CEN - 145

PORV
FAILURE REDUCTION METHODS
Final Report

Prepared for the C-E OWNERS GROUP

NUCLEAR POWER SYSTEMS DIVISION
December 1980

C-E POWER SYSTEMS
COMBUSTION ENGINEERING, INC

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1. BACKGROUND

The failure of a power-operated relief valve (PORV) to close subsequent to its actuation during an overpressure condition was a key factor in the Three Mile Island-2 (TMI-2) accident. As a result, the operating history of PORVs on all operating light water reactors (LWRs) was investigated by the Nuclear Regulatory Commission (NRC). On an overall basis, the results of the investigation indicated that the probability of a small break loss of coolant accident (LOCA) due to the failure of a PORV to close appeared to be a major contributor to the total probability of a small break LOCA from all causes.[1] Consequently, the NRC has requested[2] that methods for PORV failure reduction be evaluated by C-E for possible implementation to increase plant safety.

2. PURPOSE

The purpose of this study is to review PORV failures, to evaluate methods for failure reduction, to describe the plant changes made or recommended to reduce PORV failures, and to evaluate the effectiveness of these changes for C-E operating plants.

3. DESCRIPTION OF PORV SYSTEM

3.1 Introduction

A brief description of the provisions for overpressure protection of the typical C-E Nuclear Steam Supply System (NSSS) primary coolant system and clarification of the supporting role of the PORVs is provided below.

Overpressure protection for the primary coolant system is based on the combined action of the primary safety valves, secondary safety valves, and the reactor protection system. At operating conditions the PORVs are not formally part of the overpressure protection system; although the presence of PORVs increases the primary coolant system relieving capacity.

3.2 Function of the PORV

To reduce the number of challenges to the primary safety valves, and thus reduce the probability of gross safety valve leakage or weeping, pressurizers on all C-E operating plants (except for ANO-2) are provided with two PORVs having actuation set points below that of the primary safety valves.

Figure 1 shows a typical installation arrangement for primary system overpressure protection. Isolation valves are provided upstream of each PORV. Throughout this report, the term "PORV System" is used whenever the PORV and its isolation valve is being considered in combination. Design and operating parameters for the primary safety valves and PORVs at C-E operating plants are given in Table 1.[1]

Additional functions, not considered in the initial NSSS design, have since been assigned to the PORVs. These functions include low temperature overpressure protection, venting, and long term cooling subsequent to a LOCA. These auxiliary PORV functions have been documented elsewhere and are not included in the scope of this report.

3.3 PORV Design Basis

The PORVs are designed to have an opening setpoint pressure below that of the primary safety valves and to provide sufficient relieving capacity to ensure that the primary safety valves do not lift or weep during overpressurization transient conditions such as uncontrolled rod withdrawal, loss of load, or loss of all non-emergency AC power. The PORV opening setpoint pressure is sufficiently high to ensure that the PORVs do not open in response to normal maneuvering transients.

3.4 PORV Description

All PORVs in operating C-E NSSSs are Dresser electromatic relief valves which are pilot actuated, reverse-seated, and which use pressurizer pressure to operate the valve (Figure 2). When pressurizer pressure exceeds the valve setpoint pressure, the solenoid on the pilot valve is energized; this causes its plunger to actuate a lever to open the pilot valve. The main valve's pressure chamber above the valve disc is vented through the open pilot valve and the resulting pressure difference across the main valve disc causes the main valve to open and discharge pressurizer fluid. When pressurizer pressure decreases below the setpoint value, the solenoid is deenergized, the pilot valve closes, and steam pressure builds up in main valve pressure chamber and forces the valve disc closed.

3.5 PORV Operation

The PORVs are designed for automatic or manual operation. In automatic operation, the PORVs are opened by the high pressurizer pressure trip signal in the reactor protective system, which is actuated by a two out of four channel logic system. The PORVs, which are actuated by the same bistable trip units which actuate the reactor trip, open whenever the pressurizer pressure exceeds the high pressure reactor trip setpoint and they remain open until pressurizer pressure falls below the valve reset pressure. In the manual mode the PORVs can be operated independent of system temperature and pressurizer pressure.

The PORV actuation setpoints vary somewhat from plant to plant, at a nominal value of approximately 2400 psia, about 100 psi below the primary safety valves setpoint and 150 psi above normal operating pressure (Table 1).

3.6 PORV Isolation Valves

To permit isolation of a PORV in case of excessive seat leakage or failure to close, motor-operated block valves are provided upstream of each PORV. During power operation the block valves are normally open. However, one or both PORVs may be isolated (block valves closed) because of excessive leakage. Also, operation with one PORV isolated may be considered to avoid excessive reactor coolant discharge due to both PORVs lifting.

3.7 PORV Leakage Detection

Several methods were used prior to the TMI accident for the detection of excessive PORV leakage or failure to close. These methods include monitoring PORV discharge piping temperature, PORV pilot valve position indication, and quench tank pressure, temperature, and level. Readouts from each of these measurements are generally available in the plant main control room. Subsequent to the TMI-2 accident, the NRC required a reliable, direct means for PORV position indication. Action to respond to this requirement is described in Sections 6 and 7.

3.8 Electric Power Supplies

In performing their function to reduce the frequency of primary safety valve challenges, the PORVs provide equipment protection and as a consequence, are not considered as part of the plant safety system. Therefore, the valves as installed in the field were not provided with safety grade power sources and no credit was taken for their operation in safety analyses. Subsequent to the TMI-2 accident, consideration was given to providing the PORVs and their isolation valves with emergency power sources. Further actions on PORV system power supplies are discussed in Sections 6 and 7.

3.9 Comparison with Other PWRs

The PORV systems provided in pressurized water reactors (PWRs) supplied by Babcock and Wilcox (B&W)[3], Westinghouse (W)[4] and C-E differ in details such as the type, number, capacity, setpoint, valve vendors and control circuitry. Certain important differences among the PWR vendors' systems are described in the following sections.

On C-E plants, the initial design function of the PORVs was solely to reduce the challenges to the primary safety valves during power operation. The PORVs on B&W and W plants had an additional function, namely, to reduce the frequency of reactor trips due to high pressure. The PORV actuation set point on C-E plants coincides with the high pressure reactor trip setpoint, whereas, the other PWR vendors required that the PORV actuation pressure be below the high pressure reactor trip setpoint in order to reduce the number of high pressure trips. The C-E design allows the specification of a higher PORV actuation pressure, and therefore a greater margin above the normal plant operating pressure than do the other PWR designs. Typically, the margin between normal operating pressure and the PORV actuation setpoint was about 150 psi for C-E plants, 100 psi for W plants, and 70 psi for B&W plants. This difference provided an incremental margin to PORV challenges in C-E plants compared with those of the other PWR vendors.

The B&W plants are equipped with the same type of PORVs as those of C-E, namely, the Dresser electromatic solenoid pilot-operated valve described in Section 3.4. The majority of W plants use Copes-Vulcan spring-loaded, air-operated valves. Air pressure on the control diaphragm overcomes the spring force to open the valve. Venting the air pressure from the control diaphragm allows spring force to close the valve. A few W plants use PORVs manufactured by Masoneilan (3 plants), Dresser (1 plant), ACF Industries (1 plant), and Control Components (1 plant).

4. PORV OPERATING EXPERIENCE

4.1 Combustion Engineering Plants

The operating experience of PORVs in C-E plants has been compiled in Table 2 based on information supplied by the various plant operators during a survey conducted in early 1980. The PORV actuations noted in Table 2 do not necessarily represent the total number which have occurred, since PORV actuations were not reportable events and were not routinely recorded. Therefore, some actuations may have been overlooked. Also, since the available means for the detection of PORV actuation was not direct, but generally dependent upon an integrating effect, such as increasing quench tank level, for example, some actuations may have gone undetected.

Table 3 is a tabulation of high pressurizer pressure reactor trips occurring in C-E operating plants for which PORV actuations were not reported. The data was obtained from a review of published data, mainly from the NRC. Since, by design, a high pressurizer pressure reactor trip should be accompanied by PORV actuation, it is inferred that the actuation did occur, though it was not reported.

Table 2 indicates a total of seven confirmed PORV actuation events. Four events occurred during PORV testing or system maintenance. In two of these events the PORVs failed to close satisfactorily. The remaining three actuation events occurred during power operation, with the PORVs operating satisfactorily in each case. Table 3 indicates a total of sixteen high pressurizer pressure reactor trips, eleven of which resulted from turbine runbacks. Tables 2 and 3 extend the PORV actuation data presented in NUREG 0635[1].

It was inferred that the high pressurizer pressure trips listed in Table 3 were accompanied by PORV actuations. Combining the confirmed PORV actuation events during power operation listed in Table 2 with the inferred actuation events from Table 3, a total of nineteen events or thirty-eight PORV challenges is obtained, with no failures being reported. A total of about 29 reactor-years of operation is covered by this data.

The two PORV failures-to-close on C-E plants listed in Table 2 occurred during maintenance or testing.

The Palisades incident occurred when the Reactor Protection System (RPS) was deenergized for maintenance, which caused the PORVs to open. Due to an ambiguity in the pertinent wiring diagrams the technician failed to perceive that his action would cause PORV actuation. The spring-return-to-Auto feature of the PORV selector switch contributed to the incident since the selector switch could not be retained in the "Manual" mode and "Shut" position unless held there by the operator. Corrective action was taken to clarify the pertinent wiring drawings and eliminate the spring-return-to-Auto feature of the PORV selector switch. The PORV failure-to-close in this instance was not due to the failure of the valve.

The second PORV failure-to-close occurred in Calvert Cliffs #1 during valve operational testing following valve maintenance. The valve failed to shut completely. Modified replacement parts had been installed in the valve because original replacement parts were unavailable due to vendor upgrading of the valve design. Following adjustment of the pilot valve stroke, satsifactory valve closure was obtained.

4.2 Experience at Other PWRs

Westinghouse PWRs in the U.S. have not reported any PORV failures[4], but since they are equipped with a different type of PORV their reliability experience is not relevant to C-E PORVs.

It has been estimated that in B&W plants there have been approximately 150 actuations of PORVs[3] with six cases of failure-to-close properly. One failure occurred during low power testing upon loss of a vital bus, another during startup testing due to improper venting, and a third was a leaky valve. Three failures occurred during power operation, giving approximately 3/150 = .02 failures per demand.

5. PRIMARY SAFETY VALVES

5.1 Operating Experience

No primary safety valve lifts have been reported for C-E operating plants during approximately 30 reactor-years of operation. Westinghouse plants also have not reported any primary safety valve lifts. One primary safety valve lift has been noted[4] in a B&W plant, but no details were given. In view of the lack of challenges to the primary safety valves, a direct quantitative estimate of their reliability based on experience cannot be made.

5.2 Probabilistic Analysis

The main steam safety valves (MSSV) are much more subject to challenges than are the primary safety valves, so that data regarding their reliability has been developed. This data does not have direct applicability to the primary safety valves since, even though the MSSV bears some similarity to the primary safeties, there are distinct differences with respect to service conditions, materials, and other design features. Lacking data on the primary safety valves, the MSSV data may provide some indication of primary safety valve reliability.

A study of PWR MSSV operating experience up to May, 1978 was performed by C-E. The data sources used were NPRDS Failure Report Summaries, License Event Report Summaries, and Operating Units Status Reports.

The period reviewed included 137 reactor-years of operation at 38 PWR plants with an estimated population of 570 MSSVs. During this period there were an estimated 2070 MSSV test demands (pre-operational and annual). Assuming one demand on MSSVs for every ten scrams or turbine trips, about 2580 operational MSSV demands were estimated. The total number of MSSV demands in the study period were estimated to be 5650.

During this period two events were reported (none from C-E operating plants) in which MSSVs failed to close following a demand. The first event occurred at Turkey Point Unit 4 in 1974 when a missing cotter pin caused one MSSV to fail open. The second event occurred at Three Mile Island Unit 2 in April, 1978. A common mode failure of six MSSVs to close occurred due to cocked sleeves in the bellows assembly. Thus, the total number of MSSV failures to reseat reported during the study period was seven.

Based on the seven reported MSSV failures and the 5650 estimated MSSV demands, a failure rate of 1.24×10^{-3} per demand is estimated. This failure rate is lower than the value of 2×10^{-2} estimated for power operated relief valves in NUREG 0560.[3] Assuming that the MSSV reliability data are to some degree applicable to the primary safety valves, the data suggests that the primary safety valves may be more reliable than the PORVs. More definite conclusions must await development of operational and/or test data on primary safety valves.

6. METHODS FOR REDUCING PORV SYSTEM FAILURE

6.1 Reduction of PORV Challenges

The frequency of PORV system failures can be reduced by decreasing the frequency of challenges to the PORVs. These reductions must be made without adversely impacting safety or incurring unacceptable economic or performance penalties. Methods for potentially decreasing the frequency of PORV challenges on C-E plants and a brief summary of their impacts on the plant are provided below.

6.1.1 Raise PORV Setpoint

High pressurizer pressure trips the reactor when the pressure exceeds the trip setpoint pressure and the output from the same bistable comparator also actuates the PORV. Therefore, only one setpoint is available. Raising this Reactor Protection System (RPS) high pressurizer pressure reactor trip setpoint would invalidate the safety analysis and increase the challenges to the primary safety valves.

6.1.2 Lower High Pressurizer Pressure Trip Setpoint

This requires the concomitan lowering of the PORV actuation setpoint as described above. Doing so would increase the number of challenges to the PORVs.

6.1.3 Raise the setpoint for the existing PORV Opening/High Pressurizer Pressure Trip and Add Another High Pressurizer Pressure Reactor Trip at 2400 psi

The setpoint for the existing PORV Opening/High Pressurizer Pressure Reactor Trip would need to be raised approximately no higher than 20-40 psi to prevent primary safety valve challenges during a full loss of turbine load without a simultaneous reactor trip while simultaneously precluding PORV openings during milder pressure increases. The benefits of this alternative would be very small since only a very small fraction of the PORV openings would have been avoided by this modification (i.e., full load rejection where PORV opening was desired to preclude primary safety valve opening and the inadvertent initiations would not have been affected).

Further, there is no more room in the protective system cabinetry in some of the operating plants to accommodate additional bistable trip units and other circuitry that would be required. Adding additional trips would be expensive and would take a considerable amount of time to incorporate.

6.1.4 Block Out and/or Deactivate PORV During Power Operation

In the event of a full power incident which causes the turbine admission valves to close rapidly (e.g. full load rejection, electrical system over-frequency, turbine control failure), the reactor would trip on high pressurizer pressure in the absence of a turbine trip signal. The pressurizer pressure would continue rising above the 2400 psi setpoint until the reactor trip quenched the power output of the core and caused the pressurizer pressure to decrease. It is prudent to use the power operated relief valves to preclude challenging the primary safety valves during this transient. There are PORV block valves which can be closed in the unlikely event of a PORV failing to close. Such block valves are unavailable to mitigate the consequences in the unlikely event that a safety valve fails to reclose.

6.1.5 Reduce Operating Pressure

A reduction in operating pressure would tend to reduce the number of PORV openings, but by only a small proportion. Also, the lower the operating pressure, the higher the overshoot in pressure after a load rejection is terminated by the high pressurizer pressure trip. The higher overshoot in pressure results from the delay in the reactor trip. This increases the potential for challenging the primary safety valves. More importantly, decreasing the primary operating pressure would decrease the operating DNB ratio thus causing the core to be operated closer to one of the safety limits.

6.1.6 Elimination of Turbine Runback

Table 3 indicates that a relatively large number (11) of high pressure trips (and presumably 22 PORV actuations) occurred during turbine runback events. A review of this plant feature indicated that its elimination would not adversely affect plant operation, while at the same time reducing PORV challenges to a significant degree.

6.2 Improved Capability for Countermeasures

The frequency of PORV system failures can also be reduced by improving the capability for appropriate countermeasures (PORV isolation) subsequent to a PORV failure to close. Methods for potentially improving the capability to take appropriate action and a brief summary of their impacts on the plant are discussed.

6.2.1 Automatically Close Block Valve Whenever PORV Fails to Close on Command

There are several ways this could be implemented. The block valve closing signal could be armed by an initial PORV opening signal so that the block valve would remain open in normal operation but would be automatically closed if the PORV failed to close on command. Another approach would use the concurrence of an open PORV valve and and PORV valve closure command to automatically close the block valve. Although automatic valve closure would remove the requirements for operator action upon PORV failure, the additional control circuitry would introduce additional complexity to the system and would itself be subject to its own failure modes. These schemes require further detailed evaluation to determine their positive and negative impacts on overall plant safety. A simpler approach is to assure that the operator is able to utilize existing inplant instrumentation to identify a stuck-open PORV and to close the block valve.

6.2.2 PORV Position Indication

Reliable and positive control room indication of PORV position would provide vital information to the operator in a clear and timely manner to permit him to take the appropriate action necessary to prevent escalation of a minor incident into a LOCA. An ultrasonic flow-meter, located at the discharge piping of the PORV, with flow indication and alarm in the control room, would provide direct, positive, rapid-response, and reliable indication of PORV position. An advantage of this instrument is that it does not require any penetration of the piping. Alternatively, the PORV could be provided with a position indicator for the main valve disc position.

6.2.3 Electric Power Supplies

The PORVs and their associated block valves, which were designed for an equipment protective function rather than a safety function, were not initially provided with emergency power supplies. The provision of emergency power to these valves would maintain the availability of the relief system and also permit its isolation, if necessary, upon loss of all non- emergency power sources.

6.2.4 Improvement of Operator Capability

The evaluation of the TMI-2 incident indicated that a program to improve operator performance, particularly during emergency conditions, would significantly reduce the potential for serious nuclear incidents. Upgrading operator capability to recognize and to respond appropriately to a PORV failure-to-close should significantly reduce the possibility of the subsequent occurrence of a small break LOCA.

7. IMPLEMENTATION OF PORV SYSTEM FAILURE REDUCTION PROGRAM

The following actions to reduce PORV system failures have been completed or are pending:

1. The turbine runback feature has been eliminated from C-E operating plants.

2. The motor operators for the PORV block valves and the pilot solenoids for the PORVs have been provided with emergency power supplies to permit them to function upon the loss of all non-emergency power.

3. Ultrasonic flowmeters are being installed on the PORV discharge piping to provide a direct measurement of steam flow and therefore, of PORV position, with indication and alarm in the control room.

4. Operator training programs have been initiated to provide the operator with a more comprehensive understanding of plant operation under emergency conditions. Guidelines and detailed emergency operating procedures have been developed to aid the operator to cope with a spectrum of emergency conditions. This includes the conditioning of the operator to recognize and respond promptly to PORV failure to prevent escalation of the failure to a small break LOCA.

8. ANALYSIS AND RESULTS OF FAILURE REDUCTION PROGRAM

An analysis was performed to provide an estimate of the reliability of the PORV system as well as an estimate of the improvement in reliability expected as a result of the various actions taken or to be taken as noted in Section 7. Appendix A presents a description of the reliability analysis and the results obtained. This section provides a discussion of the analysis and results.

Table A-1 gives challenge frequencies for the PORVs and demand failure rates used in the analysis for various aspects of PORV and block valve operation. The frequency of challenges to the PORVs is based on the C-E operating plants' experience presented in Section (4.1). The PORV demand failure (failure-to-close) rate is based on the B&W operating experience described in Section 4.2. The reasons for using the B&W data as a basis are that:

1. The C-E PORV system design basis and other NSSS features as discussed in Section 3.0 tended to keep PORV actuations to a minimum, so that only a small statistical data base for PORV actuations on the C-E NSSS was available.

2. B&W operating plants had experienced a relatively large number of PORV actuations, and in addition, their operating plants are equipped, with one exception, with the same type of PORVs from the same supplier as are C-E operating plants.

3. Westinghouse operating plant experience was not included due to the fact that, in general, they used a different type of PORV from different vendors than did C-E and B&W.

The specific value of the B&W PORV demand failure rate used in the Appendix A analysis was 0.02 failures-to-close per opening. If the C-E plant experience (38 challenges with zero failures) was statistically combined with the B&W data, the demand failure rate would be reduced by about 20% to 0.016.

A value of 0.155 was used for the probability of failure of the operator to isolate the failed-open PORV. This value is based on data in WASH 1400[5], and is taken as the mean between the operator's normal stress level and severe stress level failure probabilities.

Table A-2 provides the estimated frequency of an unisolated failed-open PORV, (i.e. small break LOCA due to a failed-open PORV) for a C-E plant to which various features have been incorporated. It shows the progressive reduction in the recurrence frequency of a small break LOCA due to a failed-open PORV as the various methods for PORV system failure reduction noted in Section 7 are implemented. Case 1 is the reference case prior to elimination of the turbine runback feature. This case takes no credit for operator action to isolate the failed-open PORV on the assumption that the available instrumentation did not provide clear, positive valve position indication to the operator. Case 2 assumes elimination of the turbine runback feature, with no credit for operator action. Case 3 is similar to Case 2, except credit is taken for operator action on the basis that appropriate instrumentation has been added to give the operator clear, positive indication of PORV position. Cases 4 and 5 assume that provision for automatic closure of the block valve upon failure of the PORV to reclose has been incorporated. Case 4 assumes a control grade design which involves reliable components but has only a single isolation valve and hence is not single failure proof. Case 5 assumes a safety grade design with series isolation valves to provide single failure protection for closure.

The estimates in Table A-2 show that the elimination of the turbine runback feature and taking credit for operator action (based on positive valve position indication and alarms) serves to reduce the estimated recurrence frequency of a small break LOCA due to PORV failure by a factor of about 14.5 (or about 18 for a PORV demand failure rate of .016). The estimated recurrence frequency for a small break LOCA due to a PORV failure is 1.8×10^{-3} per reactor-year (or about 1.4×10^{-3} per reactor-year for a PORV failure demand rate of .016), which is well within the 90% confidence range of a small break LOCA due to a pipe break, 10^{-2} to 10^{-4} per reactor-year, as estimated by WASH-1400. Two factors which would further reduce the recurrence frequency of a small break LOCA due to PORV failure from the value before the TMI-2 accident have not been quantified. One is the improvement in operator capability and reduction in the probability of operator error due to new intensive operator training programs, and the updating of plant emergency procedures based on guidelines which consider the realistic response of the plant to transients and accidents. The second is the provision of emergency power to the PORV block valves to allow PORV isolation, if necessary, after loss of non-emergency power. These factors provide some additional confidence regarding the conservatism of the analytical results.

Table A-2 also shows that provision of control grade automatic block valve closure upon PORV failure to close would reduce the recurrence frequency of a small break LOCA due to PORV failure nearly to the lower limit of the range of 10^{-2} - 10^{-4} per reactor-year estimated for the small break LOCA due to pipe rupture by WASH-1400. The provision of a safety-grade, single-failure-proof design for automatic block valve closure by the addition of redundant isolation valves reduces the recurrence frequency to a negligable value.

9. SUMMARY AND CONCLUSIONS

The C-E operating plants after approximately 29 reactor-years of operation have experienced no PORV failures during power operation. The elimination of the turbine runback feature and the provision of a direct reliable means for indicating PORV position to the operator provided significant improvements in system reliability. The recurrence frequency of a small break LOCA due to PORV failure has been reduced by an estimated factor of about 15 to a value of about 1.8×10^{-3} per reactor-year. This recurrence frequency is well within the 90% confidence range of the recurrence frequencies of 10^{-2} to 10^{-4} per reactor-year for a LOCA due to a small pipe rupture estimated in WASH-1400. Improved operator training programs and emergency procedures, as well as the provision of emergency power to the PORVs and to their block valves, though not quantified, has reduced the small break LOCA recurrence frequency even further. The incorporation of the feature of automatic block valve closure upon PORV failure would further increase PORV system reliability.

10. REFERENCES

1. NUREG-0635 - Generic Evaluation of Feedwater Transients and Small-Break-Loss-of-Coolant Accidents in C-E Designated Operating Plants, January 1980.

2. NUREG-0737 Clarification of TMI Action Plan Requirements, Nov. 1980

3. NUREG-0560 - Generic Assessment of Feedwater Transients in Pressurized Water Reactor Designed by the Babcock and Wilcox Company, May, 1979.

4. NUREG-0611 - Generic Evaluation of Feedwater Transients and Small-Break-Loss-of-Coolant Accidents in Westinghouse Designed Operating Plants, January, 1980.
5. WASH-1400 - Reactor Safety Study, October, 1978 Appendix III, Table III 6-1.

TABLE 1

C-E PRIMARY SAFETY VALVE AND PORV DATA

A. PRIMARY SAFETY VALVES DATA

Plant	Valve Vendor	Valve Type	Number per plant	Setpoint psig	*Rated Minimum capacity lb/hr	*Maximum Actual capacity, lb/hr
Ft. Calhoun	Crosby	HB-BP-86	2	2530	216,000	240,000
				2485	212,000	236.000
Palisades	Dresser	31739A	3	2565	230,000	256,000
				2525	230,000	256,000
				2485	230,000	256,000
St. Lucie 1	Crosby	HB-BP-86	3	2485	212,000	236,000
Maine Yankee	Dresser	31709KA	3	2535	218,000	243,000
				2510	216,000	240,000
				2485	214,000	238,000
Calvert Cliffs 1 and 2	Dresser	31739A	2	2550	304,000	334,000
				2485	296,000	329,000
Millstone 2	Dresser	31739A	2	2485	296,000	329,000

*Capacity indicated corresponds to 3% accumulation above set pressure

B. PORV DATA

Plant	Valve Vendor	Valve Type	Number per plant	Setpoint psig	*Relieving Capacity lb/hr
Ft. Calhoun	Dresser	31533VX	2	2385	111,000
Palisades	Dresser	31533VX	2	2385	155,000
St. Lucie 1	Dresser	31533VX-30	2	2385	159,000
Maine Yankee	Dresser	31533VX	2	2385	150,000
Calvert Cliffs 1 and 2	Dresser	31533VX-30	2	2385	159,000
Millstone 2	Dresser	31533VX-30	2	2400	148,000

*Rated value at 0% accumulation, provided by vendor

TABLE 2

Summary of Events Involving PORV Operation

PLANT	DATE	PLANT CONDITIONS	INITIATING EVENT	DESCRIPTION
Consumers Power* Palisades	Sept. 8, 1971	Mode 3	Technician deenergized RPS for maintenance	PORV opened when RPS deenergized.
Baltimore Gas & Elec. Calvert Cliffs-1	July 6, 1979	Mode 5	Test of PORV	During operational test of PORV valve failed to fully close. Adjusted pilot valve stroke
2	August 20, 1980	100%	MSIV Closure	PORVs cycled on high pressure
Florida Power & Light St. Lucie -1	Feb. 21, 1977	100%	100% load rejection	PORV cycled during test when reactor tripped on high pressure.
Omaha Public Power Dist. Fort Calhoun	May 28, 1978	80%	Turbine control valve closed	PORV's cycled when plant tripped on high pressure.
Fort Calhoun	Dec. 20, 1978	Mode 5	Troubleshooting pressure recorder	PORV's opened when technician pulled recorder fuses.
Northeast Utilities Millstone-2	Aug. 10, 1979	Mode 5	Troubleshooting	PORV opened on loss of AC to emergency bus.
Maine Yankee Atomic Power Company	No PORV Operation Events			
Maine Yankee				

*Palisades has operated since 1972 with PORV block valve shut.

TABLE 3

Summary of Events Resulting
In Potential Challenge to PORV

PLANT	DATE	PLANT CONDITIONS	INITIATING EVENT	DESCRIPTION
Consumers Power Palisades (Note 1)	Mar. 19, 1973	85%	Circuit Noise	Spurious high pressure trip
	Aug. 31, 1976	100%	MSIV shutting	High pressure trip due to MSIV shutting.
	Nov. 26, 1976	15%	Generator Synchronization	Spurious high pressure trip while bringing generator on line.
	May 22, 1978	100%	Closure of both MSIV	High pressure reactor trip.
Baltimore Gas & Elec. Calvert Cliffs -1	July 8, 1975	100%	Turbine runback	High pressure trip due to turbine runback. Unable to verify PORV operation due to loss of plant computer.
	Jan. 26, 1975	20%	Power reduction with manual pressurizer spray control	High pressure reactor trip.
Northeast Utilities Millstone -2	Apr. 13, 1976	80%	Turbine runback	High pressure reactor trip.
	Apr. 23, 1976	100%	Turbine runback	High pressure reactor trip.
	May 10, 1976	100%	Turbine runback	High pressure reactor trip.
	May 24, 1976	100%	Turbine runback	High pressure reactor trip.
	May 25, 1976	100%	Turbine runback	High pressure reactor trip.
	June 8, 1976	100%	Turbine runback	High pressure reactor trip.
	June 10, 1976	100%	Turbine runback	High pressure reactor trip.
	June 19, 1976	100%	Turbine runback	High pressure reactor trip.
	June 21, 1976	100%	Turbine runback	High pressure reactor trip.
	Aug. 13, 1976	100%	Turbine runback	High pressure reactor trip.

Note 1 - Palisades has operated since 1972 with PORV blocking valve shut.

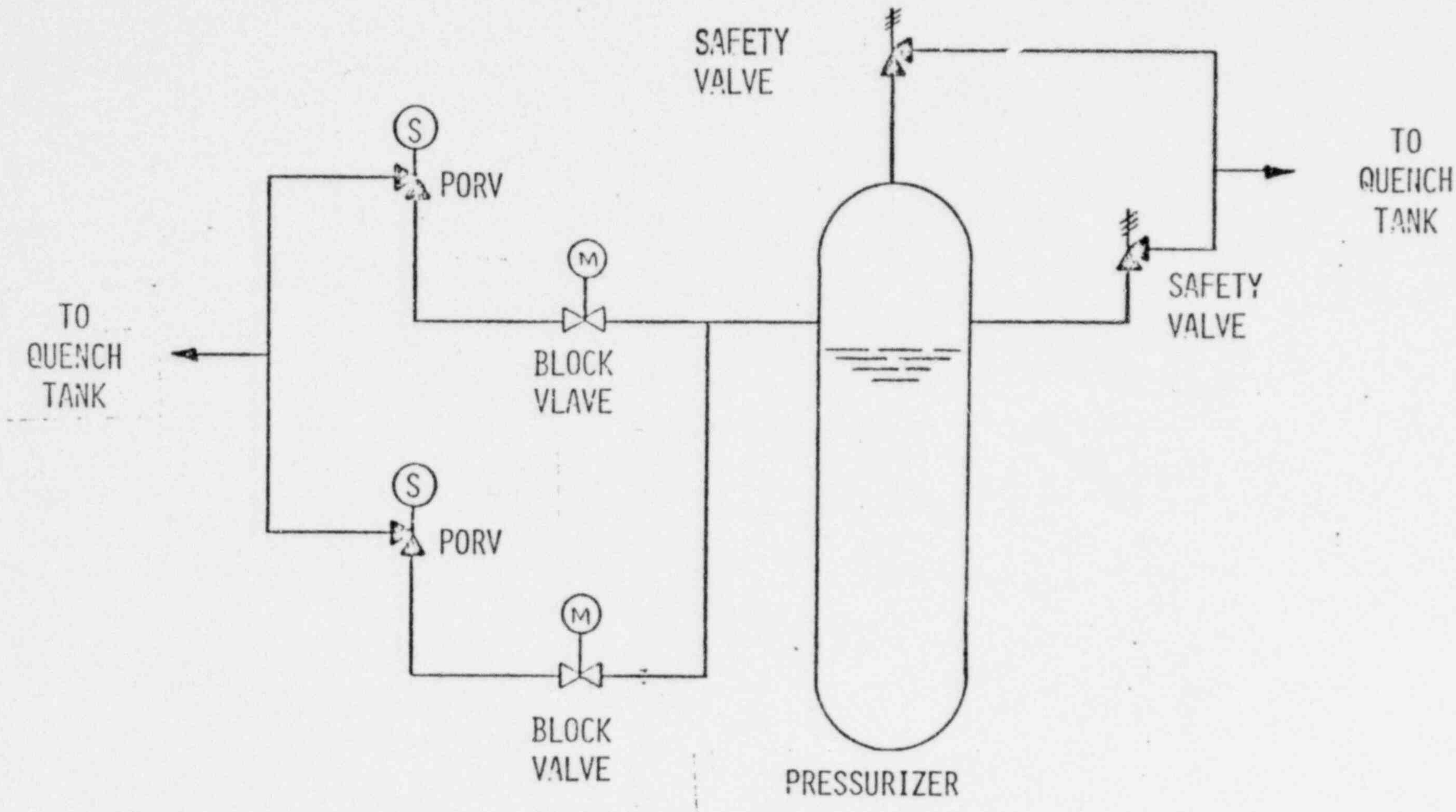


FIGURE 1
TYPICAL PRIMARY SYSTEM
OVERPRESSURE PROTECTION

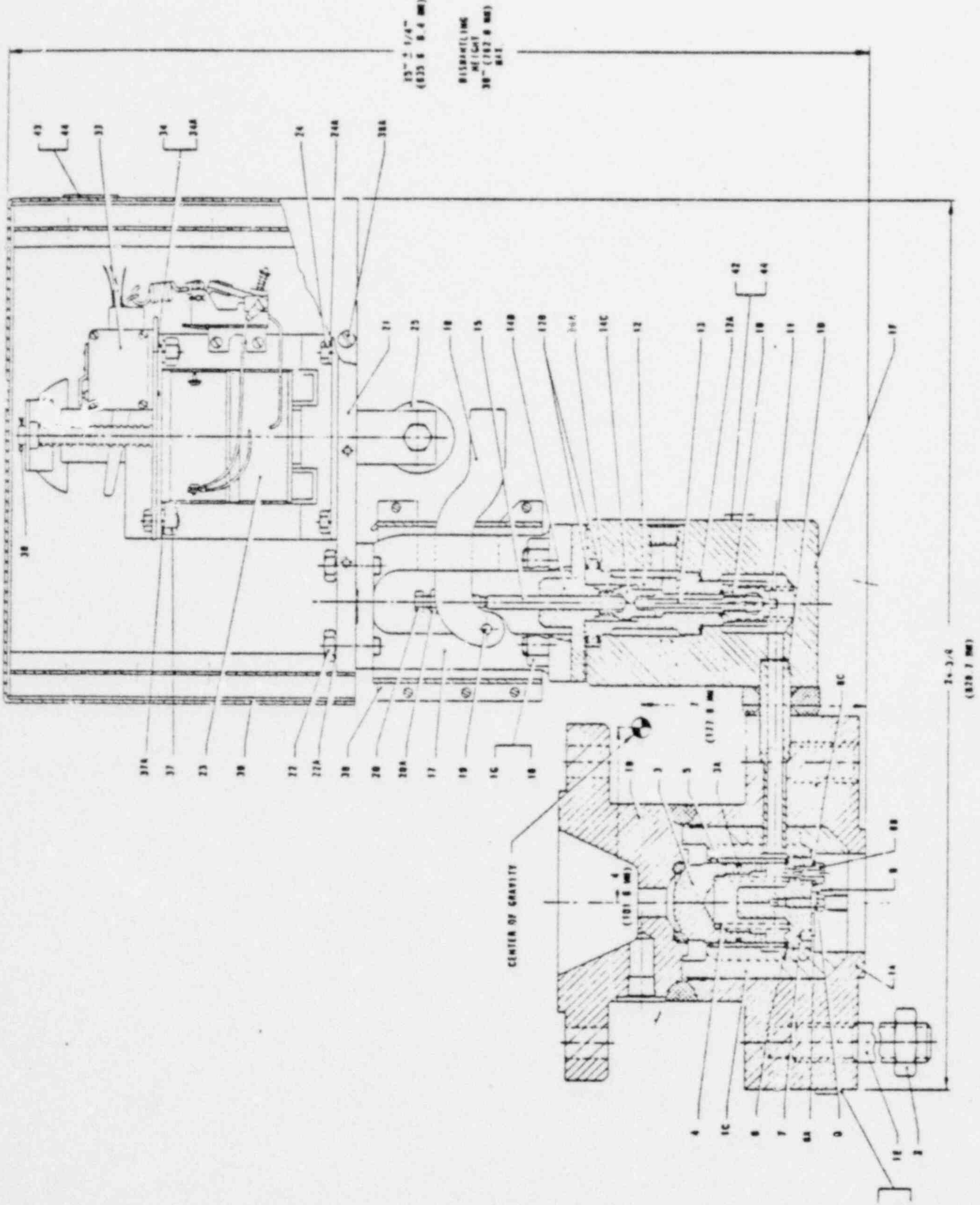


FIGURE 2 - TYPICAL ELECTROMATIC RELIEF VALVE

REF. NO.	QTY.	NOMENCLATURE
1	1	MAIN BASE-PILOT BASE ASSEM. (WELDED, INTEGRAL ASSEM.)
1A	1	INLET FLANGE
1B	1	OUTLET FLANGE
1C	1	CAGE
1D	1	TUBE INSERT
1E	8	MAIN BASE INLET STUD
1F	1	PILOT BASE
1G	4	PILOT BASE STUD
2	8	INLET STUD NUT
3	1	MAIN DISC
3A	1	PISTON RING
4	1	MAIN DISC SPRING
5	1	GUIDE
6	1	GUIDE GASKET
7	1	GUIDE RETAINER PLUG
8	1	RETAINER PLUG CAP SCREW
8A	1	CAP SCREW LOCKWASHER
8B	1	LOCK SCREW
8C	1	LOCK SCREW LOCKWASHER
9	1	SEAL WIRE
10	1	PILOT DISC
11	1	PILOT DISC SPRING
12	1	SEAT BUSHING
12A	1	LOWER GASKET
12B	2	UPPER GASKET
13	1	LOWER SPINDLE
14	1	BELLOWS ASSEM. (WELDED, INTEGRAL ASSEM.)
14A	1	BELLOWS
14B		FLANGE
14C	1	PISTON
15	1	UPPER SPINDLE
16	4	PILOT STUD NUT
17	1	SOLENOID BRACKET
18	1	LEVER
19	1	LEVER PIN ASSEM.
19A	1	SHOULDER SCREW
19B	1	NUT

FIGURE 2 - TYPICAL ELECTROMATIC RELIEF VALVE

REF. NO.	QTY.	NOMENCLATURE
19C	1	BRACKET BUSHING
19D	2	LEVER BUSHING
19E	1	COTTER PIN
20	1	ADJUSTING SCREW
20A	1	LOCKNUT
21	1	BRACKET PLATE
22	4	BRACKET PLATE CAP SCREW
22A	4	LOCKWASHER
23	1	SOLENOID
24	4	SOLENOID CAP SCREW
24A	4	LOCKWASHER
25	1	PLUNGER HEAD
26	1	LEFT HAND SPRING GUIDE
27	1	RIGHT HAND SPRING GUIDE
28	2	PLUNGER SPRING
29	2	PLAIN SPRING WASHER
30	2	SPRING COTTER PIN
31	2	GUIDE BRACKET
32	1	GUIDE BRACKET BOLT
32A	1	LOCKWASHER
32B	1	NUT
33	1	SWITCH
34	2	SWITCH MACHINE SCREW
34A	2	LOCKWASHER
35	3	SPRING GUIDE CAP SCREW
36	1	SPECIAL SPRING GUIDE SCREW
37	4	SPRING GUIDE NUT
37A	4	LOCKWASHER
38	1	BRACKET COVER ASSEM.
38A	1	LEFT HAND COVER
38B	1	RIGHT HAND COVER
38C	5	MACHINE SCREW
38D	5	LOCKWASHER
38E	5	NUT
39	1	SOLENOID COVER
39A	6	MACHINE SCREW
40	1	NAMEPLATE
41	1	TAG PLATE
42	1	CAUTION PLATE
43	1	SOLENOID NAMEPLATE
44	10	NAMEPLATE SCREW

FIGURE 2 - TYPICAL ELECTROMATIC RELIEF VALVE

Sheet 3 of 3

APPENDIX A

C-E ANALYSIS OF

REFERENCE PLANT (SL2) FAULT TREE

FOR

POWER OPERATED RELIEF VALVE

LOSS OF COOLANT ACCIDENT

TABLE OF CONTENTS

1.0 PURPOSE

This report presents the results of a reliability analysis for loss of reactor coolant through the power operated relief valves.

2.0 SCOPE

The reliability analysis considers the performance of the safety function element (SFE) strictly as defined in Sections 3 and 4, Safety Function Element Description and Analysis Assumptions. In this form, the analysis will not be applicable to all initiating events but presents a model which was determined to be most useful in terms of applicability and most amenable to later modification for application to special cases.

3.0 SAFETY FUNCTION ELEMENT DESCRIPTION

The safety function element, Relieving Reactor Coolant System Pressure through the Powered Operated Relief Valves (PORV), refers to the opening of the PORV due to high Reactor Coolant System pressure and reclosing these valves once the Reactor Coolant System pressure decreases below the valve setpoint. Included in this SFE are the opening and reclosing of the PORVs. Also included is the operator's capability to close the PORV block valve, from the control room, if the PORV fails to reclose.

A schematic of the PORV layout is shown in Figure A-1. There are two 50% flow capacity PORVs. Both PORVs receive a signal which causes them to open during a high Reactor Coolant System pressure transient. Once the Reactor Coolant System pressure decreases below the PORV setpoint, the PORVs reclose to preclude excessive loss of Reactor Coolant System inventory. However, if either or both PORVs do not reclose the operator has the capability of terminating flow through the valve(s) by closing the block valve(s).

4.0 ANALYSIS ASSUMPTIONS

The following assumptions were made in performing the reliability analysis:

1. PORV loss of coolant incident is defined as the inability to terminate flow through both PORVs to preclude excessive loss of Reactor Coolant System inventory.

2. At the actuation of the PORVs, the operator's normal stress level changes to a level intermediate between normal and severe stress (average of normal and severe stress levels).

3. Both PORVs have identical setpoint.

4. Failed components are not repaired during this SFE.

5. High pressurizer pressure condition exists at the actuation of the PORVs.

6. The reactor is at power prior to actuation of the actuation of the PORVs.

7. The component availability data for PORV loss of coolant incident which was used is given in Table A-1.

5.0 RESULTS

The fault tree logic diagram for power operated relief valve (PORV) loss of coolant incident is shown in Figure A-2. The minimal cutsets consist of at least three components. Therefore, all three component events must occur in order for a PORV loss of coolant incident to occur.

Best estimate recurrence frequencies for the PORV loss of coolant incident were calculated for the following cases:

1. Turbine runback feature and no operator action
2. Without turbine runback feature and no operator action
3. Without turbine runback feature and with operator action
4. Without turbine runback feature and with automatic closure of block valve
5. Without turbine runback feature and with automatic closure of series redundant block valves

The results are shown in Table A-2. Cases 4 and 5 assumed potential improvements to the current plant design.

6.0 LIST OF REFERENCES

Fault Tree Title: PORV LOSS OF COOLANT INCIDENT

Ref. No.	Description
1.	User's Manual and Output Guide for C-E Reliability Evaluation Code (CEREC), Rev. 1, W.S. Chow.
2.	Combustion Engineering Interim Data Base - Failure Rates for Nuclear Power Plant Components, D.J. Finnicum.
3.	IEEE STD500-1977, IEEE Guide to the Collection and Presentation of Electrical, Electronic, and Sensing Component Reliability for Nuclear Power Generating Stations.
4.	WASH 1400 (NUREG-75/014) Reactor Safety Study, An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, Appendices III and IV, (Tables III-2-1 and III-6-1).
5.	Combustion Engiheering Reliability Data System, Initiating Event Report (1-1-61 to 12-31-77), R.G. Sider.
6.	NPRDS 1977 Annual Reports of Cumulative ystem and Component Reliability, September, 1978.
7.	St. Lucie II SAR, Section(s) 5.5.12
8.	Post-TMI Evaluation Task 3 Follow-up Report, Pressurizer Systems and Emergency Power Supplies, Combustion Engineering, November, 1980.
9.	NUREG-0560, Staff Report on the Generic Assessment of Feedwater Transients in PWRs Designed by Babcock & Wilcox Company, U.S. NRC, May, 1979.
Drawings	St. Lucie II, Sequence of Events Auxiliary Diagrams St. Lucie II, Reactor Coolant System P&I Diagram, E-13172-310-109, Rev. 03

TABLE A-1

COMPONENT AVAILABILITY DATA

FOR

PORV LOSS OF COOLANT INCIDENT

Component Identification	Description	Code	Frequency (1/yr.)	Ref.	Demand Failure Rate	Ref.
Power Operated Relief Valve	Opens on Demand (With Turbine Runback)	PORV100D	6.60E-01	8		
		PORV200D	6.60E-01	8		
	Opens on Demand (Without Turbine Runback)	PORV100D	2.78E-01	8		
		PORV200D	2.78E-01	8		
	Opens Spuriously	PORV10S	2.80E-03	*		
		PORV20S	2.80E-03	*		
	Fails to Reclose	PORV1FTR			2.00E-02	9
		PORV2FTR			2.00E-02	9
Block Valve IA	Mech. Malf.	BVIAMM			6.59E-05	2
	Valve Motor Fails	BVIAMT			2.02E-04	2
	Valve Breaker Fails to close	BVIABR			1.00E-06	3
	Automatic Signal not Received	BVIAAS			1.20E-02	4
	Operator Fails to Close Valve	BV14030P			1.55E-01	**
Block Valve IIA	Mech. Malf.	BVIIAMM			6.59E-05	2
	Valve Motor Fails	BVIIAMT			2.02E-04	2
	Valve Breaker Fails to close	BVIIABR			1.00E-06	3
	Automatic Signal not Received	BVIIAAS			1.20E-02	4
	Operator Fails to Close Valve	BV14050P			1.55E-01	**

TABLE A-1 (continued)
COMPONENT AVAILABILITY DATA
FOR
PORV LOSS OF COOLANT INCIDENT

Component Identification	Description	Code	Frequency (1/yr.)	Ref.	Demand Failure Rate	Ref.
Block Valve IB	Mech. Malf.	BVIBMM			6.59E-05	2
	Valve Motor Fails	BVIBMT			2.02E-04	2
	Valve Breaker Fails to Close	BVIBBR			1.00E-06	3
	Automatic Signal not Received	BVIBAS			1.20E-02	4
Block Valve IIB	Mech. Malf.	BVIIBMM			6.59E-05	2
	Valve Motor Fails	BVIIBMT			2.02E-04	2
	Valve Breaker Fails to Close	BVIIBBR			1.00E-06	3
	Automatic Signal not Received	BVIIBAS			1.20E-02	4

* Best Estimate Using 246.2 Possible Reactor Years

** Values Were Obtained from Data in Ref. 4

Table A-2

Recurrence Frequencies for PORV Loss of Coolant Incident

CASE NO.	DESCRIPTION	FREQUENCY (1/YR.)
1	Turbine runback feature and no operator action	2.6E-02
2	Without turbine runback feature and no operator action	1.1E-02
3	Without turbine runback feature and with operator action	1.8E-03
4	Without turbine runback feature and with automatic closure of block valve	1.4E-04
5	Without turbine runback feature and with automatic closure of series redundant block valves	1.7E-06

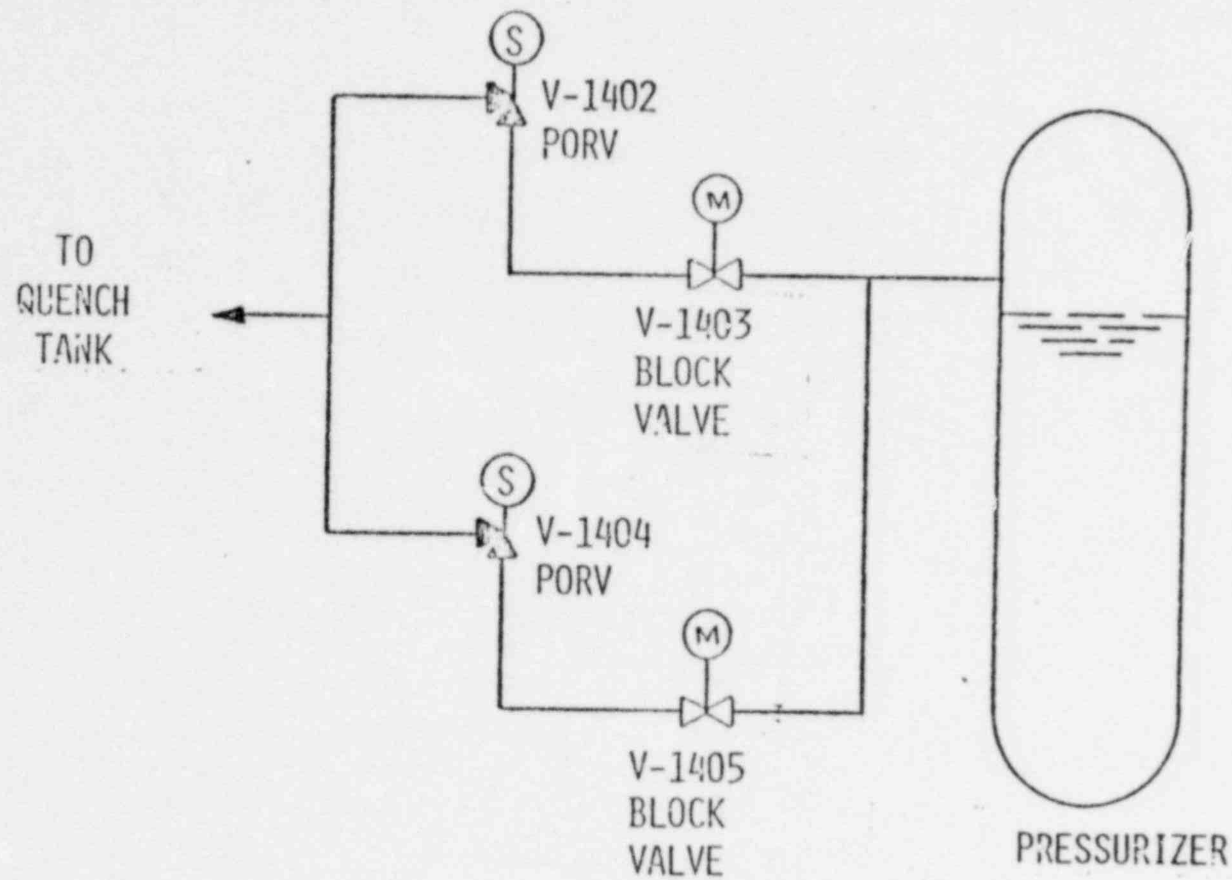


FIGURE A-1
POWER OPERATED RELIEF VALVE
SCHEMATIC

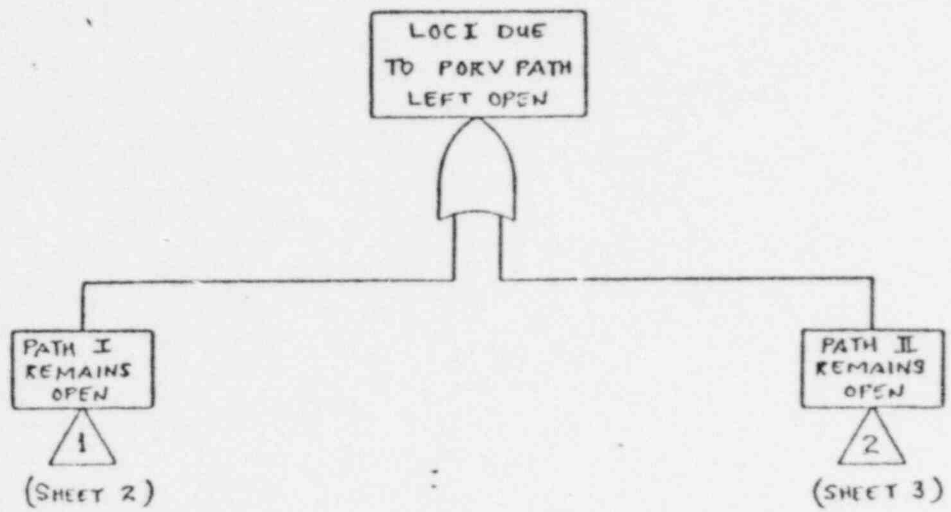


Figure A-2

Fault Tree Logic Diagram for

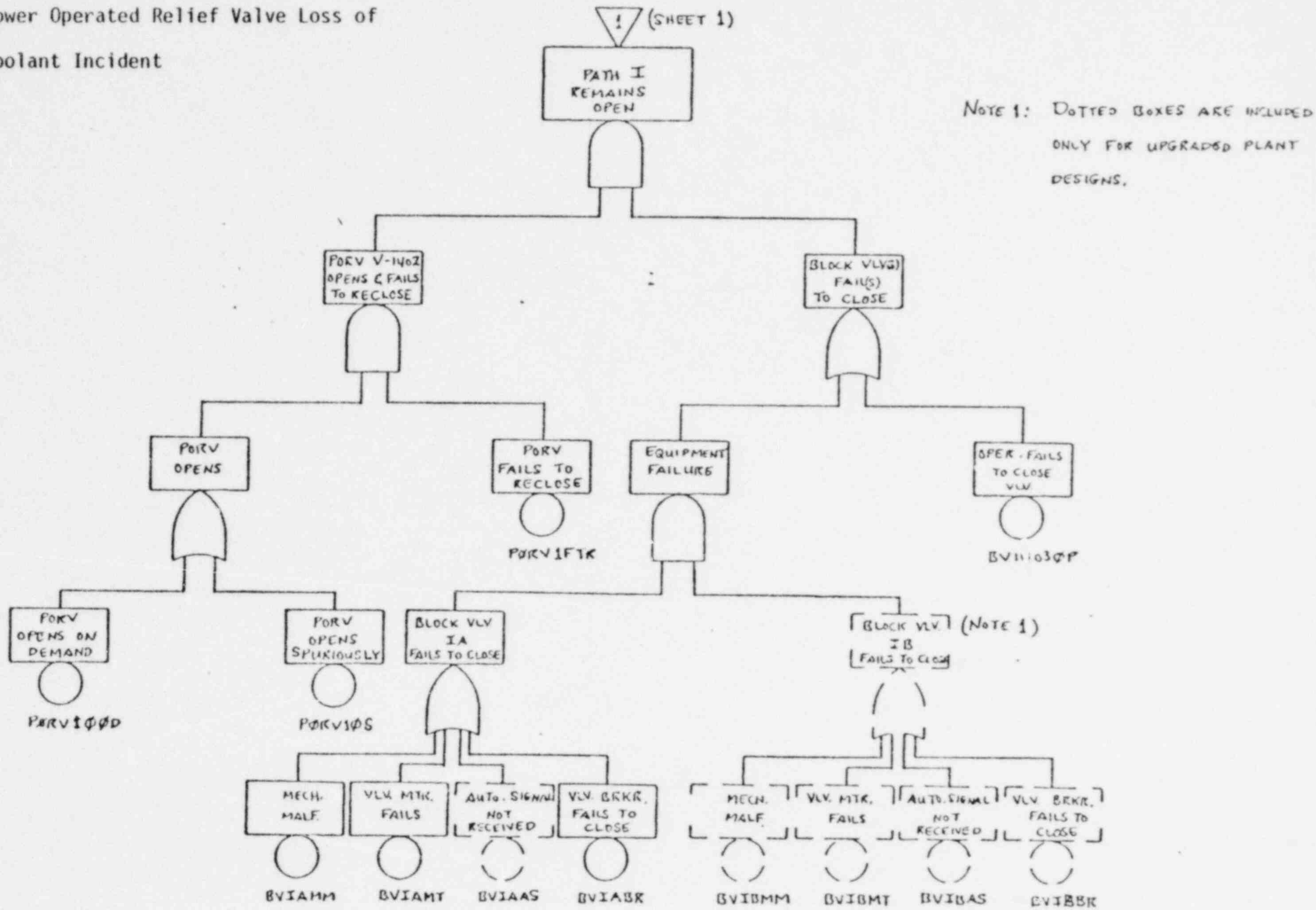
Power Operated Relief Valve Loss of

Coolant Incident

Fault Tree Logic Diagram for

Power Operated Relief Valve Loss of

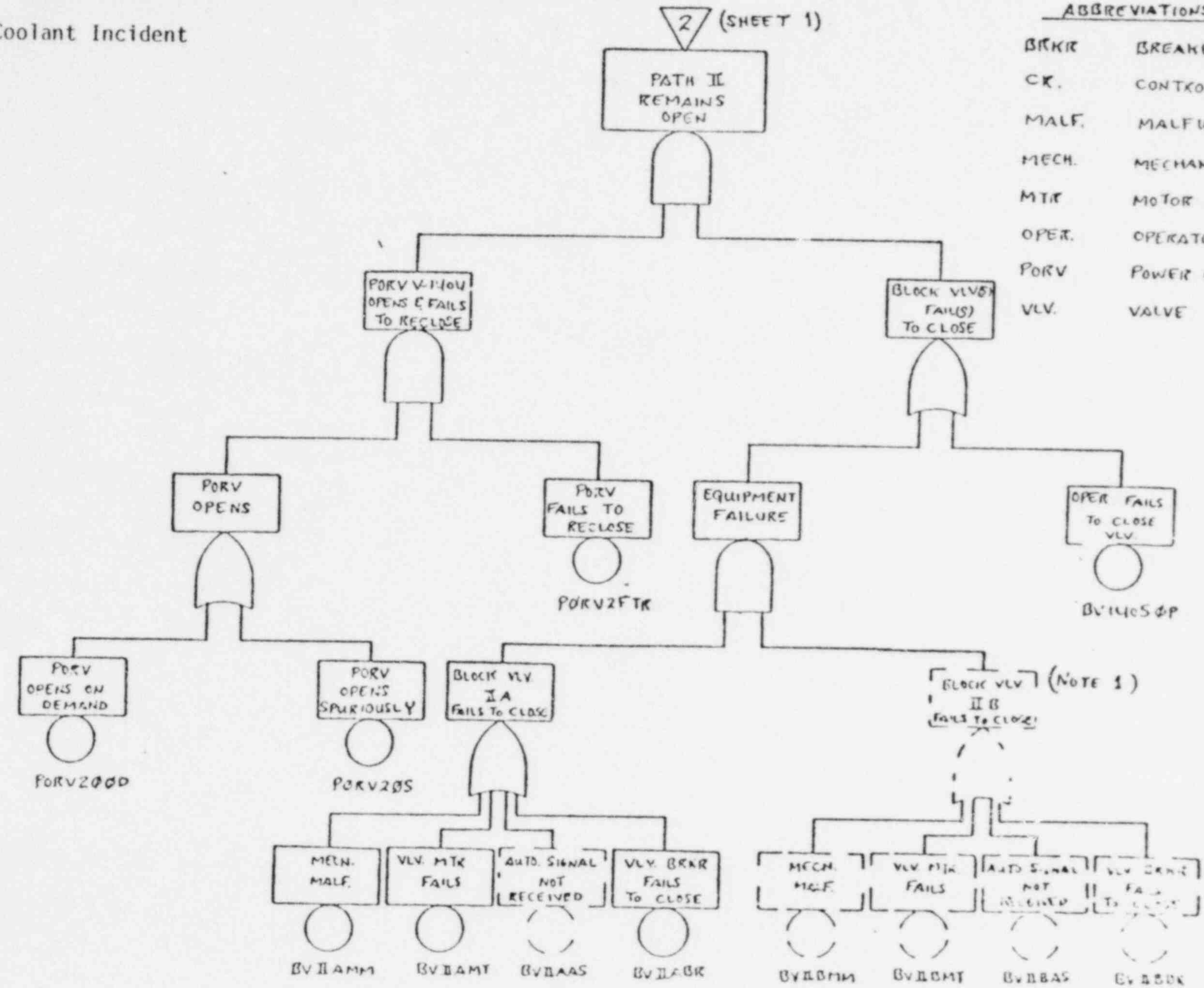
Coolant Incident



Fault Tree Logic Diagram for

Power Operted Relief Valve Loss of

Coolant Incident



ABBREVIATIONS

BRKR	BREAKER
CR.	CONTROL ROOM
MALF.	MALFUNCTION
MECH.	MECHANICAL
MTR	MOTOR
OPER.	OPERATOR
PORV	POWER OPERATED RELIEF VALVE
VLV.	VALVE

Figure A-2