operating conditions exceed the originally envisioned design conditions or if field failure experience dictates.

7.2.2 Replacement Versus Rebuilding

Rebuilding or refurbishing certain models of several manufacturers' SOVs is a difficult task that can be made even more difficult if it is done in place, requiring the workers to wear decontamination or protective clothing. However, removal and reinstallation of N-stamped valves which are welded into the primary system are not simple, inexpensive tasks either.

Incorrect rebuilding or refurbishing of SOVs have caused many premature failures (e.g., see Sections 5.2.2.1, 5.2.2.2). Contributing to the difficulty of rebuilding or refurbishing SOVs correctly is the fact that many manufacturers do not provide the licensees with adequate SOV documentation or testing apparatus to verify the effectiveness of the rebuilt or refurbished SOV. As a result, post-rebuild testing at many facilities merely involves cycling verification rather than performing appropriate tests normally performed by the manufacturer during initial SOV manufacture (see Section 6.3.4).

Discussions with plant personnel have revealed that many licensees, (e.g., Perry, River Bend, Salem, Grand Gulf, Duane Arnold) have chosen to discontinue rebuilding certain SOVs because improper rebuilding can result/has resulted in many SOV failures and costly down-times. In general, licensees have reacted favorably to ASCO's recent decision to discontinue supplying rebuild kits for their NP-1 nuclear qualified SOVs (Ref. 106, 107). ASCO's decision to discontinue supplying SOV rebuild kits was based upon field experience which indicated that many ASCO SOV failures were caused by inadequate rebuilding techniques.

7.2.3 Contamination

Many common-mode SOV failures have been caused by contaminants in the fluids which flow through SOVs; instrument air in particular (see Sections 5.2.3.1, 5.2.3.2, 5.2.3.3).

SOV contamination resulting from particulates, moisture, and hydrocarbons in the instrument air system have been a major source of common-mode SOV failures. In many plants contaminants were introduced during original construction. Many contamination problems have resulted from poor design or maintenance of the instrument air systems.

Many SOV failures are clearly attributed to subjecting the SOVs to conditions beyond their design regarding particulates, moisture, hydrocarbons, etc. Contributing to the problem is the fact that some manufacturers have specified the need for clean air or instrument quality air without quantification (e.g., maximum allowable particle sizes and dew points).

Although licensees are taking actions to improve the quality of their plants' air systems, there is concern for the residual effects of previous air system contamination (Section 5.2.3.2). Long-term SOV degradation such as deterioration of EPDM parts as a result of hydrocarbon intrusion, formation of varnish-like deposits from heatup of hydrocarbons, and residue formation from the interaction of moisture, silicone lubricant, and heat, are areas of concern.

7.2.4 Lubrication

Improper lubrication has resulted in many common-mode SOV failures. The improper lubrication has been attributed to manufacturing errors (see Section 5.2.4.1), as well as licensee errors. Errors include the wrong choice of lubricant (see Sections 5.2.4.2, 5.2.4.3), unauthorized use of incorrect lubricant (see Section 5.2.4.1), and use of excessive amounts of lubricant (see Section 5.2.4.4).

7.3 Surveillance Testing

Several cases (see Section 6.3.3) have been reported in which SOVs failed to actuate on demand during surveillance testing, however, subsequent tapping ("mechanically agitating") the SOVs would enable them to actuate. As a result, the SOVs were declared operable without addressing the cause of the original failures, thus leaving the SOVs in degraded states vulnerable to future failures upon demand.

Similarly, as noted in Section 5.3.1, incorrect surveillance testing led operators to operate a BWR with multiple failed scram pilot SOVs.

7.4 Verification of the Use of Qualified SOVs

The issue of environmental qualification of Class 1E electrical equipment and SOVs has been addressed by utilities in response to Bulletins 79-01A and B. Nonetheless, there are many instances in which SOVs that were assumed (in plant safety analyses) to operate to mitigate design-basis events, have been procured as "commercial grade" SOVs of questionable quality and are not being maintained in a manner commensurate with their intended safety function.

Examples have been found where commercially available, non-qualified SOVs are being used in safety-related applications without appropriate verification of product quality and design control. In many instances the SOVs lack verification that they can withstand the accident conditions postulated in plant safety analyses. A common problem appears to be categorization of the SOVs for use in EDG air systems. In many cases the original equipment that contained SOVs as piece-parts was certified or qualified to meet 1E requirements, whereas the individual replacement SOVs were not. (See Section 5.4.1).

7.5 Redundancy and Diversity

The root causes of many common-mode failures of safety-related SOVs have eluded many licensees' detailed failure analyses (see Section 5.2.4.4). In many such instances the search for the origins of foreign unidentified sticky substances (FUSS) have been inconclusive, and corrective actions were limited to cleaning or replacing the failed SOVs (e.g., Brunswick (Ref. 2), Franklin Institute (Ref. 76)). In some cases, the licensees discounted instrument air system contamination (oil, water, dirt) as the cause of the FUSS, but plant operating history indicated a prior history of air system contamination which could have been a contributor to the problem. Similarly, the SOV manufacturing process (see Section 5.2.4.1) and the licensee's rebuilding process (see Sections 5.2.2.1, 5.2.2.2, 5.2.2.3, Section 6.3.3) have been found to be the sources of contaminants which caused common-mode SOV malfunctions.

Staggering the maintenance, testing and replacement of redundant SOVs may represent a simple way of preventing common-mode failures of redundant SOVs. In addition, if the root causes of persistent common-mode SOV failures cannot be found, or cannot be eliminated, the need for SOV diversity (with regard to model, energization mode, failure mode, or manufacturer) becomes apparent. (See Appendix B for a discussion of an example of such a problem with the ASCO NP8323 SOVs used for MSIV control at many BWRs.)

7.6 Feedback of Operating Experience

Based upon visits to several of the major SOV manufacturers' facilities (e.g., ASCO (June 1988), Target Rock (November 1988), Valcor (December 1988), AVC (February 1990)) discussions with other SOV manufacturers (e.g., Circle Seal, Skinner Electric), and extensive discussions with manufacturers who's equipment utilize SOVs as piece-parts (e.g., Fisher Controls, Dresser-Rand/Terry Turbine, Xomox Valves, California Controls (Calcon), Colt/Fairbanks-Morse), it was found that SOV manufacturers have not been fully apprised by the utilities of many SOV failures that have occurred at nuclear power plants.

SOV manufacturers are not aware of many widespread failures of safety-related equipment that may have been caused by generic manufacturing or design deficiencies of the SOVs. Conversely, when licensees purchase SOVs commercially, without 10 CFR 50 Appendix B, and 10 CFR Part 21 requirements, they are not fully apprised by the manufacturers of generic defects that are discovered subsequent to delivery. In one case, a major SOV manufacturer did not feed back generic SOV defect information to the end user due to the manufacturer's failure to understand or properly implement the 10 CFR Part 21 requirements that were applicable to its SOVs (Ref. 74) (also see Sections 5.1.2.2, 5.2.4.3).

8.0 CONCLUSIONS

Operating experience has demonstrated that common-mode failures and degradations of SOVs can compromise multiple trains of multiple safety systems. The fact that hundreds, and in many cases thousands, of SOVs permeate all important systems at all U.S. LWRs highlights the necessity for eliminating common-mode SOV problems that jeopardize plant safety.

8.1 Safety Significance

Considering the application of the "single failure criterion," the application of "defense-in-depth," and the large population of SOVs used in safety-related systems at U.S. LWRs, it appears that the number of individual random SOV failures that have been reported do not appear to present a safety concern. However, examination of the root causes of many SOV failures at many plants demonstrate error patterns in the design/applications, maintenance and testing of SOVs which have led to a multitude of widespread common-mode failures.

Operating experience shows that SOVs are vulnerable to numerous common-mode failure mechanisms and their failures can adversely impact numerous safety systems. Some of the safety systems that were observed to be adversely impacted by common-mode failures of SOVs were: EDG air start system, BWR scram system, BWR main steam isolation system, PWR auxiliary feedwater system, PWR safety injection system, component cooling water system, containment isolation system, residual heat removal system, containment cooling system. These safety systems are required to function in order to prevent and/or mitigate accidents and/or to protect the public from release of radiation from design basis accidents. Therefore, we conclude that SOV problems represent a significant safety concern.

Chapter 5 presents examples of over twenty recent events having the potential for common-mode failures or degradations of over 600 SOVs in important plant systems.* The common-mode failures and degradations cut across multiple trains of safety systems as well as multiple safety systems. The recurrence of common-mode SOV failures or degradations highlights the gravity of the situation. Although plant safety analyses do not address common-mode, multiple train/multiple safety system failures, operating experience indicates that they have occurred and continue to occur. The common-mode SOV failures and degradations that have occurred which compromised front line safety systems such as emergency ac power, auxiliary feedwater, high pressure coolant injection, and scram systems clearly demonstrate the safety significance of SOV problems.

Chapter 6 presents estimates of SOV failure rates which were extracted from plant operating data (NPRDS). The estimates indicate failure rates of almost one order of magnitude larger than those assumed in the WASH 1400 study and in the NUREG 1150 methodology for level one PRAs. Coupling such nonconservative treatment of SOV failures with the fact that level one PRAs do not address SOV failures that cut across multiple systems leads us to conclude that the risk contribution from SOVs may have been severely underestimated in previous risk assessments.

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*There have been many other similar events. The events chosen here are intended to be illustrative. Surely they are not a complete set of all such events.

8.2 Need for Action

On the basis of our analysis of operating data, we conclude that the SOV problems outlined in this study need to be addressed to ensure that the margins of safety for all U.S. LWRs remain at the levels perceived during original plant licensing.

We note that to date the NRC has issued 36 generic communications pertaining to SOV problems (See Appendix C). Those generic communications alerted licensees to specific SOV problems. Based on our study we believe that an integrated comprehensive program is needed now to address the root causes of SOV problems described in this report. We conclude that integrated implementation of the recommendations provided in Chapter 9 will significantly reduce the likelihood for common-mode SOV failures eroding the margins of safety at all LWRs.

9.0 RECOMMENDATIONS

In order to minimize the potential for common-mode failures, attention should be focused upon certain aspects of SOVs. We recommend that the actions discussed below be initiated in order to assure that the plants retain the margins of safety perceived in their original licenses. If SOVs are found to be inadequate, prompt corrective actions should be taken.

9.1 Design Verification

Licensees should review SOV design specifications and actual operating conditions to verify that all SOVs assumed to operate in FSAR safety analyses are operating within their design service life.

9.1.1 Ambient Temperatures

The reviews should assure that the lifeshortening effects of elevated ambient temperatures are considered in the determination of SOV service life.

9.1.2 Heatup From Energization

The reviews should assure that the lifeshortening effects of heatup due to coil energization are appropriately accounted for in the determinations of SOV service life.

9.1.3 Maximum Operating Pressure Differential

The reviews should assure that the potential for overpressure due to pressure regulator failure or hydraulic fluid heatup due to postulated accident conditions have been considered in the selection of the SOVs.

9.1.4 Unrecognized SOVs Used as Piece-Parts

In addition to verifying the adequacy of the high visibility SOVs as noted above, similar verification should be made for unrecognized SOVs which are used as piece-parts of flow regulators, governors, emergency diesel generators, etc.

9.1.5 Directional SOVs

Licensees should verify that directional SOVs are installed in orientations which will assure satisfactory operation of the safety-related equipment which depend upon them.

9.2 Maintenance

9.2.1 Frequency

Licensees should implement SOV maintenance programs to replace or refurbish SOVs on timely bases. Replacement or refurbishment schedules should focus upon thermal aging due to elevated ambient conditions and heatup from continuous coil energization.

9.2.2 Replacement Versus Rebuilding*

Licensees should review their programs for rebuilding SOVs because certain SOVs are difficult to rebuild and test properly, and improperly rebuilt SOVs degrade plant safety. Numerous utilities canvassed have found that in most instances it is cost beneficial to replace SOVs rather than to rebuild them.

If licensees choose to continue to rebuild their SOVs, we recommend that they obtain or develop test equipment to enable verification that the rebuilt SOVs meet all the performance specifications of the original SOVs.

9.2.3 Contamination

Aggressive actions should be taken to assure that fluids which flow through SOVs, instrument air in particular, are maintained free of contaminants. If operational experience indicates a pattern of SOV malfunctions resulting from contamination (such as water or hydrocarbon intrusion), the affected licensees should consider replacing SOVs that have been subjected to previous air system degradation, assuming that the root causes of the air system problems have been corrected (in accordance with Generic Letter 88-14).

9.2.4 Lubrication

SOV manufacturer's lubrication instructions should be adhered to. Substitution of similar but not identical lubricants should be avoided. However, if substitutions are made, their compatibility with all associated hardware should be verified.

9.3 Surveillance Testing

Operation and maintenance personnel training should emphasize the importance of surveillance testing, root cause failure analysis, and timely repair or replacement of malfunctioning SOVs.

Licensees should review, and if appropriate, modify their surveillance testing procedures. Procedures should expressly prohibit "tapping" or mechanical agitation of SOVs as techniques to assist successful operation during surveillance testing. Procedures should include actions to be taken when unsatisfactory test results are encountered, as well as a requirement to analyze and evaluate the causes of the unsatisfactory results prior to declaring the component back in service (even though subsequent retest results may be satisfactory).

9.4 Verification of the Use of Qualified SOVs

Licensees should review all SOVs in safety-related applications, EDGs in particular, to ensure that they meet 10CFR 50 Part B and appropriate Class 1E requirements; and that they have been installed and maintained appropriately to assure they will operate in a manner consistent with the assumptions of the plants' safety analyses. If there is doubt regarding the acceptability of any such SOVs, they should be replaced with appropriately qualified ones.

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*exclusive of coil replacement - coils are generally replacement items

9.5 Redundancy and Diversity

When operating experience indicates unexplained repetitive common-mode SOV failures affecting redundant components - (such as BWR MSIVs and containment isolation valves), licensees should consider performing maintenance, testing and replacement of redundant SOVs on a staggered basis. Additional consideration should be given to using diverse SOVs (different design or manufacturer).

9.6 Feedback of Operating Experience

In order to improve SOV reliability, an industry group such as the Institute of Nuclear Power Operations (INPO) should initiate an SOV failure feedback program. The program should alert SOV manufacturers to failures of their equipment by providing them with complete failure records of their specific SOVs such as those found in NPRDS.

10.0 REFERENCES

1. V. P. Bacanskas, G. C. Roberts, G. J. Toman, "Aging and Service Wear of Solenoid-Operated Valves Used in Safety Systems of Nuclear Power Plants, Volume 1. Operating Experience and Failure Identification," Oak Ridge National Laboratory, NUREG/CR-4819, ORNL/Sub83-28915/4/V1, March 1987.

2. Carolina Power & Light Company, Licensee Event Report (LER) 50-324/88-001 Rev. 5, Brunswick Steam Electric Plant Unit 2, February 19, 1990.

3. Burns and Roe, "Investigation of Valve Failure Problems in LWR Power Plants," ALO-73, April 1980.

4. W. H. Hubble, C. F. Miller, "Data Summaries of Licensing Event Reports of Valves at U.S. Commercial Nuclear Power Plants," January 1, 1976 to December 31, 1978, EG&G Idaho, Inc. NUREG/CR-1363 EGG-EA-5125, June 1980.

5. "IEEE Maintenance Good Practices for Nuclear Power Plant Electrical Equipment; Work-In-Progress Report, Evaluation of Maintenance and Related Practices for Solenoid Operated Valves In Nuclear Power Generating Stations," IEEE Power Engineering Society, Nuclear Power Engineering Committee, Subcommittee 3, Working Group 3.3, 1988.

6. U.S. Nuclear Regulatory Commission, Inspection Report 50-440/87-024, Perry Nuclear Power Plant Unit 1, January 22, 1988.

7. Cleveland Electric Illuminating Company, Licensee Event Report (LER) 50-440/87-073 Rev. 1, Perry Nuclear Power Plant, Unit 1, June 3, 1988.

8. U.S. Nuclear Regulatory Commission, Information Notice No. 88-43, "Solenoid Valve Problems," June 23, 1988.

9. U.S. Nuclear Regulatory Commission, Inspection Report 50-440/87-027, Perry Nuclear Power Plant Unit 1, February 10, 1988.

10. U.S. Nuclear Regulatory Commission, Inspection Report 50-302/89-09, Crystal River 3, June 7, 1989.

11. U.S. Nuclear Regulatory Commission, Inspection Report Number 50-336/88-22, Millstone Nuclear Station, Unit 2, November 8, 1988.

12. Memorandum from J. W. Craig, U.S. Nuclear Regulatory Commission, to A. C. Thadani, Subject: "Status of TI 2515/98 "High Temperature Inside Containment/Drywell In BWR and PWR Plants," dated March 13, 1989.

13. U.S. Nuclear Regulatory Commission, Information Notice No. 89-30, "High Temperature Environments At Nuclear Power Plants," March 15, 1989.

14. U.S. Nuclear Regulatory Commission 10 CFR 50.72 Report Number 16313, Grand Gulf Unit 1, August 14, 1989.

15. U.S. Nuclear Regulatory Commission Region II Daily Report, August 15, 1989.

16. System Energy Resources, Inc., Licensee Event Report (LER) 50-416/89-013, Grand Gulf 1, September 13, 1989.

17. General Electric Company, Service Information Letter (SIL) No. 481, "Category 2, Malfunction of ASCO Solenoid Valves for MSIVs," February 14, 1989.

18. U.S. Nuclear Regulatory Commission, Information Notice 89-66, "Qualification Life of Solenoid Valves," September 11, 1989.

19. Automatic Switch Company (ASCO), "Field Notification Concerning the Qualified Life of ASCO Catalog NP-1 Valves," October 27, 1989.

20. Memorandum, P. T. Knutsen, Virginia Electric and Power Company, "Self Heating Effects in ASCO Solenoid Valves," dated February 3, 1987.

21. North Anna Power Station Deviation Report Number 87-105, dated February 4, 1987.

22. Memorandum, P. T. Knutsen, Virginia Electric and Power Company, "ASCO SOVs To Be Replaced at North Anna Power Station Units 1 and 2," dated March 16, 1987.

23. U.S. Nuclear Regulatory Commission, Information Notice 88-24, "Failures of Air-Operated Valves Affecting Safety-Related Systems," May 13, 1988.

24. Wisconsin Public Service Corporation, Licensee Event Report (LER), 50-305/87-012 Rev. 1, Kewaunee Nuclear Power Plant, March 4, 1988.

25. U.S. Nuclear Regulatory Commission 10 CFR 50.72 Report Number 12013, Calvert Cliffs 1 and 2, April 14, 1988.

26. U.S. Nuclear Regulatory Commission 10 CFR 50.72 Report Number 12015, Calvert Cliffs 1 and 2, April 14, 1988.

27. U.S. Nuclear Regulatory Commission, Inspection Report 50-317/88-07 and 50-318/88-08, Calvert Cliffs Nuclear Power Plant Units 1 and 2, June 3, 1988.

28. Memorandum from S. E. Scrace, Northeast Utilities, to E. Abolafia, "Failure of Air Operated Valves Affecting Safety Related Systems, NRC IN 88-24, NOA 0673, CR 0488-24 Revision 0," November 8, 1988.

29. Florida Power Corporation, Licensee Event Report (LER) 50-302/89-01 Rev. 2, Crystal River Unit 3, June 7, 1989.

30. U.S. Nuclear Regulatory Commission, Information Notice 80-40, "Excessive Nitrogen Supply Actuates Safety-Relief Valve Operation to Cause Reactor Depressurization," November 7, 1980.

31. U.S. Nuclear Regulatory Commission, Office of Inspection and Enforcement, Bulletin No. 80-25, "Operating Problems with Target Rock Safety Relief Valves at BWRs," December 19, 1980.

32. Metropolitan Edison Co., Licensee Event Report (LER) 50-289/80-018, Three Mile Island Unit 1, November 4, 1980.

33. Georgia Power Company, Licensee Event Report (LER) 50-424/87-002, Vogtle Electric Generating Plant Unit 1, February 23, 1987.

34. U.S. Nuclear Regulatory Commission 10 CFR 50.72 Report Number 12890, Pilgrim Unit 1, July 19, 1988.

35. U.S. Nuclear Regulatory Commission Region I Daily Report, July 20, 1988.

36. Boston Edison Company, Licensee Event Report (LER) 50-293/88-021, Pilgrim Nuclear Power Station, August 18, 1988.

37. U.S. Nuclear Regulatory Commission, Inspection Report 50-336/88-22, Millstone Nuclear Power Station, Unit 2, November 8, 1988.

38. U.S. Nuclear Regulatory Commission, Inspection Report 50-302/89-01, Crystal River Unit 3, April 13, 1989.

39. U.S. Nuclear Regulatory Commission 10 CFR 50.72 Report Number 14442, Crystal River Unit 3, January 7, 1989.

40. U.S. Nuclear Regulatory Commission 10 CFR 50.72 Report Number 14467, Crystal River Unit 3, January 11, 1989.

41. Target Rock Corporation Operation Manual TRP 1571J, May 23, 1978.

42. Gulf States Utilities Company, Licensee Event Report (LER) 50-458/89-022, River Bend 1, June 1, 1989.

43. U.S. Nuclear Regulatory Commission, Generic Letter 88-14, "Instrument Air Supply System Problems Affecting Safety-Related Equipment," August 8, 1988.

44. Gulf States Utilities Company, Licensee Event Report (LER) 50-458/89-024, River Bend 1, June 19, 1989.

45. U.S. Nuclear Regulatory Commission, Preliminary Notification, PNO-III-85-84, September 20, 1985.

46. U.S. Nuclear Regulatory Commission, Region III Daily Report, September 24, 1985.

47. Commonwealth Edison Company, Licensee Event Report (LER) 50-249/85-018, Dresden Nuclear Power Station, Unit 3, October 1, 1985.

48. U.S. Nuclear Regulatory Commission, Office of Inspection and Enforcement, Information Notice No. 85-95, "Leak of Reactor Water to Reactor Building Caused by Scram Solenoid Valve Problem," December 23, 1985.

49. U.S. Nuclear Regulatory Commission, Office for Analysis and Evaluation of Operational Data, Case Study No. AEOD/C403, "Edwin I. Hatch Unit No. 2 Plant Systems Interaction Event on August 25, 1982," May 1984.

50. Carolina Power & Light Company, Licensee Event Report (LER) 50-325/79-074, Brunswick Steam Electric Plant, Unit 1, November 16, 1979.

51. U.S. Nuclear Regulatory Commission, Office of Inspection and Enforcement, Bulletin No. 80-14, "Degradation of BWR Scram Discharge Volume Capability," June 12, 1980.

51a. Cleveland Illuminating Company, Licensee Event Report (LER) 50-440/87-009, Perry Nuclear Power Plant, March 27, 1987.

52. Carolina Power & Light Company, Licensee Event Report (LER) 50-325/87-020, Rev. 1, Brunswick Steam Electric Plant Unit 1, March 31, 1988.

53. U.S. Nuclear Regulatory Commission, Information Notice 87-48, "Information Concerning the Use of Anaerobic Adhesive/Sealants," October 9, 1987.

54. Philadelphia Electric Company, Licensee Event Report (LER) 50-278/83-018, Peach Bottom 3, February 10, 1984.

55. U.S. Nuclear Regulatory Commission, Office of Inspection and Enforcement, Information Notice No. 84-53, "Information Concerning the Use of Loctite 242 and Other Anaerobic Adhesive/Sealants," July 5, 1984.

56. General Electric Service Information Letter (SIL) No. 128, Revision 1, Supplement 1, Category 1, "Preventive Maintenance for CRD Scram Pilot Valves," August 1978.

57. General Electric Service Information Letter (SIL) No. 128, Revision 1, Supplement 1, Revision 2, Category 1, "Preventive Maintenance for CRD Scram Pilot Valves," dated March 2, 1984.

58. Letter from P. W. Howe, Carolina Power & Light Co., to J. N. Grace, U.S. Nuclear Regulatory Commission, Subject: Docket Nos. 50-325 and 50-324 Brunswick Steam Electric Plant, Units 1 and 2, "Failure of ASCO 8323 A36E Double Solenoid Valves," October 15, 1985.

59. Carolina Power & Light Company, Licensee Event Report (LER) 50-324/85-008, Brunswick Unit 2, October 25, 1985.

60. U.S. Nuclear Regulatory Commission, "Report to Congress on Abnormal Occurrences, October-December 1985," NUREG-0090, Vol. 8, No. 4, May 1986.

61. North Anna Station Deviation Report, 87-379, April 24, 1987.

62. U.S. Nuclear Regulatory Commission, Inspection Report 50-338/88-02, 50-339/88-02, North Anna Power Station Units 1 and 2, March 14, 1988.

63. Virginia Electric Power Company, Licensee Event Report (LER) 50-338/89-002, North Anna Unit 1, February 7, 1989.

64. North Anna Power Station, memorandum, "Water Intrusion Into Instrument Air System Event - April 1987," by T. L. Porter, August 8, 1988.

65. North Anna Power Station, memorandum, "Justification for Continued Operation, Unit 2 for ASCO CCW Trip Valves," by M. L. Bowling, February 10, 1988.

66. North Anna Power Station, memorandum, "Justification for Continued Operation, Rev. 1," by D. A. Heacock, February 9, 1988.

67. U.S. Nuclear Regulatory Commission, Region II, "Notice of Significant Meeting," February 2, 1989.

68. U.S. Nuclear Regulatory Commission, Inspection Report No. 50-387/84-35; 50-388/84-44, Susquehanna Steam Electric Station, November 15, 1984.

69. U.S. Nuclear Regulatory Commission, Inspection Report No. 50-387/85-09, 50-388/85-09, Susquehanna Steam Electric Station, April 15, 1985.

70. U.S. Nuclear Regulatory Commission, "Report to Congress on Abnormal Occurrences, October-December 1984," NUREG-0090, Vol. 7 No. 4, May 1985.

71. U.S. Nuclear Regulatory Commission, Inspection Report No. 50-387/84-38, 50-388/84-37, Susquehanna Steam Electric Station, February 27, 1985.

72. Wisconsin Public Service Corporation, Licensee Event Report (LER) 50-305/88-07, Rev. 1, Kewaunee Nuclear Power Plant, May 19, 1989.

73. Letter from J. P. Weaver, Automatic Switch Co. (ASCO) to T. E. Murley, U.S. Nuclear Regulatory Commission, "Potential Failures of NP8314 Series Valves," October 18, 1988.

74. U.S. Nuclear Regulatory Commission, Inspection Report 99900369/88-01, Automatic Switch Company, August 30, 1988.

75. Omaha Public Power District, Licensee Event Report (LER) 50-285/82-006, Fort Calhoun Station Unit 1, April 7, 1982.

76. V. P. Bacanskas, G. J. Toman, S. P. Carfagno, "Aging and Qualification Research on Solenoid Operated Valves," Franklin Research Center, NUREG/CR-5141, August 1988.

77. General Electric Service Information Letter (SIL) No. 196, Supplement 10, Category 1, "SRV Failures To Open On Manual Demand and Air Operator Seal Failures," dated April 1981.

78. Duke Power Company, Licensee Event Report (LER) 50-414/87-031, Catawba Nuclear Station, Unit 2, January 20, 1988.

79. U.S. Nuclear Regulatory Commission, Inspection Report 50-413/88-20 and 50-414/88-20, Catawba Nuclear Station Units 1 and 2, June 7, 1988.

80. U.S. Nuclear Regulatory Commission, Inspection Report 50-413/89-07 and 50-414/89-07, Catawba Nuclear Station Units 1 and 2, April 20, 1989.

81. Letter from T. Hutchins Automatic Valve Corporation (AVC) to J. Keppler, U.S. Nuclear Regulatory Commission Region III, December 19, 1986.

82. Mississippi Power & Light Company, Licensee Event Report (LER) 50-416/85-007 Rev. 2, Grand Gulf Nuclear Station, Unit 1, October 2, 1985.

83. U.S. Nuclear Regulatory Commission, Information Notice No. 85-17, Supplement 1, "Possible Sticking of ASCO Solenoid Valves," October 1, 1985.

84. Commonwealth Edison Company, LaSalle County Station, "30 Day Report on the Failure of Main Steam Isolation Valve (MSIV) Pilot Solenoid Valve 1B21-F028C," prepared by Sargent & Lundy, January 14, 1988.

85. U.S. Nuclear Regulatory Commission, Inspection Report 50-373/87-035, LaSalle County Station, Unit 1, January 1988.

86. Gulf States Utilities Company, Licensee Event Report (LER) 50-458/88-023, River Bend Station, Unit 1, October 31, 1988.

87. U.S. Nuclear Regulatory Commission 10 CFR 50.72 Report Number 13591, September 30, 1988.

88. Gulf States Utilities Co., River Bend Station, "Analysis of Components in an ASCO Solenoid Valve," Franklin Research Center Report, P-741-1, February 9, 1989.

89. U.S. Nuclear Regulatory Commission 10 CFR 50.72 Report Number 17201, November 27, 1989.

90. U.S. Nuclear Regulatory Commission Region III Daily Report, December 4, 1989.

91. Cleveland Illuminating Company, Licensee Event Report (LER) 50-440/89-030, Perry Nuclear Power Plant, December 26, 1989.

92. Automatic Switch Co. (ASCO), Installation and Maintenance Instructions, Bulletin 8323, Form No. V5972R1, 1981.

93. U.S. Nuclear Regulatory Commission, Inspection Report 50-289/88-28, Three Mile Island Nuclear Station Unit 1, February 2, 1989.

94. Facsimile Transmission, J. Shank, ASCO, to H. L. Ornstein, USNRC, February 17, 1989.

95. U.S. Nuclear Regulatory Commission, Region I Daily Report, December 9, 1988.

96. Rochester Gas & Electric Company - Ginna Station Memorandum, "Failure of Solenoid Operated Valve 5933B "A" Diesel Generator Air Start Valve ASV-1" by B. Popp, December 14, 1988.

97. U.S. Nuclear Regulatory Commission, Inspection Report 50-244/88-25, Ginna Nuclear Plant, February 2, 1989.

98. Iowa Electric Light and Power Company, Licensee Event Report (LER) 50-331/82-039, Duane Arnold Energy Center, July 6, 1982.

99. Iowa Electric Light and Power Company, Licensee Event Report (LER) 50-331/85-002, Duane Arnold Energy Center, February 27, 1985.

100. U.S. Nuclear Regulatory Commission, Inspection Report, 50-325/88-25 and 50-324/88-25, Brunswick 1 and 2, September 26, 1988.

101. U.S. Nuclear Regulatory Commission, Inspection Report, 50-338/88-02 and 50-339/88-02, North Anna 1 and 2, March 14, 1988.

102. Automatic Switch Co. (ASCO) Service Bulletin, "Discontinuation of Rebuild Kits for ASCO "NP" Series Valves," May 23, 1989.

103. Commonwealth Edison Company, Licensee Event Report (LER) 50-237/88-022, Dresden Nuclear Power Station, Unit 2, December 13, 1988.

104. D. V. Paulson, T. A. Shook, V. P. Bacanskas, S. Carfagno, "Equipment Qualification Research Test Program and Failure Analysis of Class 1E Solenoid Valves," Franklin Research Center, NUREG/CR-3424, F-C 5569-309/315, November 1983.

105. S. P. Carfagno, R. J Gibson, "A Review of Equipment Aging Theory and Technology," Franklin Research Center, EPRI NP-1558, September 1980.

106. Automatic Switch Company (ASCO), "Field Notification of Discontinuation of NP8323 Valve Line," August 3, 1989.

107. Automatic Switch Company (ASCO), "Revised Field Notification of the Discontinuation of NP8323 Valve Line," October 27, 1989.

APPENDIX A

SOV FAILURES REPORTED IN LERs: 1984-1989

Legend for Appendix A

DOC NO. = Docket Number
REP FL = Repetitive Failure
TP/OUT = Cause Reactor Trip or Plant Outage
FC = Failure Category

APPENDIX A

FAILURE CATEGORIES

OTHER	00
COIL FAILURE	01
VALVE BODY FAILURE/LEAKAGE	02
O-RING/GASKET/PLUG/SEAT/DIAPHRAGM/SPRING FAILURES/LEAKAGE	03
LUBRICANT/LUBRICATION	04
"STICKING"	05
INTERNAL WIRING/REED SWITCH/CONTACTS	06
EXTERNAL WIRING	07
INSTALLATION/MAINTENANCE ERROR-PHYSICAL (BACKWARDS, UPSIDE-DOWN, etc.)	08
INSTALLATION/MAINTENANCE ERROR-ELECTRICAL (LOOSE CONTACTS, AC vs DC, etc.)	09
EXCESSIVE ENVIRONMENT TEMPERATURE	10
MOISTURE INTRUSION (ELECTRICAL SHORTS/GROUNDING/OPEN CIRCUITS)	11
CONTAMINANTS (DIRT, WATER, RUST, HYDROCARBONS, DESICCANTS, etc.)	12
MOPD (MAXIMUM OPERATING PRESSURE DIFFERENCE)	13
DESIGN ERROR (OTHER THAN MOPD)	14
EQUIPMENT QUALIFICATION-SEISMIC	15
EQUIPMENT QUALIFICATION-RADIATION	16
INADEQUATE MAINTENANCE/EXCESSIVE TIME BETWEEN REPLACEMENT OR OVERHAUL	17
"END OF LIFE"/NORMAL WEAR	18
"STILL UNDER INVESTIGATION"	19
"UNKNOWN"	20
"UNSPECIFIED"	21
"PERSONNEL ERROR"	22
REQUIRED CLOSING/OPENING TIME SPECIFICATIONS NOT MET	24
LEAKAGE UNSPECIFIED	26
ASSEMBLY ERROR (PLUG/DIAPHRAGM/SPRING etc.)	27
EQUIPMENT QUALIFICATION (ELECTRICAL)	28

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
206	San Onofre 1	12/30/86	86-014-01	One	Ground fault, moisture in junction box	Feedwater & Safety Injection System	Not Specified	Not Specified	Moisture in junction box	No	New junction box installed	Corrective action taken on failed junction box and seven other vulnerable ones.	LER 87-001	No	11
206	San Onofre 1	01/17/87	87-001	One	Ground fault	Feedwater			Inadequate installation/vibration	Yes	Eliminated ground.tightened connections	Vibration caused loosening of terminal box conduit locking ring		No	07
206	San Onofre 1	11/10/87	87-016	Five failures of four valves	Slug sticking	Containment Isolation, Containment Spray	ASCO	206-380	Lubricant suspected	Yes	Secured SOVs in safety position and initiated weekly testing	Cause of sticking under investigation	Insp Rpt 89-24	No	05
206	San Onofre 1	12/01/87	87-017	Two	Not Specified	Safety injection vent	Not Specified	Not Specified	Unknown	No	Repaired or replaced SOV	SOV required for venting SIS to avoid water hammer	None	No	19
206	San Onofre 1	12/16/87	87-018	One	Ground fault moisture in SOV housing	Plant cooling water	Not Specified	Not Specified	Loose screws and inadequate seal. Root cause not specified	Yes	The ground was eliminated by removing the water inside the solenoid housing and resealing the housing.	The loose screws were probably stripped from excessive tightening. Ref. Docs. LERs 206/86-014/01, and 361/87-001,031	See comments	No	11
206	San Onofre 1	02/15/88	88-004-02	One	SOV sleeve and position indication switch	Safety Injection	Target Rock	80EE-001	Still under investigation	Yes	SOV was replaced. Modified maintenance procedures(including implementation of mfr's recommend for new reed switch calibration	SOV failure prevented bleed off from double disc gate valve bonnet.	LER 206/81-020	No	19

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
206	San Onofre 1	03/03/89	89-008			Containment fire suppression			Design error		Design modification made	Discovered that a single SOV could degrade containment spray system,resulting in containment overpressure during a LOCA			14
206	San Onofre 1	08/23/89	89-026	One	Failed to shift, "sticking slug"	Recirc system (safety injection/containment spray)	ASCO	206-380	Suspect lubricant	Yes	Replaced SOV		LER 87-016	No	05
213	Haddam Neck	11/02/84	85-005	Two	Failed to shift "stuck"	Auxiliary Feedwater System	ASCO	NP8320	Unknown	No	SOV retested acceptably, declared operational, more frequent cycling tests planned	SOVs failed during testing. SOVs required for auto-initiation of AFW	None	No	05
213	Haddam Neck	09/10/85	85-024	One	Failed to shift,"stuck"	Auxiliary Feedwater System	ASCO	NP-8320	Unknown	Yes	Replaced SOVs. Initiated more frequent periodic cycling	Cause of sticking has not been determined. Same SOVs as in LER 85-005	LER 85-005	No	05
213	Haddam Neck	01/14/88	88-001	Four incipients	SOV operating mode	Containment Isolation - Steam Generator Blowdown	Not Specified	Not Specified	Design Deficiency	No	Corrected circuit design, rather than changing the SOVs	Installed SOVs close upon deenergizing instead of opening upon deenergizing per design. Condition existed for seven years	None	No	08

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/OUT	FC
219	Oyster Creek	10/16/84	84-022	Three	Diaphragm	Scram Discharge Volume	Not specified	Not specified	Installed diaphragm backwards. Inadequate SOV rebuilding and inadequate post-maintenance test	No	Install diaphram correctly and develop improved post-maintenance testing	Caused slow closure of 3 air-operated SDV vent and drain valves	None	No	27
220	Nine Mile Pt 1	06/14/84	84-013	Three	Seat leakage(2),mispositioned wires	Main steam line	Dresser/Consol. Electromatic	1525VX	Wear and contaminants suspected	Yes	1 refurbished, 2 replaced	Retest of all 6 valves found all to be leaking due to material lodged in the seat area (see LER 84-014)	LER 84-014	No	03
220	Nine Mile Pt 1	06/17/84	84-014	Six	5 seat leakage / 1 stuck open due to foreign matl	Main steam	Dresser / Consol. Electromatic	1525 VX	Foreign material intrusion (source not stated)	Yes	Cleaned and refurbished SOVs	Retest of all 6 SOVs (LER 84-013) found all to be leaking due to foreign material lodged in the seat area	84-013	No	12
220	Nine Mile Pt 1	11/01/85	85-021	One plus two incipients	Jammed springs	Main steam	Dresser/Consol. Electromatic	1525VX	Wear	Yes	Replaced all three valves		None	No	03
237	Dresden 2	07/17/87	87-023	One	Internal passageway restriction	Feedwater (FWRV)	ASCO	8300	Wear	Yes	Replaced SOV	SOV is a piecepart of the FWRV.	None	Yes	18
245	Millstone 1	12/24/85	85-034-01	Between three and six	1 core spring, many discs	Control rod drive	Asco	Not specified	Deterioration of the Buna-N discs and a detached spring.	Yes	SOVs rebuilt, upgraded SPSV maintenance program per GE SIL 128	Failure of three control rods to scram was attributed to failure of three to six associated scram pilot solenoid valves.	None	No	17

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
245	Millstone 1	06/06/87	87-015-02	One	Excessive leakage	Containment isolation - post accident sampling	Target Rock	Not Specified	Plunger tube scored	No	Replaced plunger tube	None	None	No	03
247	Indian Point 2	01/04/84	84-001	One	Failed closed	Containment purge	ASCO	Not Specified	Not Specified	No	Replaced SOV	None	None	No	21
247	Indian Point 2	11/27/84	84-022	Two	Not Specified	AFW Steam	Not Specified	Not Specified	Not Specified	No	Reconnected power leads to SOVs	SOVs control AFW turbine inlet steam isolation valves	None	No	09
247	Indian Point 2	02/02/87	87-003-01	One	Sluggish performance	Condensate (storage tank isolation)	Not Specified	Not Specified	Design deficiency (sizing)	No	Enlarged SOV orifice and cleaned regulator	SOV controls AOV. Slow closure attributed to orifice size. Debris could have also contributed.	None	No	24
249	Dresden 3	01/12/85	85-001	One	Manual operator	Main turbine	Sperry Vickers	FSDG454 012A	Grease contaimination	No	Replaced SOV	SOV controls overspeed trip	None	Yes	04
249	Dresden 3	08/07/87	87-013	One	Coil	Feedwater	ASCO	8300	Shorted coil	No	Replaced SOV	SOV controls FWRV air operator	None	Yes	01
250	Turkey Point 3	12/02/84	84-031	One	Not Specified	Containment isolation (nitrogen supply)	Asco	Not specified	Not Specified	No	Replaced SOV valve		LER250/84-09,020	No	03
250	Turkey Point 3	12/13/84	84-034	One	Not specified	CVCS (isolation valve)	ASCO	Not Specified		Yes	Replaced SOV	SOV controls AOV. Ref. Documents: LER 250/84-032, 251/84-009,84-020	See Comments	No	02

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
250	Turkey Point 3	01/13/85	85-002	One	Clogged SOV air filters	Not Specified	Not Specified	Not Specifi ed	Not Specified	No	Cleaned air filters on this and other similar SOVs in both units 3 and 4	Similar occurrences: LER 250-84-034, LER 250-84-031, LER 251-84-020, LER 251-84-009, and LER 250-83-016	None	No	17
250	Turkey Point 3	01/27/86	86-005	Two	Not Specified	Main steam (MSIV)	ASCO	8316	1 internal interference, 1 bent contact pins at fuse block.	No	Replaced 1 SOV, fuse block pins were straightened on other SOV.	2 independent SOV failures discovered during testing. MSIV couldn't be closed	None	Yes	09
250	Turkey Point 3	08/03/86	86-031	One	Not specified	Auxiliary/em ergency feedwater	ASCO	206-381	Water entering the SOV	No	SOV replaced	Similar occurrences: LER 251-84-020, and LER 251-84-009	See comment	Yes	03
250	Turkey Point 3	01/03/87	87-002	One	Coil	Component Cooling Water	ASCO	8316	Not Specified	No	Replaced SOV	None		NO	01
250	Turkey Point 3	09/13/87	87-023	One	Internal wiring	Steam Generator Blowdown	Target Rock	300525-1	Faulty wires going to Reed switch	No	Not Specified	None	None	Yes	06
251	Turkey Point 4	07/15/87	87-015-01	One	Ground fault	Containment Isolation (pressurizer sampling)	Not Specified	Not Specifi ed	Deterioration of insulating tape from "normal ageing"	No	Cleaned and retaped wiring connections	SOV is a piece-part of AOV	None	No	18
254	Quad Cities 1	02/05/85	85-001	Two	Connectio n to SOV power lead	HPCI	Barksdale	178250H C204	Faulty terminal connection and vibration		Repair terminal connections and secure wires to SOV housing	Failure of HPCI turbine tripand reset SOVs		No	07

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
254	Quad Cities 1	04/03/87	87-006-01	One	Wiring connection to coil	High Pressure Coolant Injection	Barksdale	101B433 ACP1	Vibration/inadequate connection/inadequate support	Yes	Replaced coils on failed SOV and three others replaced at units 1 and 2	HPCI inoperable. Replaced SOV coils with newer model, also added wiring restraint to all four SOVs.	LER 85-001	No	07
255	Palisades	04/10/86	86-017-01	Three fail + three incipients	Valve seat leakage	Reactor Coolant - (head vent)	Target Rock	80B-001	Metal shavings in valve seat area.	Yes	Repaired SOVs and system flushed to remove remaining metal shavings			Yes	12
255	Palisades	01/14/87	87-001-01	Eight	Inadequate isolation logic	Containment isolation(hydrogen monitoring)	Not Specified	Not Specified	AE design error	No	Isolation logic modified	None	None	No	14
259	Browns Ferry 1	07/03/86	86-022	Six incipients		ECCS	Rockwell/ Atwood Morrill		Design error		Remove air supply to affected actuator	Potential for overpressurizing low pressure systems due to use of non qualified SOVs (six in each of three Browns Ferry units)		No	14
260	Browns Ferry 2	08/31/87	87-007-01	Potential failures all 3 units	Loss of SOV function	Containment Drywell Control Air	Not Specified	Not Specified	Design error	Yes	Replace SOVs with qualified ones	Use of non-qualified SOVs could prevent primary containment isolation. All 3 Browns Ferry units affected.	None	No	14

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
260	Browns Ferry 2	06/06/89	89-018	One	Valve seats	Emergency diesel generator air start	Salem	812-6	Corrosion debris from starting air system	Yes	Replaced SOV	Licensee upgraded EDG air system and performed maintenance on it prior to event but debris was believed to be there from before		No	12
261	H.B. Robinson 2	05/13/87	87-007	Two	Not Specified	Not Specified	ASCO	Not Specified	Inadequate installations of conduit seals	Yes	Install correct seals	Incorrectly installed conduit seals at entrance to several harsh environment 1E qualified SOVs. Potential for moisture intrusion	None	No	14
261	H.B. Robinson 2	07/15/87	87-020	One	Electrical short	Feedwater (FWRV)	Not specified	Not Specified	Water trapped in SOV condolet	No	Wire was repaired and water removed from the condulet. Other SOVs examined for similar problems.	SOV is piece-part of FWRV	None	Yes	11
261	H.B. Robinson 2	11/05/87	87-028-01	Two	SOV internals	Diesel Generator Starting Air	Not Specified	Not Specified	Internal wear	No	Replaced SOVs	SOV failures caused venting of starting air	None	No	18
263	Monticello	10/25/89	89-032	One	Loose terminal screw	Main steam (MSIV)					Tighten terminal screw and inspect similar SOVs			No	09

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
265	Quad Cities 2	06/28/85	85-015	One	Not Specified	Reactor Bldg. Vent. System	Versa	See comment	Not Specified	No	SOV replaced	VGS-4422-U-10-3 1-3BC	None	No	20
265	Quad Cities 2	02/18/87	87-004	One	Not specified	Containment vacuum	ASCO	8317	"Solenoid rusted and corroded" (reason/source not stated)		Replaced SOV	SOV is piece-part of vacuum breaker air test cylinder		No	2[illegible]
265	Quad Cities 2	09/18/87	87-012	One plus two incipients	Not specified	Containment Vacuum Relief	ASCO	8317	Unknown	Yes	Not Specified	SOV is piece-part of vacuum breaker air test cylinder	LER 87-004	No	20
265	Quad Cities 2	12/10/87	87-020	One	Not Specified	Main Turbine Control Fluid	Sperry Vickers	F3-SDG4 54-0124	Not Specified	No	Rplaced SOV	None	None	Yes	02
265	Quad Cities 2	04/06/89	89-001	One		Turbogenerat or				No	Rebuilt SOV	Failed SOV controls turbine master trip solenoid	LER 87-020	Yes	21
266	Point Beach 1	06/01/89	89-003	One		Containment isolation (SG blowdown sampling)	ASCO	8302			Replace SOV			No	21
271	Vermont Yankee	08/18/87	87-009-01	Not Specified	Seat leakage	Automatic Depressuriza tion	ASCO	206-381	Dirt/corrosion products from the air supply	Yes	SOV cycled	None	None	No	12
272	Salem 1	12/31/84	84-029	One	Faulty electrica l connectio n and seat leakage	Feedwater (FWRV)	ASCO	Not Specifi ed	Not Specified	Yes	Replaced SOV	SOV is a piece-part of FWRV	None	Yes	09
272	Salem 1	01/31/86	86-003	One	Seat leakage	Feedwater (FWRV)	ASCO	Not Specifi ed	Probably contaminated air	Yes	Two SOVs were replaced	SOV is a piece-part of the FWRV. Dirt and moisture were detected in air lines causing other associated failures	None	Yes	12

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
272	Salem 1	02/20/86	86-006	One	Broken wire	Feedwater (FWRV)	Not specified	Not Specified	Installation error and vibration	No	Replaced wire and checked similar SOVs	None	None	Yes	09
272	Salem 1	04/08/86	86-007	Eighteen incipients	Electrical connectors	Post accident sampling	Not Specified	Not Specified	Design/installation error, inadequate installation procedures	No	Install required connectors	18 SOVs on units 1 and 2 had inadequate connectors	None	No	14
275	Diablo Canyon 1	01/02/85	85-001	Two	SOV "stuck open"	Main turbine (overspeed protection)	Not Specified	Not Specified	Not Specified	No	Replaced SOV		None	Yes	21
275	Diablo Canyon 1	07/24/87	87-011	None		Containment isolation	Not Specified	Not Specified	Procedural inadequacies	No	Perform necessary verification. Upgrade procedures	Failure to verify penetration isolation subsequent to SOV replacement.	None	No	22
277	Peach Bottom 2	04/27/84	84-008	One	Not Specified	Containment Isolation (SBGT)	Asco	8320	Not specified	No	Replaced SOV	Potential existed for a single failure to have prevented the fulfilment of the safety function of the SBGT system	None	No	19
277	Peach Bottom 2	01/24/86	86-003	Two	DC coils	Main Steam (MSIV)	Automatic Valve Company (AVC)	Not specified	Under investigation	No	The failed DC solenoids were replaced.	Failure of 2 DC SOVs in 2 separate lines caused closure of MSIVs	None	Yes	19
277	Peach Bottom 2	05/29/87	87-008	Three		Control room ventilation/ radiation monitoring			Piping configuration error	No	Reconnected tubing to SOVs properly	Sample lines to three SOVs had been connected incorrectly. Affected control rooms at both units 2 and 3		No	20

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
277	Peach Bottom 2	10/05/89	89-023	One	Binding of SOV slug	Main steam (MSIV)	Automatic Valve Company (AVC)	6910-20	Inadequate manufacturer's installation instructions	No	Replaced SOV and revised installation and maintenance procedures	Reference LERs 277/86-003, 278/85-018, 278/86-016	See comments	Yes	27
278	Peach Bottom 3	09/30/85	85-015-01	One	Leaked	ADS backup nitrogen	Target Rock	Not Specifi ed	Not Specified	Yes	Replaced SOV with an upgraded one	Previous similar occurrences reported in LERs 277/85-01 and 278/85-05	See Comments	No	03
278	Peach Bottom 3	07/11/84	85-018	One	DC coil	Main steam (MSIV)	Automatic Valve Co.	Not specifi ed	Reason for coil failure not specified	Yes	Task force recomended testing of DC solenoids more often and analyze cause of future failures.	DC SOV failure coupled with momentary loss of AC power resulted in MSIV closure	None	Yes	01
278	Peach Bottom 3	07/19/86	86-016	One	Coil	Main Steam (MSIV)	Automatic Valve Corp. (AVC)	Not Specifi ed	Reason for coil failure not specified	Yes	The dc coil on each MSIV's SOV was replaced.	Similar reactor scrams in 1985 and 1986(defective dc coil coupled with ac power interruption): LERs 278/85-018, 277/86-03	See comments	Yes	01
280	Surry 1	03/28/84	84-007	None	Unspecifi ed	Feedwater (FWRV)			Maintenance had been done without approved procedures inadequate post maintenance testing	No	Reconnected IA lines to proper SOV ports	Instrument air lines were connected to the wrong ports of 5 SOVs at Surry units 1 and 2		No	08

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
280	Surry 1	11/12/87	87-031	One	SOV wiring blocked isolation valve operator	Containment isolation	Masoneilan (SOV unspecified)	3500 series	Improper installation	No	Secured SOV	Wiring to unspecified SOV caused mechanical binding of containment isolation valve's operator		No	09
281	Surry 2	01/27/88	88-001-01	Two	SOV leakage	Containment isolation(pressurizer vapor space sampling)	Target Rock/ASCO	86V-001/206-380	Cause of SOV leakage not specified. Cause of wrong lead lifting: electrical maintenance "personnel error"	No	Repair or replace SOVs	Electricians trying to isolate leaking SOVs lifted wrong leads	None	No	26
281	Surry 2	02/02/88	88-002-01	Two	Seat leakage	Reactor coolant sampling isolation	Valcor	V526-5683-19	Impurities in reactor coolant system water prevented complete seat closure		SOVs replaced			No	12
285	Fort Calhoun	05/01/86	86-003-01	Two	Failure positions of SOVs reversed	Waste gas	Not Specified	Not Specified	Personnel error	None	Return SOVs to correct failure positions	Fail closed SOVs had been changed to fail open, resulting in volume control tank leakage to auxiliary building.	None	No	22
286	Indian Point 3	02/11/87	87-002	One	Coil	Containment leakage control	ASCO	8308	Not Specified	Yes	The failed solenoid valve replaced with one of a higher temperature design. 3 similar SOV coils were also replaced.	The design of no. 34 static inverter was improved to allow isolation of single branch circuits if a short circuit develops.	LER 85-001-00	Yes	11

SOLENOID-OPERATED VALVE FAILURE DATA

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293	Pilgrim	07/19/88	88-021	Four incipients	Potential for exceeding MOPD limits	Primary containment, control rm,+ turb bldg HVAC/SGTS	ASCO	8320 and NP8320	Design error	No	Replace SOVs with ones rated for higher MOPD	Failure of pressure regulator would result in inoperability of 4 SOVs due to exceeding MOPD limits	None	No	13
293	Pilgrim	01/27/89	89-004			Containment isolation	ASCO	NP8320			Repaired leaks and replaced 2 SOVs	Failure of 2 AOVs due to air system leaks. 2 SOVs were replaced as a precaution against exceeding MOPD limits of the SOVs	LER 89-002	Yes	21
293	Pilgrim	05/03/89	89-015	One	Coil	Main Steam (MSIV)	Automatic Valve Corp. (AVC)	6910-02 0	"Random failure"	No	Replaced SOV assembly			Yes	01
295	Zion 1	08/08/85	85-029	Two	"Stuck" pilot valve	EDG building ventilation	Not specified	Not specifi ed	Not specified	Yes	Replaced SOVs	40 such valves used in both units. Common-mode failures found during testing. Additional CMFs ocurred next day at unit 2.	LER 304/85-015	No	05
295	Zion 1	01/12/89	89-001	One	Failed to shift	Ventilation (service water building)	ASCO	8320	Weakened coil	Yes	Replaced SOV		LER 89-001	No	01

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
298	Cooper	08/18/86	86-018	One	Not Specified	Reactor Recirculation System	Not Specified	Not Specified	Not Specified	No	Not Specified	None	None	No	21
302	Crystal River 3	01/05/89	89-001-02	None		Multiple systems	ASCO	8320/NP 8316/8320	Design error-MOPD	Yes	Replaced SOVs with others having higher MOPD rating	See section 5.1.3 of this report for additional info. Reference documents: LER 78-054, 83-023, 88-013	See comments	No	13
302	Crystal River 3	04/07/89	89-012			Containment isolation (RX cavity cooling system)	ASCO	8320	Design error		Replace SOV coils with coils having correct temperature ratings	8 SOVs were affected. Reference documents: LER 78-054, 83-023, 88-013, 89-001	See comments	No	14
302	Crystal River 3	04/18/89	89-015			Reactor coolant pump seal bleed off			Inadequate seismic installation		Modified SOV supports				15
302	Crystal River 3	09/26/89	89-034		Electrical power supplies	HVAC, containment isolation, Main steam (MSIV)			Design error		Modified power supplies	Intermingling of 1E and non-1E power sources to SOVs		No	09
304	Zion 2	07/11/84	84-015	Not Specified	Internal leakage	Main steam (MSIV)	Keane	51-170	Licensee could not find cause of failure	No	Three SOVs to be replaced with environmentally qualified SOVs	None	None	No	26
304	Zion 2	08/09/85	85-015	Two	"Stuck"pilot valve	EDG building vent	Not specified	Not Specified	Not specified	Yes	The valves were replaced.	Common-mode failures found during testing. Also occurred on unit 1 the previous day. 40 such valves on units 1 and 2.	LER 295/85-029	No	05

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
304	Zion 2	02/03/87	87-001	One	O-Ring	Main steam (MSIV)	Chicago 'luid Power	NSV1-16 -C-XP	Manufacturing defect cr damage during installation	No	Replaced SOV	None	None	Yes	08
305	Kewaunee	07/02/84	84-013	One	Coil	Auxiliar' buildin/, specia' ventilation	Johnson	V-24	Not Specified	Yes	The Johnson valves were to be replaced with ASCO NP8320 SOVs as they failed.	SOV failures resulted in initiating safeguards equipment. 59 such SOVs remaining would be replaced with ASCOs.ed at next outage	82-03,28, 81-34	No	01
305	Kewaunee	12/16/84	84-020	One	Coil	Auxiliary building special ventilation	Johnson	V-24	"Burnt out" coil, root cause not specified	Yes	The Johnson SOV was replaced with an ASCO NP8320.	Due to repetitive failures of these Johnson SOVs, they were all being replaced with ASCO NP8320 SOVs on an as-fail basis	LER 84-13	No	01
305	Kewaunee	02/11/85	85-005	One	Coil	Auxiliary building special ventilation	Johnson	V-24	Coil "burnt out," root cause not stated	Yes	Replaced SOV with an Asco	Due to repetetive failures of these Johnson SOVs, they were all being replaced with ASCO NP8320 SOVs on an as-fail basis.	LER 84-013,020	No	01
305	Kewaunee	11/28/87	87-012-01	Two failed plus 58 incipients	Failed to shift	Containment Isolation-Pz r relief,make-up,RCDT discharge	ASCO	NP8314	Design error. Conditions exceeded SOVs' MOPD limits	Yes	Replace SOVs and correct regulator settings so that MOPD ratings will not be exceeded	See Section 5.1.3 of this report	None	No	13

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
305	Kewaunee	05/28/88	88-007-01	Three plus 7 incipients	Failed to shift	Containment Isolation (pzr relief, makeup isolation)	ASCO	NP8314	Manufacturing error (unauthorized use of incorrect lubricant)	No	Cleaned and refurbished the affected SOVs	Initiated an extensive root cause analysis. See Section 5.2.4.1 of this report.	LER 87-012-01	No	05
309	Maine Yankee	08/10/86	86-005-01	One	Ground fault	Cardox Fire Protection system	Chemetron	5-020-0074-8	Not Specified	No	Replaced SOV	SOV failure tripped Cardox system power supply breaker, thereby disabling the Cardox system.		No	21
309	Maine Yankee	05/23/88	88-005-02	Four incipients	Not Specified	HPSI/charging pump suction vent	R.G. Laurence	620WA24DCSW	Design error	No	Modified system	SOVs in high rad. fields not environ. qual. Failure could cause uncontrolled release of radioactivity to non qual. systems.	None	No	16
311	Salem 2	05/22/89	89-011-01	None		Main steam (isolation valve)			Inadequate surveillance testing	No	Modified testing circuitry	Testing deficiencies would prevent detection of SOV failure Deficiency existed at unit 2 also		Yes	14
313	ANO 1	05/06/85	88-001	Two	Lifting of plunger (spurious actuation)	Post accident sampling	Target Rock Corp.	80E-001/81P-006N	Design error	No	SOVs were reoriented correctly	Incorrectly oriented SOVs could open upon small increases in backpressure. See Section 5.1.4 of this report	LER 368/88-001	No	08

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
317	Calvert Cliffs 1	04/01/87	87-007-03	Four incipients	Unqualified electrical connectors	Auxiliary Feedwater	Not Specified	Not Specified	Design error	No	Deficient electrical connections were upgraded with EQ qualified ones	Two SOVs on each unit found to have inadequate (EQ) electrical connections	None	Yes	28
317	Calvert Cliffs 1	08/22/89	89-015	0		Iodine filter dousing system			Design error (Q list classification)		Replace with seismically qualified SOVs	SOV failure could prevent iodine filters from performing their function		No	15
317	Calvert Cliffs 1	11/13/89	89-020	0		Salt water cooling			Design error (Q list classification)		Replace with seismically qualified SOVs and power sources	4 SOVs in safety system not able to withstand seismic event power sources for 5 safety-related SOVs not seismically qualified		No	15
318	Calvert Cliffs 2	09/05/86	86-006-01	One	Seat leakage	Main Steam (atmospheric dump)	ASCO	8300	Not specified	No	SOV internals were replaced	None	None	No	03
321	Hatch 1	12/07/85	85-043-01	Number of failed SOVs not spec	Seat leakage	Containment isolation -multiple systems	Not specified	Not specified	Normal equipment use or wear	Yes	Leaking valves in 42 penetrations repaired,rebuilt, or replaced.	None	LER 84-017	No	18
321	Hatch 1	04/15/87	87-004	One incipient		Main control room environmental control	Not Specified	Not Specified	AE design deficiency	No	Redesign main control room environmental control system	Single SOV failure could compromise control room hability	None	No	14

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TF, OUT	FC
321	Hatch 1	03/18/87	87-005	Two	1.Missing lock nut 2.Stuck plunger	Containment ventilation	ASCO	NP8321	Unspecified	Yes	1. Installed a missing lock nut./ 2. No corrective action taken on stuck SOV because it tested okay subsequent to failure.	2 damper failures. (1 caused by missing lock nut on SOV, 1 caused by stuck SOV plunger)	LER 85-015-01	No	00
322	Shoreham	11/15/89	89-009	0		Containment isolation (RX building standby ventilation)	ASCO	206-832 206-380	Design error, SOVs were oriented incorrectly		Reorient SOVs to correct positions (vertical vs. horizontal)	Common-mode failures having potential to prevent fulfillment of safety function		No	08
323	Diablo Canyon 2	08/14/85	85-019-01	Three	Incorrect wiring to SOV	Main Steam (MSIV)	Not Specified	None	Personnel error(incorrect undocumented wiring change)	Yes	Replaced SOV	Undetected SOV failure caused 5 month loss of 1 train of ESFAS actuation of MSIVs	LER 85-014	No	07
323	Diablo Canyon 2	12/21/85	85-022	One	Open circuit	Feedwater	Not specified	Not Specified	Improper wiring installation and bumped junction box	No	The wiring connection was properly reteriminated other similar SOVs' terminations were inspected.	SOV is a piecepart of the FWRV	LER 275/85-030	Yes	09
324	Brunswick 2	09/27/85	85-008	Three	Disc-to-seat sticking	Main steam (MSIV)	ASCO	8323	Hydrocarbon, water and high temperatures caused degradation of seat material.	No	Replaced SOVs	Common-mode failures. See Section 5.2.3.1 of this report.	None	No	12

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
324	Brunswick 2	10/15/85	85-011-01	Two	DC coil	Main Steam (MSIV)	ASCO	NP8323	Licensee suspected chloride corrosion	No	Replaced SOVs. Extensive failure analysis initiated.	None	None	Yes	01
324	Brunswick 2	01/02/88	88-001-05	Four	Failed to shift	Containment isol./drywell floor and eqpmt drain sumps	ASCO		Still under investigation. Found debris and oil film on one SOV. Suspect high temperatures from self heating of energized SOVs	Yes	Replace SOVs. Performing extensive failure analysis	Four previous similar failures had been experienced		Yes	19
324	Brunswick 2	06/17/89	89-009-01	One	Failed to shift	Drywell purge and vent	ASCO	Not specified	Suspected that foreign particulates found in the SOV had attacked elastomeric parts of the SOV	No	Replaced SOV	Extensive analysis of root cause was not totally conclusive		No	12
325	Brunswick 1	02/28/87	87-005-02	Two	Discs	Containment isolation	Valcor	V52645-5683-14	Not Specified	No	Replaced SOVs	SOV leakage found during LLRT	None	No	03
325	Brunswick 1	07/01/87	87-019	One	Stuck plunger	Main Steam (MSRV)	Target Rock	1/2-SMS-A-01	Excess Loctite used by manufacturer's field rep	Yes	Refurbished SOV	See Section 5.2.2.2 of this report	LER 87-020-01	No	17
325	Brunswick 1	07/03/87	87-020-01	Four	Stuck plunger	Main steam (MSRV)	Target Rock	1/2-SMS-A-01	Excess Loctite used by manufacturer's field rep	No	Replaced SOVs	See Section 5.2.2.2 of this report	LER 87-019	No	17

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
327	Sequoyah 1	05/18/84	87-020	Not Specified	Not Specified	Not Specified	Not Specified	Not Specified	Design error	No	Plant modifcations to protect vulnerable 1E equipment	1E SOVs were not protected from water spray which could emanate from pipes which were vulnerable to an SSE	None	No	14
328	Sequoyah 2	08/30/84	84-014-02	One	Seat leakage	Feedwater	ASCO	8320	Design Error	No	Replaced SOV	An incorrectly selected SOV failed when put in service where its MOPD limits were exceeded	None	No	13
328	Sequoyah 2	06/11/88	88-026-01	Two	Incorrect external wiring	Auxiliary feedwater level control	Not Specified	Not Specified	Inadequate maintenance configuration control	Yes	Reconnected SOVs correctly	Incorrect external wiring to 2 SOVs	None	No	07
328	Sequoyah 2	06/06/88	88-027-01		Not Specified	Auxiliary feedwater	Not Specified	Not Specified	Inadequate electrical maintenance	Yes	Replaced diodes missing from external circuitry connecting 2 SOVs	None	None	No	07
331	Duane Arnold	01/10/84	84-004	Two	Blockage of internal passageway	Standby filtration	ASCO	8316	Foreign material in instrument air		Air path cleaned			No	12
331	Duane Arnold	01/28/85	85-002-00	One	Diaphragm	High pressure coolant injection	Skinner Electric	L2DB5150	End of life/excessive time between maintenance	No	Replaced SOV	None	None	No	17

SOLENOID-OPERATED VALVE FAILURE DATA

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331	Duane Arnold	05/27/88	88-005	One	Not Specified	Fire Suppression	Electro-Manual (Chemetron Corp.)	20100083	Design error and inadequate post maintenance testing	No	Replaced SOV	Licensee had upgraded SOV with an incorrect one. Deficiency was not found during post maintenance testing.	None	No	14
331	Duane Arnold	03/05/89	89-008	One	Coil	Main steam (MSIV)	ASCO	NP8323	Moisture intrusion from steam leak / inadequate torqueing of enclosure fasteners	No	Replaced SOV. Tightened enclosure covers of other similar SOVs.	7 other similar SOVs were subject to moisture intrusion failure due to common-mode torqueing deficiency		Yes	11
333	Fitzpatrick	08/20/85	85-022	One	Electrical fault	Main steam (MSIV)	ASCO	Not Specified	Maintenance personnel error in external wiring	No	SOVs replaced and rewired correctly	AC coil had been connected to DC source and DC coil had been connected to AC source	None	Yes	09
333	Fitzpatrick	11/22/85	85-027-01	One	SOV unable to seat properly	Main steam (MSIV)	ASCO	NP8323	Brass sliver due to cross threading air line fitting	No	Cleaned/refurbished SOV check other for similar problem	MSIV unable to close	None	No	12
333	Fitzpatrick	08/03/89	89-013	None		Containment isolation			Design error		Correct wiring error			No	07
334	Beaver Valley 1	06/07/88	88-007	One	Not Specified	Diesel generator air start	Johnson	Not Specified	Not specified	No	Replaced SOV	EDG air start SOV failed	None	No	22
336	Millstone 2	12/31/86	86-021	Two	Broken springs in SOVs	Reactor Coolant Head Vent	Valcor Engg Corp.	V526-6042-3A	Suspect hydrogen embrittlement	No	Replaced 17-7 PH springs of all similar Valcor SOVs	Prior to event these SOVs had been leaking and had been isolated	None	No	03

SOLENOID-OPERATED VALVE FAILURE DATA

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336	Millstone 2	01/02/87	87-002	One	Diaphragm leakage	Main feedwater (FWRV)	ASCO	8262	Not specified	Yes	Inspected and replaced			Yes	02
338	North Anna 1	02/02/84	84-005	6 failed and 54 incipients	Electrical (moisture intrusion)	Containment isolation)hydrogen control/pass)	Valcor and ASCO	Valcor 526series	Inadequate conduit sealing methods did not meet mfrs specs to meet IEEE-324 qualifications		Replaced failed SOVs and sealed all deficient conduit seals	6 SOVS failed and 54 SOVs were installed incorrectly in both units			09
338	North Anna 1	11/23/87	87-020	Two	Not Specified	Main Steam (Atmospheric Dump Valves)	Copes-Vulcan	Not Specified	Not Specified	No	Water induction circuits were de-energized in order to start the condensate pumps and begin secondary system recovery actions.	To prevent recurrence of this type event, an evaluation to install additional level switches will be performed.	None	No	02
338	North Anna 1	01/08/88	88-002	One	Not Specified	Condenser waterbox vacuum	Not Specified	Not Specified	Not Specified	Yes	Replaced SOV	None	None	Yes	21
338	North Anna 1	03/11/88	88-011	Nine	Sluggish operation	Containment isolation	ASCO	NP-1 series	Design error	Yes	Reworked SOVs to meet manufacturer's instructions	Failure to follow manufacturer's installation instructions modified the SOVs' performance and qualification.	LER 339/87-15-01	No	14

SOLENOID-OPERATED VALVE FAILURE DATA

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338	North Anna 1	03/15/88	88-012	One	Not Specified	Component Cooling Water	ASCO	Not Specified	Not Specified	Yes	SOV from 1-CC-TV-103A was installed on 1-CC-TV-103B, and the SOV from 1-CC-TV-103B was refurbished and installed on 1-CC-TV-103A	None	LER 88-011	No	02
338	North Anna 1	07/19/89	89-014	1	O-ring	Turbogenerator (EHC)	Parker-Hannefin	MRFN16MX0834	O-ring pinched during SOV refurbishment by turbine manufacturer's maintenance team	No	Replace O-ring	Supplemental info obtained from licensee 5/16/90, H.L. Ornstein/ C.W. Allen	LER 88-013	Yes	03
344	Trojan	04/16/87	87-009		Not Specified	Reactor coolant (PORV)	Not Specified	Not Specified	Design/installation error	No	Replaced splices which did not meet EQ installation requirements	None	None	No	28
346	Davis-Besse	09/11/84	84-013-01	One	Not Specified	Main steam (Atmospheric Vent)	Control Component International	Not Specified	Not Specified	Yes	Replace or refurbish SOV	SOV is a piece-part of the atmospheric vent valve's air-operated controller	None	No	21
346	Davis-Besse	01/03/86	86-006-01	Thirty two incipients	Coil	Not specified	ASCO	Not specified	Failure to perform preventive maintenance when required		Replaced SOV coils	Coils on EQ SOVs had been in service beyond their qualified lifetime	None	No	17

SOLENOID-OPERATED VALVE FAILURE DATA

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346	Davis-Besse	12/07/87	87-015	One	SOV vented air	Instrument air dryer	ASCO	1179237	Not Specified	No	Replaced SOV, instrument air dryers replaced with upgraded ones	Failure of SOV caused loss of instrument air/reactor trip. O-rings on several SOVs in turbine bypass system also found degraded	None	Yes	21
348	Farley 1	01/18/87	87-005	Two	Not Specified	Containment isolation (containment sump discharge)	ASCO	8316	Unknown	No	1 SOV closed on additional attempts. Inboard SOV to be inspected subsequent to shutdown.	Redundant SOVs in one penetration failed to close	None	No	20
348	Farley 1	07/21/87	87-012	84 incipients at each unit	Inadequate electrical install. (splices/terminals)	Not Specified	Not Specified	Not Specified	Root cause of inadequate splices and terminations not stated	No	All accessible SOVs'installations modified to an approved EQ splice and termination configuration on a priority basis.	84 SOVs at each unit were found not to be installed in accordance with EQ requirements (splices and junction box connections)	None	No	28
352	Limerick 1	05/09/88	88-017	One	leakage-slug stuck in mid-position	Reactor Bldg Ventilation	ASCO	8316	Not Specified	No	Replaced SOV	Licensee could not determine cause of SOV failure. Called a "component failure of unknown cause"	None	No	20
352	Limerick 1	03/14/89	89-019	0	Electrical failure/moisture intrusion potential	RX building ventilation			Design error (EQ). Inadequate conduit sealing for HELB environment		Sealed electrical conduits	Potential for common-mode failures		No	07

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354	Hope Creek	08/28/86	86-063	12 incipients	Not Specified	Containment Atmosphere Control	ASCO	NP8316	Design error	No	Replaced all twelve SOVs with ones having a higher MOPD rating.	Failure of non-Q regulators could have caused failures of the SOVs.	None	No	13
354	Hope Creek	02/24/87	87-018-01	One	Failed to shift	Main Steam (MSIV)	Automatic Valve Corp. (AVC)	Not Specified	Foreign material inside SOV body, manufacturing defect, and inadequate installation	No	Replaced failed SOV and its manifold assembly. Replaced 7 SOVs for other MSIVs. Sent failed SOV to supplier (GE) for analysis	Foreign material in SOV, Plunger in SOV not per design (incorrect length), mounting screws on junction box were loose.	LER 87-037,038	No	03
354	Hope Creek	10/10/87	87-047	One	Failed to shift	Main Steam (MSRV)	Target Rock	Not Specified	Inadequate protection of MSRVs during plant construction	No	The malfunctioning SRV and its SOV piece-part were replaced in kind.	Failure caused by intrusion of sandblasting grit which was used during plant construction	None	No	12
361	San Onofre 2	01/09/86	86-004	Two	Coil	Feedwater	Not specified	Not Specified	Moisture intrusion - faulty conduit connection	No	The valves were replaced and visual inspections made of the conduit connections of similar SOVs	None	None	Yes	11
361	San Onofre 2	12/17/87	87-031-01	One	Corrosion of power leads and terminal block	Main Feedwater MFIV)	Marotta Scientific Controls Inc.	MV233C / MV238C	Inadequate maintence instructions	Yes	Replaced SOV, terminal block, and power leads. Sealed conduit connections properly.	Water and foreign material intrusion (inadequately sealed conduit connection)	LER 206/86-004	Yes	12

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366	Hatch 2	09/21/84	84-021	One	Gasket	Main Steam (MSIV)	ASCO	Not Specified	Not Specified	No	Replaced gasket	None	None	Yes	03
366	Hatch 2	01/20/88	88-004	Numerous	Leakage	Containment isolation (many systems)	Target Rock	75F-009 /7567F	Inadequate instructions/ normal use and wear	No	Reverse orientation of many SOVs/ replace failed o-rings	See Section 5.1.4 of this report	LER 366/86-020	No	08
366	Hatch 2	02/12/88	88-007	Twelve	Not Specified	Containment Isolation - Torus Drywell Vacuum Breaker	Target Rock	73K-001 /75F-009	Inadequate instructions/ design deficiency	No	Reversed orientation/for unit one installed stronger springs	See Section 5.1.4 of this report	None	No	08
368	ANO 2	04/24/87	87-003	Two	Seat leakage	Reactor Coolant (pressurizer high point vent)	Not Specified	Not Specified	Seat leakage	No	Replaced SOV and installed a collector for any future leakage	Concern for leak causing corrosion damage to other components	None	No	03
368	ANO 2	04/29/85	88-001	2	Leakage	Containment isolation (pass)	Target Rock	80E-001	Backwards installation due to inadequate installation instructions		Reinstalled SOVs in reversed orientation	See section 5.1.4 of this report for additional info		No	08
368	ANO 2	02/16/89	89-003	0		Containment isolation (hydrogen analyzer sampling)	Target Rock	74F	Design error-incorrect assessment of SOV life-failure to account for heatup due to energization		Refurbished SOV. Checked others for similar design error	Valve had exceeded EQ life 6 years prior to discovery of problem		No	14
369	McGuire 1	07/23/84	84-023	One	Seat deformation	Main Feedwater	Borg Warner	Not Specified	Hydraulic fluid was leaking	No	Adjusted SOV and modified system	None	None	Yes	03

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369	McGuire 1	09/19/85	85-028	One plus three incipients	Cable termination sealing	Post accident sampling	Valcor	526-529 5-45	Personnel error (installation not performed per installation specification)	No	All four valves were repaired, resealed. Wiring on all other Valcor 526 series SOVs at station to be upgraded and seals replaced	Similar valves checked at Unit 2, and found to be okay	None	No	11
369	McGuire 1	04/15/87	87-009	One	System perturbation	Main turbine	Not Specified	Not Specified	Modification of design and maintenance	No	Change maintenance schedule to avoid testing while at power.	System operation logic and time of preventive maintenance had beenchanged. Both factors contributed to a reactor trip.	None	Yes	00
370	McGuire 2	06/24/85	85-018-01	Two (of the same SOV)	Coil and short circuit	Main feedwater	Borg-Warner	Not Specified	1- coil failure - not specified. 2- short circuit - water spray onto open electrical box	No	1- replaced SOV. 2- dried water from SOV, electrical box	Second failure occurred prior to complete installation of replacement SOV	None	Yes	01
370	McGuire 2	08/27/86	86-017	One	Coil	Main Feedwater	Borg Warner	Not Specified	Not Specified	Yes	SOV coil was replaced and original coil was sent to the manufacturer for analysis.	None	LER 85-018-01	Yes	01
373	LaSalle 1	08/29/84	84-051	One SOV (3 malfunctions)	Electrical ground	Main steam (MSRV)	Crosby Valve	IMF-2	Cause of short to ground not specified	No	Replaced SOV	Caused SRV to lift three times	None	No	11

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373	LaSalle 1	02/02/85	85-008	Four	Diaphragms	Reactor building ventilation	ASCO	8316	Diaphragms lost their resilience	Yes	Rebuilt SOVs, cycling frequency to be increased	Will change SOVs to nuclear qualified NP8316 model		No	03
373	LaSalle 1	03/12/87	87-013	Six incipients	Not Specified	Main Steam (MSRV)	Not Specified	Not Specified	High drywell temperature	No	Analyze effects of high drywell temperature	Three SOVs declared inoperable. Three SOVs suspect due to high local temperatures	None	No	10
374	LaSalle 2	06/08/84	84-033	One plus many incipients	Passageway blocked	Containment isolation	ASCO	206-832	SOV was improperly positioned		Repositioned SOV	Other similarly affected SOVs were repositioned or replaced		No	08
374	LaSalle 2	11/20/84	84-076	One	Coil	Turbine Steam Bypass	Not Specified	Not Specified	Junction box was full of water of unknown origin	No	Replaced SOV	None	None	No	11
374	LaSalle 2	07/31/86	86-013	None - Many incipients	Electrical connections	CRD, RCS recirc, RCIC, service water, floor drain, air	ASCO	See comments	Design error	Yes	Repaired all affected electrical terminations to meet qualification requirements	1E equipment used unqualified electrical connections. SOV model nos. HVA-206, NP206, NP-8320, NP-8323	LER 86-012	No	28
374	LaSalle 2	01/17/87	87-002	One	Leakage	Feedwater	Valcor	V52660-5292-16	Root cause of corrosion, dirt and o-ring deformation not stated	Yes	Refurbished SOV	SOV body and stem corroded, SOV filled with dirt, and o-ring was deformed	None	No	12

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382	Waterford	12/1[illegible]/87	87-028	One	SOV "stuck open"	Main Steam (MSIV)	Fluid Control Inc.	7WXP4774-600K865	Not Specified	No	Replaced SOV	SOV failed during testing. LER noted previous unrelated SOV failure due to open coil.	None	Yes	05
387	Susquehanna 1	02/25/84	84-010	One	SOV "stuck open"	Main steam (MSRV)	Not Specified	Not Specified	Not Specified	No	Replaced SOV	SOV stuck open causing SRV to remain open	None	Yes	05
387	Susquehanna 1	05/13/84	84-044	Several repetetive failures	Discs, seats	Control Rod Drive	ASCO	HV-176-816	Contamination of the air system and elevated temperatures	Yes	Refurbished SOVs, upgraded disc material from polyurethene to Viton	See Section 5.2.3.3 of this report	None	No	12
387	Susquehanna 1	07/06/87	87-023	One	Coil	Containment Vacuum Relief	Circle Seal Controls	Not Specified	"Burned open" coil	Yes	Replaced coil	Open coil found on same vacuum breaker in 10/82. A unit 2 vacuum breaker also had a similar Circle Seal SOV coil failure in 4/87	None	No	01
387	Susquehanna 1	02/04/89	89-006	Three	"Mechanically bound"	Suppression chamber drywell vacuum breaker	Circle Seal		Root cause analysis planned but not complete yet	Yes	Replaced failed SOV and eight similar ones	One SOV failed, however two similar SOVs had "problems" ("problems" not specified)	LER 87-023	Yes	19
388	Susquehanna 2	01/10/87	87-001	Two	Not Specified	Reactor Building Chilled Water	ASCO	Not Specified	Not Specified	No	Replaced SOV	None	None	Yes	02

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388	Susquehanna 2	02/27/89	89-003	One		Containment isolation (recirculation pump chilled water	ASCO			Yes	Replaced SOV	Licensee shut down plant instead of continuing operation at reduced power per tech specs	LER 84-036	No	21
389	St. Lucie 2	08/16/89	89-006	One	Not specified	Hydrogen sampling	Valcor	52600-515	Not specified	No	Replaced SOV			No	21
395	Summer	06/29/86	86-011	One	Electric connector	Feedwater (FWIV)	Not Specified	Not Specified	Oxidation of connector pins	No	Electrical connector and SOV were replaced.	None	None	Yes	07
395	Summer	12/02/88	88-012-01	None many incipients	Ground faults	Main Steam and Feedwater	ASCO	Not Specified	Design deficiency	No	Isolated SOV contacts to prevent spurious actuations	Found that ground faults could cause spurious SOV actuations	None	No	14
395	Summer	02/17/89	89-003-01	None, 3 incipients	Electrical grounding	Main steam (MSIV)			Incorrectly designed isolation relay	No	Modified wiring	Common-mode failure potential for all 3 MSIVs	LER 88-012	No	07
397	WNP 2	03/22/84	84-027-02	Fifteen	Ground faults	Main steam (MSRV)	Not Specified	Not Specified	SOV susceptibility to spurious actuation due to ground faults	Yes	Replaced defective SOVs. Tested potentially affected SOVs. Voltage spike suppression diodes were installed on all MSRV+ADS SOVs	Events at WNP occurred during startup testing. Common-mode failure potential. Previous similar events at La Salle + Susquehanna	LER 84-027-01	No	14
397	WNP 2	07/23/85	85-050	Two failures (1 SOV)	Diaphragm /seat leakage	Fire protection	Not Specified	Not Specified	Root cause of diaphragm leakage not specified. Backwards bonnet due to inadequate maintenance	No	1- Replaced diaphragm/valve seat. 2- backwards bonnet "repaired"	None	None	No	08

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400	Shearon Harris 1	02/[illegible]/88	88-006	Two	Failed to close	Emergency service water pump seal water supply	Target Rock	790-024	Source of debris accumulation not specified	Yes	The failed SOVs were repaired. No statement made about actions taken for removal of debris or prevention of additional debris	Common-mode failure affecting both trains of Emergency Service Water	None	No	12
400	Shearon Harris 1	05/13/88	88-012	Two	Failed to shift	Emergency service water seal water supply	Target Rock	790-024	Debris in water	Yes	Repaired SOVs and blockec off source of debris				14
400	Shearon Harris 1	09/09/88	88-026	Eleven or more	Internal /reed switch wiring	Containment isolation (many systems)	Target Rock	Eleven models	Manufacturing deficiency	No	Unqualified parts of 1E harsh env. SOVs replaced with qualified ones. Corrective action for non-harsh env. SOVs not specified.	Common-mode failure potential for 1E SOVs for harsh environments. SOVs for ex-containment also deficient.	None	No	06
409	La Crosse	12/03/84	84-022	One	Seat leakage	Isolation Condenser	ASCO	8210	Not Specified	Yes	Replaced SOV	None	None	No	03
409	La Crosse	04/20/85	85-008	One	Coil	Control Rod Drive	Royal Industries	Not Specified	Not Specified	Yes	Replaced SOV	None	LER 81-13	YES	01
409	La Crosse	05/17/85	85-012	One	Seat	Control Rod Drive	Royal Industries	Not Specified	Root cause of metal chip in SOV seat not specified	Yes	Replaced SOV	[illegible]	None	Yes	12

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409	La Crosse	07/08/86	86-020	One	Coil	Control Rod Drive	Royal Industries	Not Specified	Uncertain, water intrusion or random coil failure suspected	Yes	Replaced SOV	There have been 7 previous scrams due to the scram solenoid shorting out.	LER 85-08	Yes	01
409	La Crosse	07/19/86	86-024	One	Electrical short	Reactor cavity ventilation	ASCO	8300	Personnel error-splashed water on SOV	No	Replaced SOV	ESFAS actuation, cascading event	None	No	11
409	La Crosse	12/09/86	86-036-01	One	Coil	Control Rod Drive	Royal Industries	Not Specified	Uncertain, ageing or moisture intrusion suspected	Yes	Replaced several SOVs. Replacement of SOVs will be included in CRDM preventive maintenance program	There have been 8 previous scrams due to these SOV failures. SOV that failed was about 20 years old.	LER 85-08,86-020	Yes	18
410	Nine Mile Pt 2	06/22/88	88-025	Numerous internal parts	Hydraulic Control Unit	Feedwater	Keane	33896	Foreign object in SOV, due to manufacturing deficiency or failure to install filter screen	No	Replaced SOV, also replaced similar SOVs in other trains because of serious degradation of their internals	SOV is piece-part of level control valve	None	Yes	03
414	Catawba 2	10/11/85	86-045	One	Failed to shift	AFW (steam admission to turbine)			SOV incorrectly installed per an incorrect design drawing		Reconnected SOV properly	SOV failure defeated manual start capability of AFW turbine		NO	08
416	Grand Gulf 1	02/10/85	85-007-02	Three	Core-plug nut sticking	Main Steam (MSIV)	ASCO	8323	FUSS	No	Replaced all 8 MSIV SOVs	See section 5.2.4.4	None	Yes	05

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416	Grand Gulf 1	09/25/85	85-038-01	One	Coil	Drywell equipment drain	ASCO	8320	Excessive corrosion within the coil housing believed to be caused by water which entered during plant construction	No	Failed SOV replaced with a duplicate	Licensee stated that the SOV did not need to be environmentally sealed	None	No	11
416	Grand Gulf 1	07/30/86	86-026-01	One	Coil	Control Rod Drive	ASCO	1050602 5P1	Particulate accumulation on the valve seating surface	No	Replaced SOV, system filters to be checked and sampled for particulates	Particulate accumulation resulted in an inavertent control rod withdrawal	None	No	12
416	Grand Gulf 1	01/08/87	87-001	One	SOV failed in mid-position	Offgas sampling	ASCO	8320	Not specified	No	Not specified	Modified system - specific actions taken regarding SOV not stated	None	No	00
416	Grand Gulf 1	03/15/88	88-010	One	Loose terminal box connection to SOVs	Control Rod	ASCO	Not Specified	Cause of loose connection not found	No	The loose terminal connection was cleaned & tightened. Other SOV terminal connections checked, all were okay	Licensee to evaluate design change to improve reliability of power leads	None	Yes	07
423	Millstone 3	09/06/86	86-051	Not Specified	"Failed electrically"	Feedwater	Not Specified	Not Specified	Intermittent open circuit, root cause unknown, suspect vibration and steam impingement from a packing leak	No	All local terminations on the SOV wiring to be checked for tightness during the next shutdown.	None	None	Yes	01

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
423	Millstone 3	03/07/87	87-008	One	Coil (open circuit)	Feedwater	Skinner	V5H6620 0	Cause for open circuit not specified	Yes	Replaced SOV	SOV was operating within its "design life"	LER 86-051	Yes	00
423	Millstone 3	05/06/87	87-024	One	SOV would not shift within spec	Emergency diesel generator air start	Circle Seal	N2990-9 617	Not specified	No	Failed air start SOV and the diesel's redundant SOV were replaced with new ones	Failed SOV resulted in slow (out of spec) EDG starting time	None	No	20
423	Millstone 3	09/23/87	87-034	One	Coil	Feedwater	Skinner Electric	V5H6620 0	Root cause of coil failure (open circuit) not determined. Coil was within its "qualified life"	Yes	Replaced SOV	SOV controls hydraulic oil flow to FWIV	LER 87-08/86-0 51	Yes	01
424	Vogtle 1	01/22/87	87-002	Eight incipients	Potential for MOPD	Main Steam	Keane	Not specified	Design error	No	Installed a relief valve on each hydraulic system to limit pressure to below MOPD limits	Potential for common-mode MOPD failures due to heatup of hydraulic fluid. See Section 5.1.3 of this report.	None	No	13
424	Vogtle 1	04/24/88	88-013	One	Coil	Feedwater	Skinner Electric	V5H6559 0	Coil burnout	No	Replaced SOV and similar SOV on other train of FWIV control system	SOV is a piece-part of AOV controlling FWIV	None	No	01
440	Perry	06/30/86	86-030	One	Seat leakage	Containment Vessel and Drywell Purge	ASCO	8320	Dust from instrument air prevented proper valve sealing	No	Replaced SOV	None	None	No	12

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
440	Perry	02/27/87	87-009	Two	Air leakage (through elastomeric parts)	Emergency Diesel Generator Control Air	Humphrey Products	TOG2E1-3-10-35	Failure due to extended service with high local temperatures and continuous energization. SOVs in svc 10 years and never had PM	Yes	Replaced Both SOVs. Returned failed SOVs to EDG manufacturer for analysis. Will upgrade preventive maintenance and elastomers	Simultaneous common-mode failure of both diesels. Delay in repairing leaking SOVs contributed. See Section this report	None	No	17
440	Perry	10/29/87	87-073-01	Five SOVs on two occasions	Elastomeric seats, discs, etc	Main steam (MSIV)	ASCO	NP8323	Heat and moisture from steam leaks	Yes	Replaced or refurbished SOVs	Common-mode failures. See Section 5.1.1.1 of this report for additional information	Insp Rpt 87-024	Yes	10
440	Perry	03/10/88	88-010	One	Core shaft wear	Auxiliary Building Ventilation	ASCO	8320	Inadequate (no) preventive maintenance for this SOV (replace when fail). Valve had been in service for over 5 years	No	Replaced SOV. Instituted a preventive maintenance program upgrade to replace those SOVs every 2 years	Failure of SOV results in loss of RWCU room cooling	None	No	17
440	Perry	02/03/89	89-004	One		Auxiliary building ventilation	ASCO	8320		Yes	Replaced SOV	Licensee investigating root cause	LER 88-010	No	19
456	Braidwood 1	09/15/89	89-010	One	Coil	Containment Isolation (hydrogen analyzer)	Valcor	V526-5395-1	Coil leads labeled backwards	No	Replaced with different model SOV	Also replaced 5 other similar SOVs. Licensee investigating source of mislabeling (manufacturer vs. plant)		No	09

SOLENOID-OPERATED VALVE FAILURE DATA

DOC NO.	PLANT NAME	EVENT DATE	LER NUMBER	NO. OF FAILURES	FAILED PART	SYSTEM	MANUFACT	MODEL NO.	ROOT CAUSE	REP FL	CORRECTIVE ACTION	COMMENTS	REFERENCE DOCUMENTS	TP/ OUT	FC
458	River Bend	05/02/89	89-022			Affected many systems. See comment	Target Rock	77kk-013	Backwards installation due to inadequate installation instructions	Yes	SOVs reinstalled in reverse orientation	See section 5.1.4.1 for additional details	LER 89-024	No	14
458	River Bend	04/06/89	89-024	0		Affected many systems. See comment	Target Rock	77KK-013	Backwards installation - design error. Inadequate installation instructions.	Yes	Reversed orientation of SOVs	Potential common-mode failures. 6 SOVs had the same installation deficiency. See section 5.1.4.1 of this report for info	LER 89-022	No	08
461	Clinton	03/06/87	87-009	One	SOV failed in mid position	Fuel Building Ventilation	Not Specified	Not Speciifed	Not Specified	No	Replaced SOV	None	None	No	03
461	Clinton	04/14/89	89-019		Electrical connections	Main steam (MSIV)	Seitz		Design error (EQ). Inadequate electrical connector sealing		Install heat shrink tubing per EQ requirements	Failed to meet EQ installation requirements		No	08
461	Clinton	11/29/89	89-037	One	O-rings	Vacuum relief	GPE Controls (SOV unspecified)	L0240-420 (GPE)	Inadequate preventive maintenance	No	Refurbished SOV, replaced O-rings	No scheduled preventive maintenance program. Failure discovered during stroke testing		No	03
483	Callaway	01/02/85	85-001	One	Not Specified	Feedwater	Not Specified	Not Specified	Licensee considered this to be a random failure	Yes	Replaced SOV	SOV is a piece-part of FWIV hydraulic operator	None	Yes	00

SOLENOID-OPERATED VALVE FAILURE DATA

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483	Callaway	02/20/86	86-002-01	None	Electrical connectors	Reactor head vent and chemical volume control	Not Specified	Not Specified	Construction and startup program deficiencies	Yes	Not Specified	On 2 occasions licensee found it had not installed environmentally qualified connectors on SOVs as required (3 SOVs)	None	No	28
528	Palo Verde 1	08/08/85	85-052	Two or more incipients	potential insulation breakdown /shorts to ground	Post accident sampling	Airmatic	Not Specified	Design error	No	Affected SOVs were shielded to reduce post accident radiation	SOVs control air-operated sample flow control valves	None	No	14

APPENDIX B

DISPOSITION OF ASCO DUAL-COIL 8323 SOVs USED FOR MSIV CONTROL

APPENDIX B

Disposition of ASCO Dual-Coil 8323 SOVs Used for MSIV Control

Many plants have experienced problems with ASCO dual-coil 8323 SOVs which have been used for MSIV control. Several examples are provided in Chapter 5. ASCO issued two field notifications (Refs. 106, 107) addressing NP8323 SOVs. The notifications stated that the NP8323 SOVs have no defects, and that their malfunctions were primarily caused by foreign materials, aggrevated by adverse service conditions. Furthermore, because ASCO does not envision significant changes in the service conditions that the NP8323 SOVs are subjected to, ASCO is phasing out the sale of those valves. As an alternative, ASCO recommends the use of a pair of single-coil NP8320 SOVs. Two NP8320 SOVs can be configured to perform the function of one NP8323. Because of the NP8320 SOV's single-coil construction, ASCO anticipates that they will perform more satisfactorily than the NP8323 SOVs under adverse service conditions.

In anticipation of ASCO's discontinuance of the NP8323 SOVs, the MSIV air pack manufacturer (R. A. Hiller Company) has initiated a program to select a suitable replacement of the ASCO NP8323 SOVs.* The Hiller company has assembled five MSIV air packs for baseline testing. The SOVs to be tested in the MSIV air packs are:

ASCO: NP8320 V (2 valves configured as recommended by ASCO in Refs. 102, 103).

AVC: C4964

Target Rock: $\frac{1}{2}$ SMS - S02 (modified)

Valcor: V70900-87V
Zeiss: 629-60007 (assembly)

GE and Hiller Company have noted that all of the American SOVs are 1E qualified; and that although the Zeiss assembly is not 1E qualified, it has been used successfully in Europe.

It should be noted that the choice of a replacement for the NP8323 SOVs can affect the qualification of the overall MSIV air packs (e.g. seismic/dynamic loading). Final selection of replacements for the NP8323 SOV should address this issue.

In the past, GE was actively involved in the qualification testing of MSIV air packs which were used at many plants. GE has indicated that as a result of ASCO's discontinuance of NP8323 SOVs they are trying to interest BWR owners to support a consolidated effort with the Hiller Company to qualify MSIV air packs having suitable replacements for the ASCO NP8323.**

*Telephone discussion between J. Nanci, R. A. Hiller Company, and H. L. Ornstein, USNRC, December 8, 1989.

**Telephone discussion between C. Nieh, GE, and H. L. Ornstein, USNRC, December 1989.

APPENDIX C

GENERIC COMMUNICATIONS ON SOVs

APPENDIX C

Generic Communications on SOVs

Bulletin Number	Date	Title
Bulletin 75-03	March 14, 1975	Incorrect Lower Disc Spring and Clearance Dimension in 8300 and 8302 ASCO Solenoid Valves
Bulletin 78-14	December 19, 1978	Deterioration of Buna-N Components in ASCO Solenoids
Bulletin 79-01A	June 6, 1979	Environmental Qualification of Class 1E Equipment (Deficiencies in the Environmental Qualification of ASCO Solenoid Valves)
Bulletin 80-14	June 12, 1980	Degradation of BWR Scram Discharge Volume Capability
Bulletin 80-17	July 3, 1980	Failure of 76 of 185 Control Rods to Fully Insert During a Scram at a BWR
Bulletin 80-17 Supplement 1	July 18, 1980	Failure of 76 of 185 Control Rods to Fully Insert During a Scram at a BWR
Bulletin 80-17 Supplement 2	July 22, 1980	Failures Revealed by Testing Subsequent to Failure of Control Rods to Insert During a Scram at a BWR
Bulletin 80-23	November 14, 1980	Failures of Solenoid Valves Manufactured by Valcor Engineering Corporation
Bulletin 80-25	December 19, 1980	Operating Problems with Target Rock Safety Relief Valves at BWRs

Information Notice Number	Date	Title
Information Notice 80-11	March 14, 1980	Generic Problems with ASCO Valves in Nuclear Applications Including Fire Protection Systems
Information Notice 80-39	October 31, 1980	Malfunction of Solenoid Valves Manufactured by Valcor Engineering Corporation
Information Notice 80-40	November 7, 1980	Excessive Nitrogen Supply Pressure Actuates Safety-Relief Valve Operation to Cause Reactor Depressurization
Information Notice 81-29	September 24, 1981	Equipment Quantification Testing Experience, Equipment Qualification Notice No. 1
Information Notice 81-38	December 17, 1981	Potentially Significant Equipment Failures Resulting from Contamination of Air-Operated Systems
Information Notice 82-52	December 21, 1982	Equipment Environmental Qualification Testing Experience - Updating of Test Summaries Previously Published in IN 81-29
Information Notice 83-57	August 31, 1983	Potential Misassembly Problem with Automatic Switch Company (ASCO) Solenoid Valve Model NP 8316
Information Notice 84-23	April 15, 1984	Results of NRC Sponsored Qualification Methodology Research Test on ASCO Solenoid Valves
Information Notice 84-53	July 5, 1984	Information Concerning the Use of Loctite 242 and Other Anaerobic Adhesive Sealants
Information Notice 84-68	August 21, 1984	Potential Deficiency in Improperly Rated Field Wiring to Solenoid Valves

Information Notice Number	Date	Title
Information Notice 85-08	January 30, 1985	Industry Experience on Certain Materials Used in Safety-Related Equipment
Information Notice 85-17	March 1, 1985	Possible Sticking of ASCO Solenoid Valves
Information Notice 85-17 Supplement 1	October 1, 1985	Possible Sticking of ASCO Solenoid Valves
Information Notice 85-47	June 18, 1985	Potential Effect of Line-Induced Vibration on Certain Target Rock Solenoid-Operated Valves
Information Notice 85-95	December 23, 1985	Leak of Reactor Building Caused by Scram Solenoid Valve Problem
Information Notice 86-57	July 11, 1986	Operating Problems with Solenoid Operated Valves at Nuclear Power Plants
Information Notice 86-72	August 19, 1986	Failure of 17-7 PH Stainless Steel Springs in Valcor Valves Due to Hydrogen Embrittlement
Information Notice 86-78	September 2, 1986	Scram Solenoid Pilot Valve (SSPV) Rebuild Kit Problems
Information Notice 87-48	October 9, 1987	Information Concerning the Use of Anaerobic Adhesive/Sealants
Information Notice 88-24	May 13, 1988	Failures of Air-Operated Valves Affecting Safety-Related Systems
Information Notice 88-43	June 23, 1988	Solenoid Valve Problems
Information Notice 88-51	July 21, 1988	Failure of Main Steam Isolation Valves
Information Notice 88-86 Supplement 1	March 31, 1989	Operating with Multiple Grounds in Direct Current Distribution Systems

Information Notice Number	Date	Title
Information Notice 89-30	March 15, 1989	High Temperature Environments at Nuclear Power Plants
Information Notice 89-66	September 11, 1989	Qualification Life of Solenoid Valves
Information Notice 90-11	February 28, 1990	Maintenance Deficiency Associated with Solenoid Operated Valves

Circular Number	Date	Title
Circular 81-14	November 5, 1981	Main Steam Isolation Valve Failures to Close