NUREG/CR-4692
ORNL/NOAC-233

Rm

ornl

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

Operating Experience Review of Failures of Power Operated Relief Valves and Block Valves in Nuclear Power Plants

G. A. Murphy
J. W. Cletcher II

Prepared for the
U.S. Nuclear Regulatory Commission
Division of Engineering Technology
under Interagency Agreement DOE 40-544-75

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Available from

Superintendent of Documents
U.S. Government Printing Office
Post Office Box 37082
Washington, D.C. 20013-7982

and

National Technical Information Service
Springfield, VA 22161

NUREG/CR-4692
ORNL/NOAC-233
Dist. Category AN, RM

Engineering Technology Division
Nuclear Operations Analysis Center

OPERATING EXPERIENCE REVIEW OF FAILURES OF POWER OPERATED RELIEF VALVES AND BLOCK VALVES IN NUCLEAR POWER PLANTS

G. A. Murphy
J. W. Cletcher II*

*Professional Analysis, Incorporated

Manuscript Completed — September 9, 1987
Date of Issue — October 1987

Prepared for the
U.S. Nuclear Regulatory Commission
Division of Engineering Technology
under Interagency Agreement DOE 40-544-75

NRC FIN No. B0828

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

CONTENTS

FOREWORD

The Nuclear Operations Analysis Center (NOAC) has supported the Oak Ridge National Laboratory Nuclear Plant Aging Research Program (NPAR) for the past 4 years. The first major report of that program, *Survey of Operating Experience From LERs to Identify Aging Trends* (NUREG/CR-3543) was prepared by NOAC in 1983 and formally published in January 1984. Since that time, NOAC has contributed to several other documents for the NPAR Program, including reports on motor-operated valves, check valves, auxiliary feedwater pumps, and other nuclear plant components.

The present document reports the results of a survey of operating experience with power-operated relief valves (PORVs). It includes an analysis of reported events of PORV failures, interview responses of four PORV manufacturers, and conclusions concerning PORVs designated as safety-related components.

NOAC has designed and developed a number of major data bases that it operates and maintains for the Nuclear Regulatory Commission. These data bases collect diverse types of information on nuclear power plants from the construction phase through routine and off-normal operation. These data bases make extensive use of plant-operator-submitted reports, such as the Licensee Event Reports.

NOAC also publishes staff studies and bibliographies, disseminates monthly nuclear power plant operating event reports, and prepares the Technical Progress Review Journal *Nuclear Safety*.

Joel R. Buchanan, Director
Nuclear Operations Analysis Center
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37831
615-574-0377 (FTS: 624-0377)

LIST OF ACRONYMS

B&W	Babcock & Wilcox
BV	block valve
BWR	boiling water reactor
CE	Combustion Engineering
DET/RES	Division of Engineering Technology/Office of Research
DOE	Department of Energy
EPRI	Electric Power Research Institute
INPO	Institute for Nuclear Power Operations
IPRDS	In-Plant Reliability Data System
LER	Licensee Event Report
LTOP	Low-temperature overpressure protection
MOV	motor-operated valve
NOAC	Nuclear Operations Analysis Center
NPAR	Nuclear Plant Aging Research (Program)
NPE	Nuclear Power Experience
NPRDS	Nuclear Plant Reliability Data System
NSSS	Nuclear Steam Supply System
POP	primary overpressure protection
POPS	primary overpressure protection system
PORV	power-operated relief valve
PSV	pressurizer safety valve
PWR	pressurized water reactor
RCS	reactor coolant system
RECON	REmote CONsole
SCSS	Sequence Coding and Search System
TMI	Three Mile Island
W	Westinghouse
10 CFR 21	Title 10 *Code of Federal Regulations* Part 21
I&C	Instrumentation and Control

OPERATING EXPERIENCE REVIEW OF FAILURES OF POWER-OPERATED RELIEF VALVES AND BLOCK VALVES IN NUCLEAR POWER PLANTS

G. A. Murphy J. W. Cletcher II*

ABSTRACT

This report contains a review of nuclear power plant operating events involving failures of power-operated relief valves (PORVs) and associated block valves (BVs). Of the 230 events identified, 101 involved PORV mechanical failure, 91 were attributable to PORV control failure, 6 events involved design or fabrication of the PORVs, and 32 events involved BV failures. The report contains a compilation of the PORV and BV failure events, including failure cause and severity. The events are identified as to plant and valve manufacturer. An assessment of the need to upgrade PORVs and BVs to safety-grade status concludes that such action would improve PORV and BV reliability. The greatest improvement in reliability would result from using newer, more reliable PORV designs and improving testing, diagnostics, and maintenance applied to PORVs and BVs, particularly the BV motor operator. A summary of interviews conducted with four PORV manufacturers is also included in the report.

1. INTRODUCTION

This report was prepared by the Nuclear Operations Analysis Center (NOAC) in response to a request from the Nuclear Regulatory Commission (NRC) Division of Engineering Technology (DET)[1] for a survey of power-operated relief valve (PORV) and block valve (BV) operating experience. The information is provided under the Nuclear Plant Aging Research (NPAR) Program to support the resolution of Generic Issue 70 (GI-70) "PORV and Block Valve Reliability."

PORVs are valves that require an external power supply (normally air and/or electric) for actuation and are typically controlled by an electrical signal resulting from high system pressure or by manual actuation from the control room.

This report contains a compilation and review of operating events involving PORVs and their associated BVs in pressurized-water reactor (PWR) nuclear power plants. Most of the event descriptions were obtained from Licensee Events Reports (LERs) contained in the NOAC file on the Department of Energy (DOE) RECON data base (pre-1981) and the

*Professional Analysis, Incorporated.

Sequence Coding and Search System (SCSS) data base (post-1981). Additional information on selected events was obtained from the Institute for Nuclear Power Operations (INPO) Nuclear Plant Reliability Data System (NPRDS), the NRC Foreign Event File at NOAC, Nuclear Power Experience (NPE) reports, and other relevant reports.

Four PORV manufacturers were interviewed to obtain their response regarding selected questions of interest to the NRC. A summary of the manufacturers' responses is contained in Appendix D.

2. PURPOSE

The purpose of this study was to survey nuclear plant operating experience for PORV and BV failure events in support of the resolution of GI-70. Neither PORVs nor BVs have been shown by safety analysis to be needed for safe shutdown of the plant or to mitigate the consequences of an accident. However, NRC has recently determined that PORVs are, in fact, relied upon to mitigate certain design-basis accidents. The acceptability of relying on non-safety-grade PORVs to mitigate a design-basis accident is presently the subject of NRC Generic Issue 70: "PORV and Block Valve Reliability."

3. SCOPE

This report reviewed events reported from 1971 to mid-1986. The earliest PORV failure event found in the search occurred in 1971. However, because LER reporting requirements were upgraded in 1976, more complete information is available for later events, especially those coded into the LER SCSS data base (1980 to present).

Note that because PORVs are not classified as safety related, their failures were not always reported, especially in earlier years (before 1979) (see Fig. 1). Consequently, PORV failures may have been more prevalent than indicated. However, after the Three Mile Island Unit 2 (TMI-2) accident, increased sensitivity to PORV (and BV) operability problems probably led to increased reporting of such events. Nonetheless, a revised LER reporting rule, which went into effect Jan. 1, 1984, did not specifically require reporting of all PORV or BV failures; hence, the number of LER-reported failures of these components has decreased sharply from post-TMI levels. In both cases, the actual number of PORV and BV failures may actually be higher than shown on Fig. 1. One purpose of the new LER rule was to shift reporting of single failures to the INPO NPRDS system. In time, NPRDS should have better PORV failure data, provided that the utilities accurately and consistently report such failures.

ORNL-DWG 87-4168 ETD

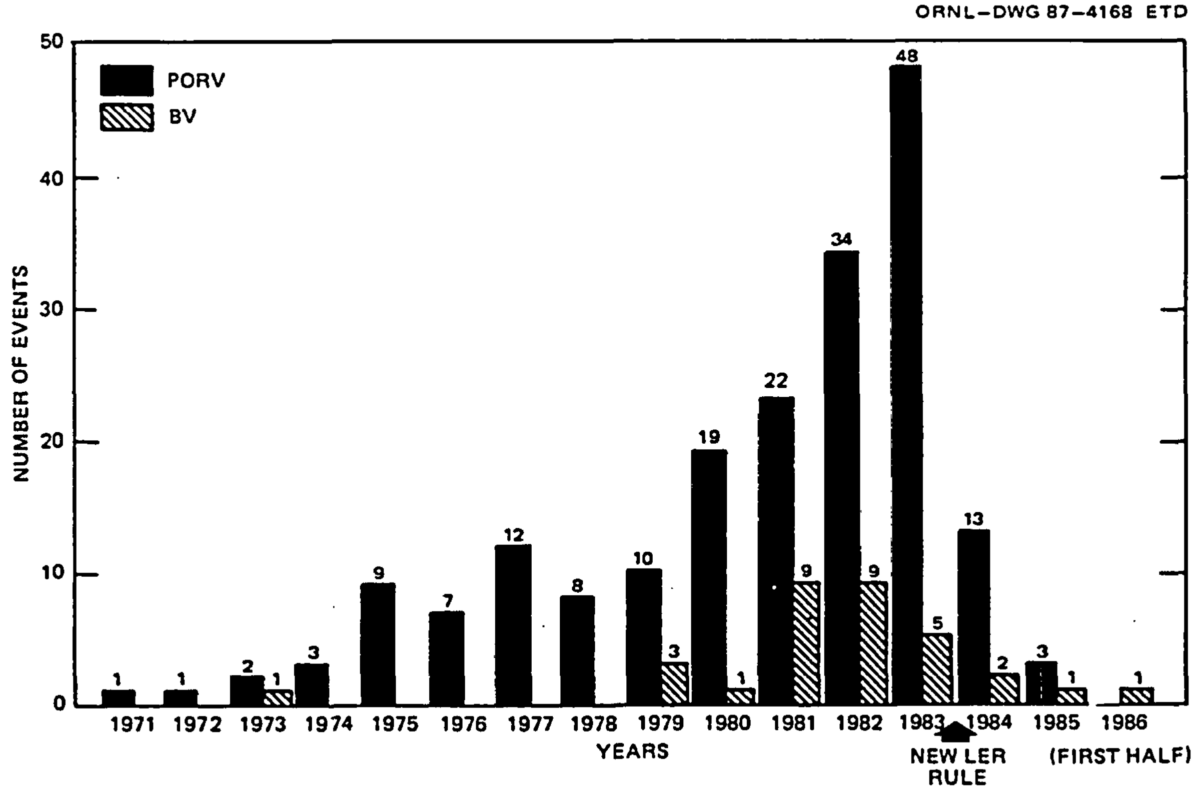


Fig. 1. Reported PORV failure events 1971—1986

Computer searching of the NOAC/RECON and SCSS LER data bases yielded 548 event descriptions; the NPE data base provided 202 event descriptions; and the INPO NPRDS provided 78 event descriptions. In addition, several reports that addressed PORV failures were reviewed to gather information leading to identification of other PORV failure events — both reported and unreported (formally). Appendix A contains a list of the computer data bases that were searched and a description of the search strategy applied to each one. In many cases, an event reported in an LER was also contained in NPE, NPRDS, or other reports. In addition, NPE and NPRDS were searched independently for PORV and BV failures. Those found were also added to the data base for this report (and correlated with an LER if one was filed).

All the events collected were reviewed and screened for cases that involved actual failures of PORVs, BVs, or the associated control systems. A total of 230 events were identified; some events are duplicated because they involved a failure of both the PORV and its control system. These events are contained in Tables 1–8 in Appendix B. Events that included successful actuation and reseating of PORVs or BVs in the course of a plant transient or test evolution are not included in this report.

4. STYLES OF PORVs

Two styles of PORVs are in general use in domestic PWRs — the pilot-operated relief valve and the air-operated (spring-closure) valve.

4.1 Pilot-Operated Relief Valves)

Manufacturers: Crosby Valve and Gage Company
Dresser Industries
Garrett Corporation*
Target Rock Corporation

The pilot-operated relief valve consists of a main valve with piston- or diaphragm-operated disk and a pilot (Figs. 2—5). Under normal operating conditions, the pilot allows system pressure into the piston chamber. Because the piston area is greater than the disk seat area, the disk is held closed. When the set pressure is reached, the pilot is actuated to vent the piston chamber, which allows the disk to open. Some valve designs also shut off system fluid to the piston chamber.

The Target Rock PORVs are normally installed with system pressure over the disk. The system fluid fills a cavity above the main disk and in the bonnet tube. When the solenoid coil is energized, the resulting electromagnetic force lifts the movable core together with the stem and pilot disk, uncovering a pilot port and exhausting the fluid into the outlet nozzle. This creates a low-pressure area above the main disk that is sustained as long as the pilot valve remains open. The higher inlet pressure acts on the unbalanced area of the main disk to provide the opening force.

Target Rock PORVs have been provided to Tennessee Valley Authority (TVA) for replacement of present PORVs at Bellefonte, Sequoyah, and Watts Bar Nuclear Plants.

4.2 Air-Operated (Spring-Closure) Relief Valves

Manufacturers: Control Components, Inc.
Copes Vulcan
Fisher Controls Company
Masoneilan
MUESCO Controls, Inc.

The air-operated (spring-closure) style of PORV (Figs. 6 and 7) utilizes a large compression spring to provide seating force to the

*The Garrett PORV product line was acquired by Crosby in 1984.

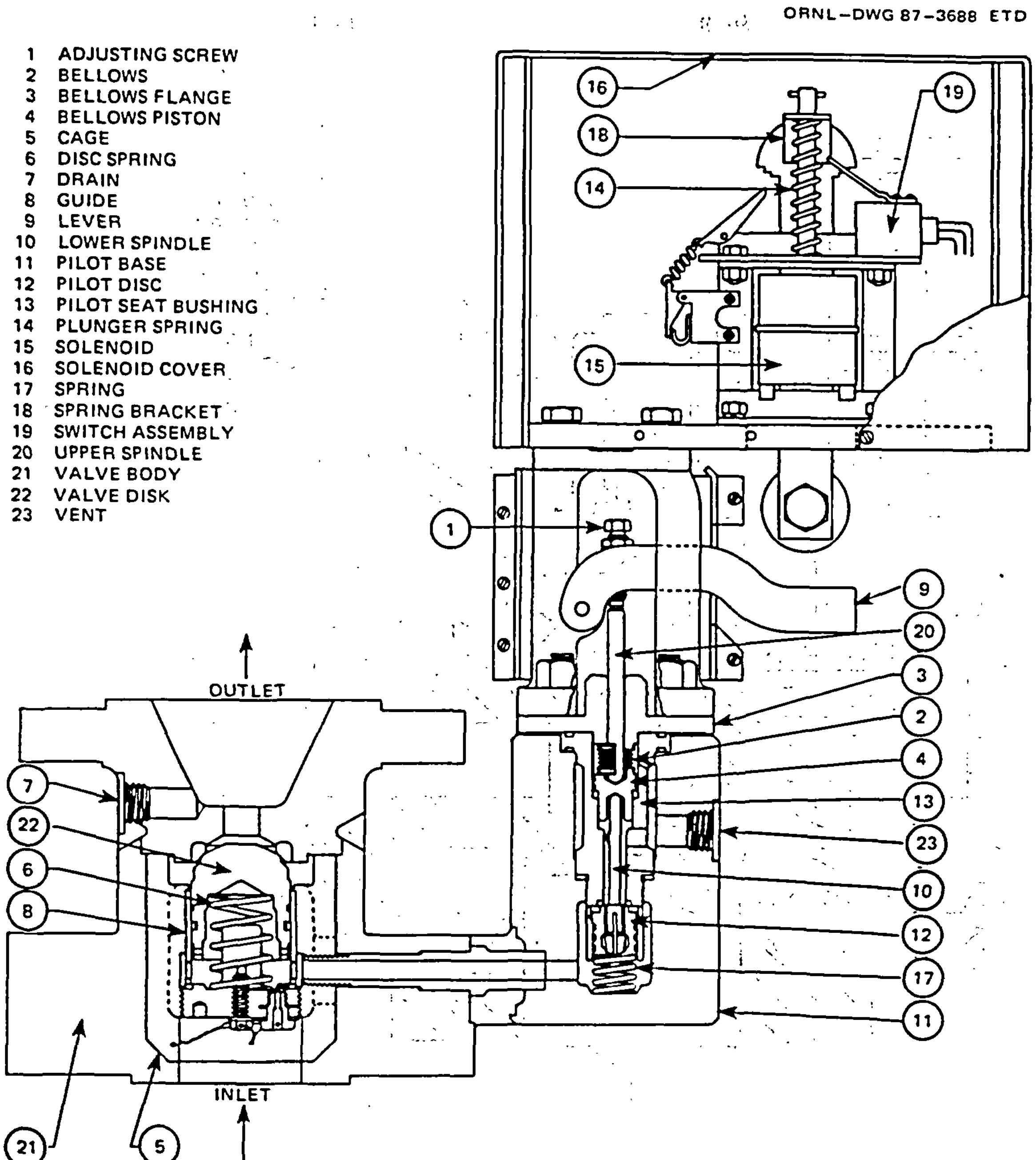


Fig. 2. Pilot-operated relief valve (Courtesy of Dresser Industries)

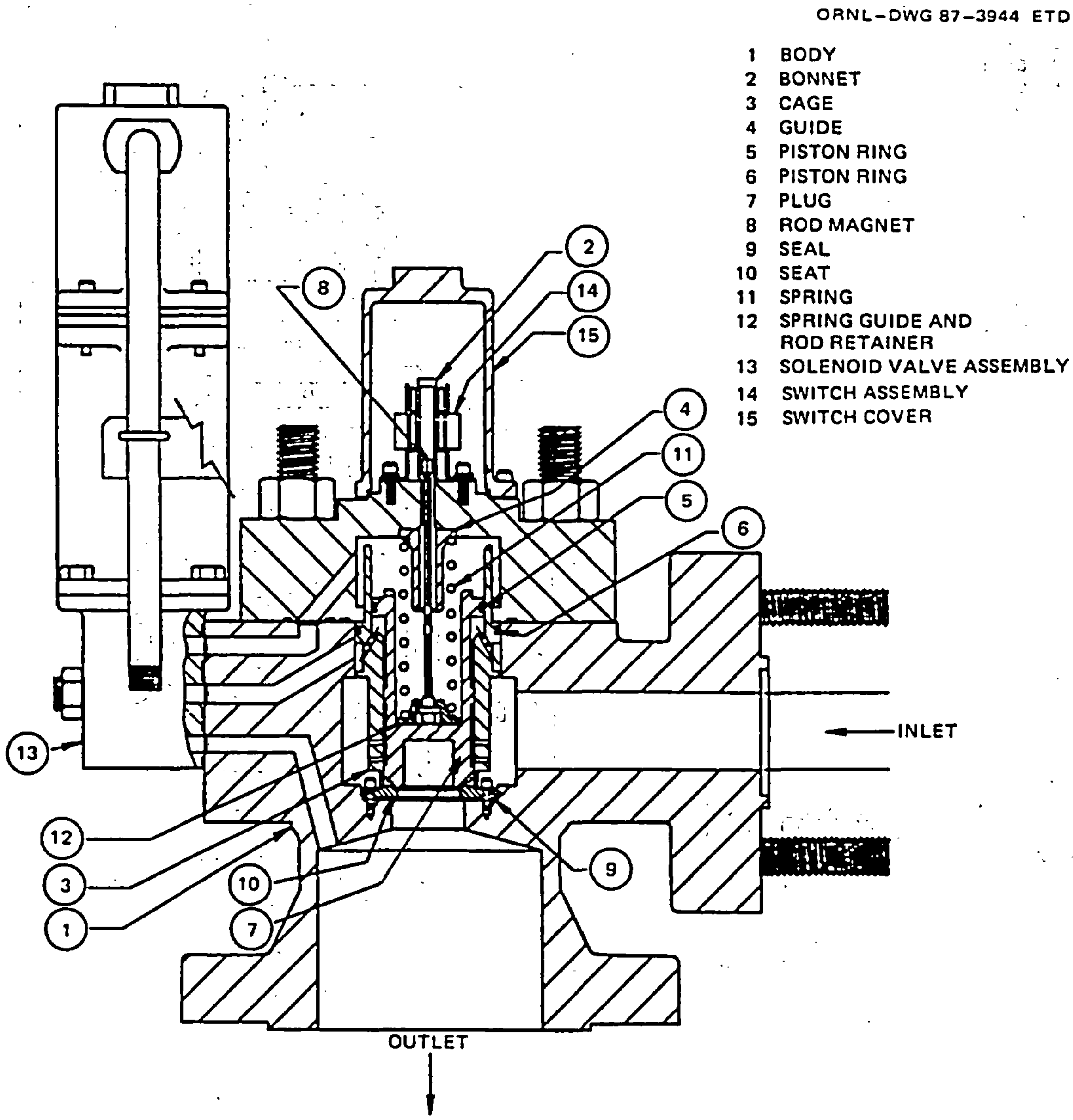


Fig. 3. Pilot-operated relief valve (Courtesy of Crosby Valve and Gage Company)

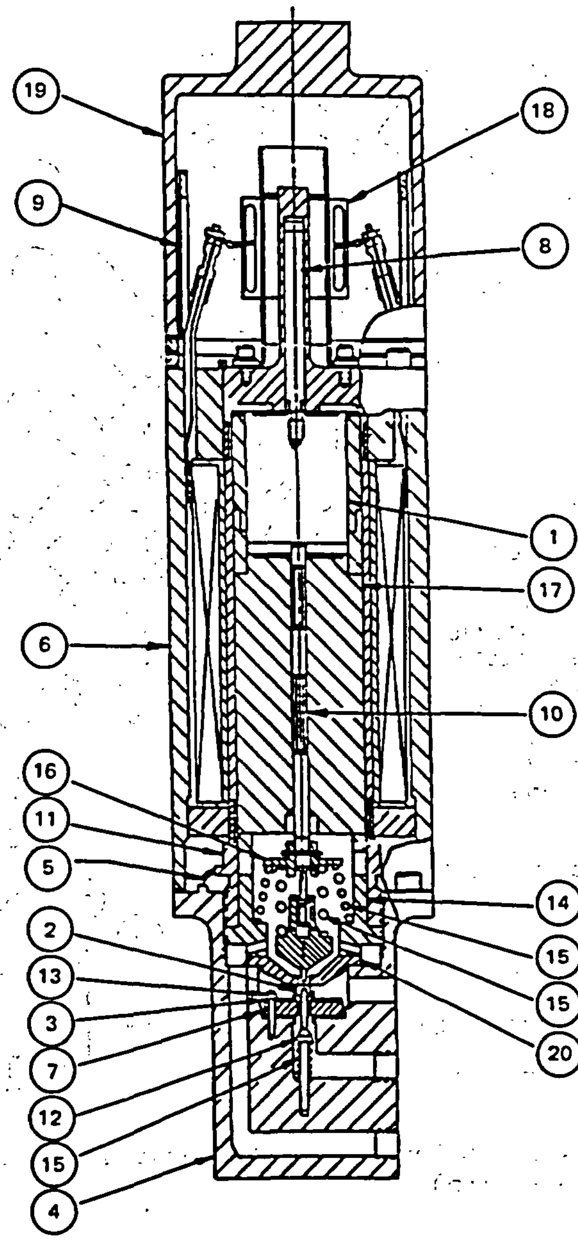


Fig. 4. Solenoid valve assembly for Crosby PORV — part No. 13 on Fig. 3 (Courtesy of Crosby Valve and Gage Company)

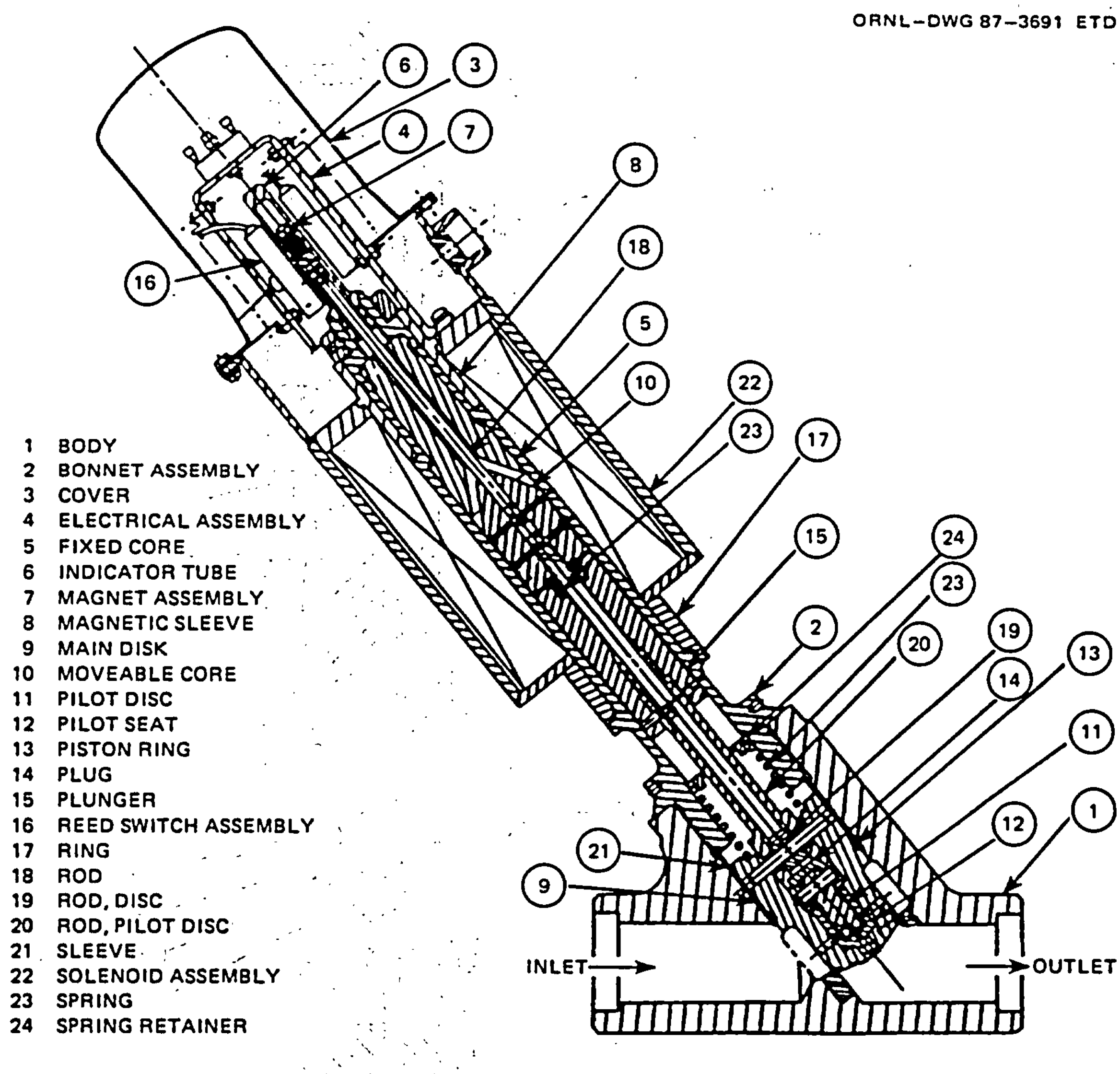


Fig. 5. Solenoid pilot-operated relief valve (Courtesy of Target Rock Corporation)

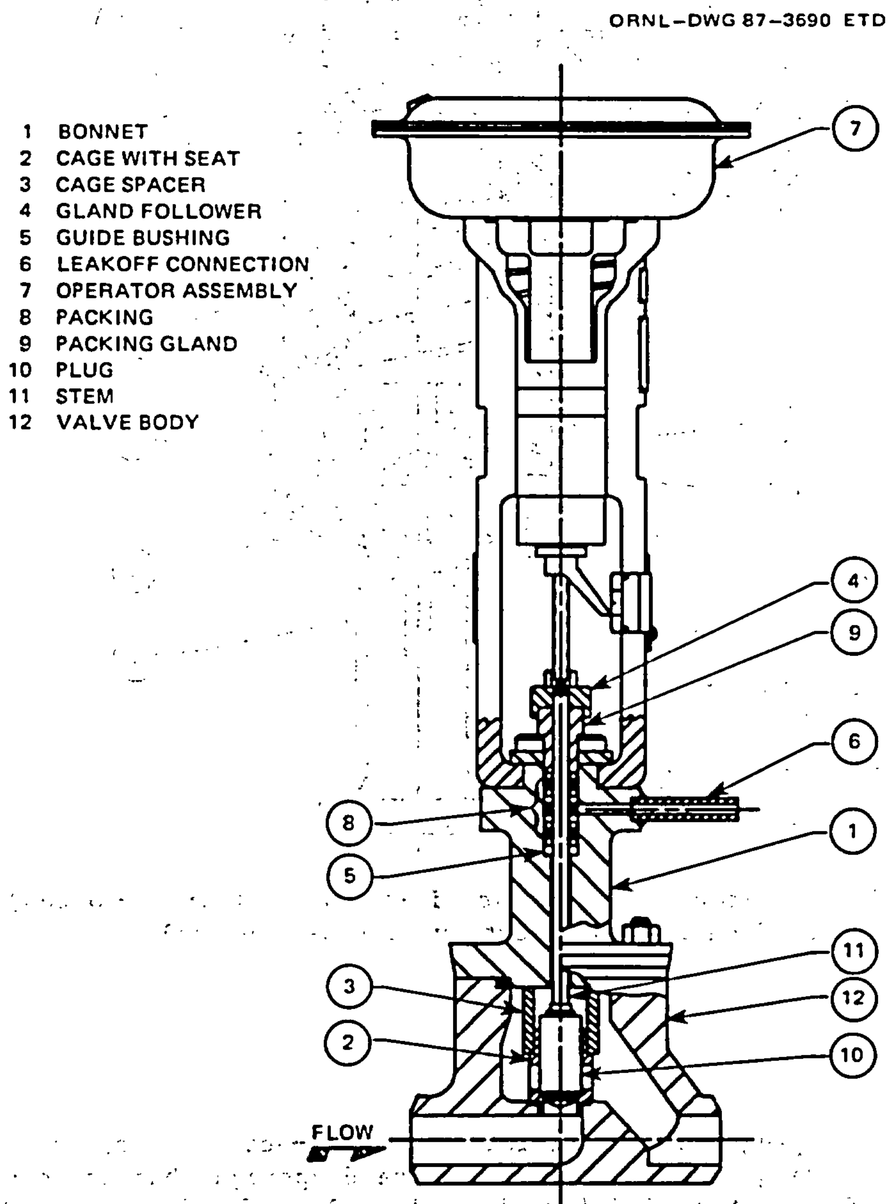
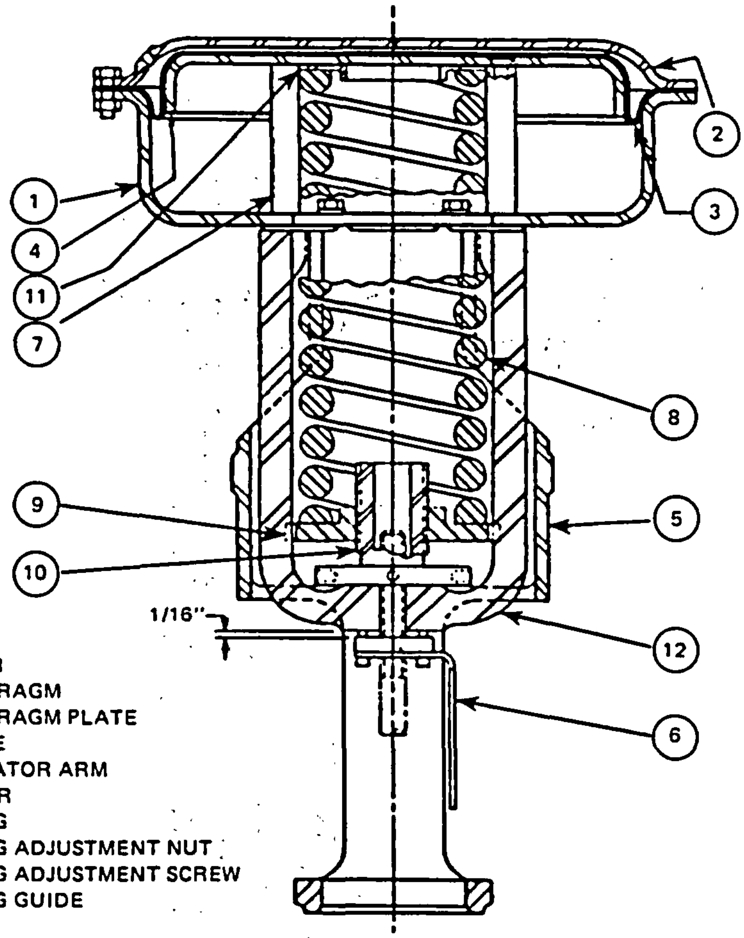


Fig. 6. Air-operated (spring-loaded) relief valve (Courtesy of Copes-Vulcan)

ORNL-DWG 87-3689 ETD



1 BASE
2 COVER
3 DIAPHRAGM
4 DIAPHRAGM PLATE
5 FRAME
6 INDICATOR ARM
7 SPACER
8 SPRING
9 SPRING ADJUSTMENT NUT
10 SPRING ADJUSTMENT SCREW
11 SPRING GUIDE
12 YOKE

Fig. 7. Operator assembly for air-operated (spring-loaded) relief valve — part No. 7 on Fig. 6 (Courtesy of Copes-Vulcan)

valve stem and plug with an air-loaded reverse-acting operator attached. To open the valve, air pressure loads the diaphragm chamber to overcome the spring force, thus lifting the valve plug off the seat. Positive closure is provided by the spring return upon venting the air pressure from the diaphragm chamber. The Control Components, Inc., PORV differs in that air pressure provides both the valve opening and closing forces with a compression spring providing a backup closing force.

Detailed descriptions of each manufacturer's valve may be found in Ref. 2.

5. FAILURE RATES OF PORVS AND BLOCK VALVES

Because of the historically inconsistent reporting of PORV and BV failures, no meaningful failure rates for these devices could be calculated from the data collected for this report. However, two reports that contain an analysis of PORV and BV reliability were reviewed. A summary of the findings from each report follows.

5.1 "Estimating Failure-to-Close Probabilities for Pressurizer Valves," W. W. Weaver, Babcock & Wilcox, Nuclear Power Generation Division (Ref. 3)

Three categories of valves were considered in this study for failure to close: (1) motor-operated valves (MOVs), 2 to 4 in. in diameter; (2) PORVs; and (3) pressurizer safety valves (PSVs). For each category a Bayesian approach was employed to estimate failure-to-close probabilities incorporating previously unreported data. The resultant values differ from other published sources of data, such as *WASH-1400* and NPRDS. For PORVs of the type in use at Babcock & Wilcox (B&W) and Combustion Engineering (CE) plants, Weaver calculated a mean value of 9.8×10^{-3} (total number of failures/total number of demands). The report also mentions an unnamed different type of PORV* that was being considered for use in the larger [205 fuel assembly (FA)] B&W units. This new valve has accumulated ~25,000 cycles without failure as a pressurizer spray valve, which is a different environment from a PORV application. Pressurizer spray is actually more stressful to the valve internals than a PORV application; however, the intermittent operation of a PORV would appear to induce a higher chance of failure than the regular demand (e.g., typically eight per day) of the spray valve application. For the new valve, a failure distribution with a mean of 4×10^{-4} per demand was calculated.

---

*The unnamed valve alluded to is a Target Rock—supplied solenoid-operated pressurizer spray valve. These valves were supplied to Oconee 1, 2, and 3 and have been in operation since 1976. Prior to installation, a 100,000-cycle test was conducted by the Nuclear Steam System (NSS) supplier (B&W) at 225°F ambient temperature, 2200 psi, with fluid temperature at 600°F. At Oconee, it was reported that the valves have not required a single incidence of maintenance.

Weaver's report states that the pressurizer spray valve duty cycle is "actually more stressful to the valve internals than a PORV application." This is true in the case of an air- or motor-operated valve with stem packing, but not for the Target Rock solenoid valve. This valve has no packing and as such does not require a stem to be driven through pressure-loaded packing, which can quickly start leaking under this service. Target Rock states that because the ΔP in a pressurizer spray application is relatively low, their solenoid valve has a slow, gentle action, taking about 3.5 s to open and 4 s to close. For the valve tested by B&W, Target Rock states that the gentle burnishing action of disc to seat contact resulted in valve leakage improving to 1/10 of the initial value after 100,000 cycles.

The MOV data is based on NUREG/CR-1363 (Ref. 4) and RADCAS (Ref. 5). A value of 8.1×10^{-4} for failure to close per demand was calculated from the tables in Ref. 4, which was used in a Bayesian analysis of RADCAS data of 34 failures in 1433 demands.

The table below summarizes the values obtained for the MOV failure to reclose:

Prior		Evidence	Posterior		
Mean	Range factor		5th percentile	Mean	95th percentile
8.1×10^{-4}	3	34/1433	1.33×10^{-2}	1.85×10^{-2}	2.46×10^{-2}
8.1×10^{-4}	10	34/1433	1.63×10^{-2}	2.22×10^{-2}	2.98×10^{-2}

5.2 The In-Plant Reliability Data Base (IPRDS) for Nuclear Plant Components: Interim Report — The Valve Component (Ref. 6)

The IPRDS is a data base developed primarily from in-plant records of maintenance actions. These records were obtained directly from selected nuclear plant maintenance files. Data were collected from two PWRs, which included PORVs and pressurizer MOVs. A preliminary compilation of reliability for 26 PWR safety system MOVs yielded, for 10 failures, a mean failure rate to operate on demand of 6.4×10^{-3}.

A summary of the valve failures for PORVs and MOVs for Plants 1 and 2 is shown in Table 5.1 below.

Failure and repair descriptions for PORVs and pressurizer MOVs from Plant 1 and Plant 2 are shown in Tables 5.2 and 5.3.

Table 5.1 Summary of valve failure

	Plant 1		Plant 2	
	PORV	MOV	PORV	MOV
Valve seat leakage[a]	10	2	3	3
Limit[b] switch	3	0	0	0
Air/regulator leak	4	0	0	0
Operator failure	2	0	0	0
Failed to reset	0	0	1	0
Lifted prematurely		0	1	0
Solenoid failure	0	0	1	0
Other	1	0	0	4
TOTAL	20	2	6	7

[a]The amount of valve seat leakage was not given in the maintenance records.

[b]Position indication.

Table 5.2. IPRDS Plant 1

Valve	Failure description	Repair description
PORV-1	Valve leaks	Replaced gasket and lapped seat
PORV-1	Excessive leakage	Beveled and lapped seat — replaced gasket
PORV-1	Leaking	Polished both seats and replaced gasket
PORV-1	During test, cycled once but not twice	Installed gaskets and one screen
PORV-1	Regulators leak	Renew gaskets and gages
PORV-1	Limit[a] switches need adjustment	Adjusted limit[a] switches
PORV-1	Valve leaks through	Adjusted spring tension
PORV-1	Leaks through	Loosened lock and adjusted valve
PORV-1	Air leak in inlet to PORV nipple	Installed solenoid, tested
PORV-1	(No documentation)	Changed diaphragm
PORV-2	Leaks slightly	No leaks at normal pressure
PORV-2	Leaks by	Machined seat, straightened
PORV-2	High-temperature alarm in-indicating seat leakage	Replaced stem and flex gasket
PORV-2	Limit[a] switches require setting	Adjusted limit[a] switches
PORV-2	Regulator leaks	Renewed gaskets and gages
PORV-2	Stem plug and cage assembly removed during shutdown	Machined stem plug face and cage seat; lapped plug and seat
PORV-2	Limit[a] switches out of adjustment	Adjusted upper limit[a] switch
PORV-2	Valve leaks through	Inspected and repaired valve
PORV-2	Diaphragm on operator leaking	Repair as instructed
PORV-2	Air regulator for PORV	Replaced regulator
MOV-1	Small body to bonnet leak	Retorqued and seal welded
MOV-2	Small body to bonnet leak	Retorqued and seal welded

[a]Position indication.

Table 5.3. IPRDS Plant 2

Valve	Failure description	Repair description
PORV-1	Valve opened for preoperation test crew, and it did not reset; incorrect preload tension on valve spring (failure occurred prior to commercial operation date)	Adjusted preload tension on valve spring and functionally checked
PORV-1	PORV-1, -2, 3 lift prematurely (failure occurred prior to commercial operation date)	Found bad solenoid valve on PORV-3; replaced solenoid and calibrated
PORV-1	Valve leaks through; seat and plug wire drawn	Installed new seat and lapped plug; new gaskets, repacked, functionally checked
PORV-2	Valve is leaking by (failure prior to commercial operation date)	Valve not seated; seated valve and stroked to ensure properly seated
PORV-2	Valve leaking by at normal pressure because disk is ruined	Deterioration from service; installed new stem and disc; replaced seat ring gasket and bonnet gasket; replaced packing
PORV-3	Valve failed to open	Solenoid valve no good; replaced solenoid valve
MOV-1	(Not documented)	Retorqued packing gland per procedure
MOV-1	Packing leak	Natural end of packing life; repacked valve
MOV-1	(Not documented)	Valve was jammed shut at clearance point
MOV-1	Packing leak	Natural end of packing life; repacked valve
MOV-2	(Not documented)	Valve was jammed shut at clearance point
MOV-3	Valve wedge jammed in seat; overtorqued by motor operator and by hand to effect isolation for another job	Pulled bonnet and freed wedge; stem reassembled and repacked
MOV-3	Will not open electrically; broken terminal on switch	Broken terminal on benchboard switch repaired

6. RESPONSE TO SPECIFIC QUESTIONS

Task 7 of the NRC NPAR Program Brief FIN NO. B0828 for FY 1985–1986 contained nine questions concerning PORV and BV operating experience. This section of the report addresses those questions.

6.1 How Many PORV/BV Failures Have Occurred?

Because PORV and BV failures were not reportable events, it is not possible to state exactly how many failures have occurred. However, this report surveyed five nuclear plant operating experience data bases, plus several industry reports to compile a list of reported events involving PORV and BV failures. For the period 1971 to July 1986, 192 PORV failure events, 32 BV failure events, and 6 reported design "failure" events were identified. A compilation of these 230 events is contained in Tables 1–8 of Appendix B of this report.

6.2 What Were the Causes of Valve Failures and Type of Plant Where Failures Occurred?

The root cause(s) of PORV or BV failures could not be determined from the information found in the various event reports. However, details from LER and other event descriptions were pieced together to provide information on the proximate cause for most of the failures.

Tables 1–8 of Appendix B contain descriptions of PORV and BV failure events listed by PWR NSSS vendor.

Table 1	B&W PORV events — mechanical failure	(32 events)
Table 2	B&W PORV events — control failure	(10 events)
Table 3	W* PORV events — mechanical failure	(53 events)
Table 4	W PORV events — control failure	(68 events)
Table 5	CE PORV events — mechanical failure	(16 events)
Table 6	CE PORV events — control failure	(13 events)
Table 7	PORV BV events	(32 events)
Table 8	PORV events — design/fabrication failures	(6 events)

There were ten events for which no plant identification was available from the source data base. One event is a Westinghouse (W) PORV control failure, and nine events involve PORV mechanical failures — four at W, four at CE, and one at a B&W plant.

The PORV events for each NSSS vendor are broken down into two general categories:

Mechanical failures — failures of the PORV or its pilot valve/solenoid, if the pilot is an integral part of the PORV. Failures of remotely located pilot solenoid valves were classified as

*W = Westinghouse

control failures (below). Mechanical failures of BVs include the motor operator or valve, but not associated controls or indicators. Control failures — those cases where remote switches, solenoid valves, wiring, relays, accumulators, etc., failed or caused degraded operation or immediate failure of the PORV or BV function.

6.2.1 Failures at B&W plants

About half of the reported mechanical failures of PORVs at B&W plants (Dresser and older Crosby designs) appeared to occur in the main portion of the valve and involved seat leakage, while the rest of the failures originated in the pilot valve portion. The Dresser and Crosby valve designs use steam pressure to open or close the valve via the pilot valve. The pilot valve internals are therefore continuously subjected to reactor coolant system (RCS) heat and pressure, plus the dynamic effects of steam during actuation. The close tolerances and greater number of moving parts exposed to steam in these designs can make them more susceptible to failure than the air-operated (spring-closure) designs. Four out of seven PORV failure-to-close events occurred at B&W plants that used the Dresser or Crosby pilot-operated design:

ANO-1	September 1974 (Dresser)
Davis-Besse	September 1977 and June 1985 (Crosby)
TMI-2	March 1979 (Dresser)

In these cases, the PORV was stuck open. Such occurrences can represent a challenge to plant safety if the PORV BV cannot be closed to isolate the stuck-open PORV.

6.2.2 Failures at W plants

The majority of the reported mechanical failures for air-operated (spring-closure) PORVs involved seat leakage. W units used mostly Copes-Vulcan or Masoneilan designs. The seat/plug/cage interface is the only portion of these designs that is subject to steam temperature and pressure. The external appurtenances such as actuator diaphragm, limit switches, and pilot solenoid valve are normally only exposed to containment atmosphere, which is relatively benign under normal operating conditions.

6.2.3 Failures at CE plants

Seat leakage was also predominant in the reported failures for PORVs in CE plants. Since most CE units have blocked off their PORVs (or do not have any), there are only a few PORV mechanical failures reported for these plants. One interesting event at St. Lucie 2 (Table 5, Appendix B) involved loss of magnetism on the position indication magnets due to high temperature.

6.2.4 Control failures

Reported control failures for PORVs involved loss of power, circuit design errors, controller malfunctions, and degradation or loss of the air/nitrogen actuating pressure. North Anna Units 1 and 2 accounted for a substantial number of reported PORV control problems. Both units were plagued by design problems in the PORV nitrogen supply system. The event descriptions indicate that a design change was to be implemented at a future outage.

6.2.5 PORV BV failures

Table 7 in Appendix B contains a compilation of PORV BV events. Twelve events involved failure of the valve motor operator, mostly torque or limit switch problems. Four events described problems with the valve (mostly packing leaks). Five events involved failures in the controls to the BV operator. PORV BV failures do not appear to occur any more frequently than failures of other MOVs subjected to similar conditions. The valves and motor operators used in PORV BV service are similar to those used for other purposes in the plant. An assessment of MOV service wear and aging is contained in Ref. 7.

6.2.6 Design/fabrication failures

Table 8 in Appendix B contains six events that describe problems that originated in the design phase of valve procurement. These type failures were, until recently, not reportable. Hence, not many events of this type were found. New reporting requirements for deficiencies found during plant construction are now included under 10 CFR Part 21 and 10 CFR Part 50.55(e), the Construction Deficiency Report system. This new system, in use since April 1984, should provide more data on this type event. Reference 8 provides more information on the reporting requirements and describes the Construction Deficiency Report event data base.

6.3 What was the Failure Severity — Degraded or Failed?

Each PORV and BV event collected for the report was judged as to the severity of the failure. The terms chosen for this report are defined as follows:

Degraded: (but operable)	(D)	The component operates at less than its specified performance level.
Failed:	(F)	The component is completely unable to perform its function.

Seventy-six percent of the PORV events attributable to mechanical failure were judged as degraded, that is, the valve was operable but leaking through or the packing leaked. The amount or severity of leakage was not found in the reports. About two-thirds of the PORV control events (67%) were failures — that is, immediate loss of control.

Slightly over half the BV events (53%) were degraded, with the balance (47%) being failures. Five BV failures involved the valve controls. Fifteen BV events were attributable to some failure of the valve, while 12 events involved the motor operator.

A compilation of PORV and BV events as to failure severity is shown below:

Failure severity - PORV and BV events

	Degraded	Failures	Total
PORV mechanical	77	24	101
PORV control	30	61	91
PORV design	6	0	6
BV events	17	15	32
Total	130	100	230

6.4 To What Extent Did Operator or Maintenance Actions Contribute to Valve Failures?

The 230 events compiled for this report were reviewed to determine to what extent operator or maintenance actions could have contributed to the failure. Appendix C contains a summary list of 38 events that were judged to involve some human error.

Ten events specifically identified operator error as a cause, mostly from administrative errors. Twenty-eight events involved maintenance or Instrumentation and Control (I&C) errors. Six of these could be attributed to procedure or drawing error; the remaining 22 appeared to be simply mechanical or electrical miscues — such as shorted leads or misassembled components. Nine events could be attributed to errors in original design, errors in design changes, or other administrative problems.

6.5 Are Certain Designs More Prone to Failure than Others?

A review of the events collected for this report indicates that the Dresser and Crosby pilot-valve designs accounted for about 40% of the PORV mechanical failures. These designs were involved in failures that occurred at all nine B&W plants and four CE plants. (Most CE units have blocked off their PORVs or do not employ them in the design.)

The pilot-operated relief valve has been a contributing factor in all the major B&W transient events, most notably the TMI-2 accident and two events at Davis-Besse (9/77 and 6/85). The close tolerances and greater number of moving parts exposed to steam in these designs can make them more susceptible to failure. Careful selection of materials and proper design for the expected service conditions are necessary. However, a newer design of the Crosby (formerly Garrett) pilot-valve type appears to have better reliability than the original version. Target Rock Corporation has developed a solenoid pilot-operated relief valve (SPORV) that has been extensively tested and is apparently reliable, but no long-term nuclear operating experience has been accumulated on this design.

The pilot-operated relief valve does have several advantages. As the system pressure increases, the force holding the disk in the closed position increases. This allows the system operating pressure to be increased to values within 5% of set pressure without danger of increased seat leakage in the main valve. Pilots can be designed with a separate control for set pressure and blowdown. The valves can be set to open fully at the set pressure and close with a very short blowdown.

Another advantage of pilot-operated valves is cost. The large spring and associated space envelope of air-operated (spring-closure) valves can be replaced by a small pilot, thus reducing the mass and cost of the valve. Additionally, the lower profile of the pilot-operated relief valve provides greater resistance to seismic forces.

A disadvantage of the pilot-operated relief valve is in the increased complexity of the pilot with multiple parts (versus a single spring) and the associated reduction in reliability. A particular concern is the susceptibility to foreign matter of the small control passages in the pilot.

In contrast, the air-operated (spring-closure) relief valve design appears less susceptible to catastrophic (stuck-open) failure than the pilot-operated relief valve design. But the spring-loaded design requires a system of solenoid valves, accumulators, and associated piping to operate. Upgrading this additional equipment to safety-grade quality to provide needed reliability under normal and worst case (LOCA) loss-of-coolant accident conditions introduces additional cost and complexity to the PORV controls. Such design requirements present a trade-off versus the relatively compact pilot-operated design, which needs only electrical connections for operation.

Table 6.1 presents a compilation of PORV mechanical failures listed by PORV manufacturer. Note that the Dresser and Copes-Vulcan designs have been used for a number of years, hence the relatively high total number of events.

Table 6.1. PORV mechanical failures (excludes design events)

Manufacturer	Failure severity[a]		
	F	D	Total
Crosby (p)[b]	2	5	7
Dresser (p)	8	25	33
Garrett (p)		5	5
Copes-Vulcan (a)[c]	3	25	28
Masoneilan (a)	3	7	10
Control components (a)		2	2
Unknown	8	8	16
Total	24	77	101

[a]F — failed
D — degraded

[b](p) pilot-operated

[c](a) air-operated (spring close)

6.6 To What Extent Would Upgrading of Valves, Operators, and Control Systems to Safety-Related Criteria Have Prevented the Failures?

Based on a review of the failure events, it appears that if the valves, operators, and control components involved in the failures had been installed, tested, and maintained in accordance with requirements applied to safety-grade components, some of the failures most likely would have been prevented. Upgrading the components to safety-grade standards would provide a documented history of each activity applied to the component and provide redundant control circuitry constructed to Institute of Electrical and Electronic Engineers (IEEE) requirements. However, the basic design of the components would be unchanged, other than having to meet the environmental qualification criteria required for safety-grade equipment. For example, there are few differences between motor operators used for PORV BVs and the same make and model used in safety-related applications. Similarly, the physical design of PWR pressurizer PORVs in wide use would not be appreciably different if they were constructed to safety-grade standards.

Because the performance of certain PORV designs appears to degrade with use, consideration should be given to choosing or specifying PORV designs that can be periodically tested to meet the inservice inspection and testing requirements of 10 CFR 50.55a(g).

The causes of component failure in the events collected for this report do not appear to have any relationship to the quality level that would have been applied to the components had they been safety-grade. Safety-grade components of similar design suffer similar failures — especially in the case of MOVs. The air-operated (spring-closure) relief valve designs appear to mechanically fail mostly through seat leakage, while the pilot-operated designs appear more likely to stick open (and challenge the BV). (See events at Davis-Besse and TMI-2 in Appendix B, Table B.1.)

A severe challenge to safety could occur in a PWR if the PORV sticks open and the BV fails to close, that is, a small-break LOCA. On the other hand, PORV or BV seat leakage (occurring after closure) is a tolerable condition that can be mitigated through normal shutdown procedures. Based on a review of the failure events collected for this study, it is concluded that the greatest safety benefit could be achieved by using PORV designs which are resistant to sticking open, coupled with improved diagnostics, maintenance, and testing of PORVs, BVs, and BV motor operators. Appendix E contains a summary from the Electric Power Research Institute (EPRI) of recommended testing, diagnostic, and maintenance practices for PORVs and BVs.

As for BV motor operators, considerable NRC and industry effort is presently being applied to improving valve motor-operator reliability in nuclear power plants. Based on a review of the BV failures in this report, it appears that the application of advanced diagnostic techniques and improved maintenance and testing of BV operators could provide more reliable operation of this key component. Reference 7 contains a detailed analysis of valve motor operator aging and service wear effects.

6.7 To What Extent Was Valve QA/QC Inadequate?

The sources of information for the PORV and BV failure events collected for this report do not contain information about the level of quality assurance (QA)/quality control (QC) applied to the component(s) in question. Each of the valve manufacturers contacted for this project indicated that they have QA program in place and that it conforms to the requirements of Appendix B of 10 CFR 50. Their nuclear grade PORVs are constructed to ASME Sect. III under 10 CFR 50 Appendix B when so specified by the utility or architect/engineer (A/E). A judgment as to whether the QA/QC applied to the PORVs involved in the reported events was adequate was not possible.

6.8 To What Extent Have Other Human Factor Considerations Affected the Valve Failures That Have Occurred (i.e., Procedures, Maintenance Practices, Control Room Configuration?)

Section 4.4 of this report summarizes the operator and maintenance actions that may have contributed to the failures. The human factors that may have contributed to these events are complex and interrelated. Such detail was not available in the sources of operating experience data searched for this report. The PORV manufacturers contacted for this project stated that there was little feedback from utilities regarding the effect of procedures or maintenance practices on PORV reliability. All PORV manufacturers provide maintenance procedures for their valves and felt that most utilities followed them.

6.9 What Are the Most Common Failure Mechanisms for PORVs and BVs?

A review of the PORV mechanical failure events indicates that most problems occurred due to high-pressure steam/water cutting the seat/plug interface, eventually leading to leakage. In only one event was boric acid a problem. In this case, boric acid crystal buildup on the (Dresser) valve lever (exterior to the valve) was given as one of several reasons for the PORV sticking open. No events reviewed listed boron incompatibility with PORV materials as a possible failure cause. Other problems for PORVs included packing leakage (probably due to aging, heat, and pressure) and galling of moving parts.

For block valves, motor-operator torque and limit switch problems and valve packing leakage were involved in most of the failures. An assessment of MOV service wear and aging is contained in Ref. 6.

Internal leakage was the predominant PORV mechanical failure mode apparent from the study (61%). This is leakage through the valve seat into the valve outlet tailpipe. Only 12% of the PORV mechanical failure events involved a failure to open.

For PORV controls, 52 out of 91 events (57%) involved a degradation of the air or electrical actuation controls that would have prevented operation of the PORV if it had been required. Eleven events where the PORV unintentionally opened resulted mostly from inadvertent or accidental actuation by human error.

For BVs, about one-third of the events involved external leakage, and about one-third involved failure of the BV to close on demand. Such a failure can pose a threat to safety if it occurs in coincidence with a stuck-open PORV. For this reason, ability to close is the most important function for PORV BVs.

There are a number of apparent PORV internal leakage events, and many plants operate with the BV closed when the unit is at power. Therefore, it is also important that the BV be able to open reliably as well as close.

A summary of the identified failure modes for PORVs and BVs is shown in Tables 6.2 through 6.4.

Table 6.2. Failure modes — PORV mechanical

	B&W	W	CE	Total
Leakage - internal	19	33	10	62
Leakage - external	–	3	–	3
Fail to open	3	8	1	12
Fail to close	4	3	–	7
Other	6	6	5	17
Total	32	53	16	101

Table 6.3. Failure modes — PORV controls

	B&W	W	CE	Total
Fail to open	3	2	1	6
Fail to close	1	1	–	2
Spurious opening	1	4	6	11
Control degraded	1	49[a]	2	52
Other	4	12	4	20
Total	10	68	13	91

[a]Twenty-five events involved recurring problems with nitrogen control systems at North Anna 1 and 2.

Table 6.4. Failure modes — BVs

Leakage - external	12
Fail to open	2
Fail to close	12
Spurious opening	3
Other	3
Total	32

7. SUMMARY

PORVs and their BVs were not designed as safety-related components. They are used to relieve reactor coolant pressure at a level below the setpoint of the spring-loaded pressurizer code safety valves. This prevents the lifting of the code safety valves and the resultant increased maintenance frequency that is usually required to tightly reseat them (necessitating cold shutdown). The pressure-relieving capacity of the PORVs is normally not considered in plant safety analyses. The PORV block valves are installed because of expected leakage through the PORVs. The pressure-retaining elements of PORVs and BVs are within the reactor coolant pressure boundary and are constructed to the same codes and standards as those required for safety-related components within the reactor coolant pressure boundary.

Neither PORVs nor BVs have been shown by safety analysis to be needed for safe shutdown of the plant or mitigating the consequences of accidents. However, NRC has recently determined that PORVs are, in fact, relied upon to mitigate certain design-basis accidents. The acceptability of relying on nonsafety-grade PORVs to mitigate a design-basis accident is presently the subject of NRC Generic Issue 70: "PORV and Block Valve Reliability."

In support of the resolution of GI-70, the purpose of this study was to survey nuclear plant operating experience for PORV and BV failure events. The survey yielded 230 events occurring from 1971 to mid-1986, including PORV, PORV BVs, and their associated controls. One hundred and one events involved mechanical failure or degradation of the PORV; 91 events were attributable to the PORV controls. There were 32 BV failure events of which four involved BV controls. Six events involved the design or fabrication of PORVs.

Although the root cause of the majority of the identified failures could not be determined, the proximate cause appears to be wear, galling, or steam/water cutting of the valve disk and seat. The nine B&W plants accounted for a disproportionate number of mechanical failures in comparison to W and CE plants. The B&W plants use the Dresser/Crosby type PORV design and accounted for 45% of the PORV mechanical failure events. The close tolerances and greater number of moving parts exposed to steam in those designs can make them more susceptible to failure. Careful selection of materials and proper design for the expected service conditions are necessary. New pilot-operated PORV designs from Crosby and Target Rock appear to be more reliable and are qualified as safety-grade components. The air-operated (spring-closure) type PORV designs appear less susceptible to catastrophic (stuck-open) failure than the pilot-operated relief design. However, note that a substantial number of events (over 70%), describing failed or degraded PORV controls, involved problems with the air/nitrogen control components required to operate the air-operated (spring-closure) PORV.

Seventy-six percent of the PORV mechanical failures surveyed in the report were judged as degraded. Operator and maintenance errors were involved in only 18% (41) of the events; of these, 6 events were drawing or administrative error, and 25 were mechanical or electrical maintenance mistakes. An improvement in operations and maintenance QA could effect some reduction in these types errors.

8. CONCLUSIONS

Based on a review of the failure events, it is concluded that the greatest safety benefit could be achieved by using PORV designs that are resistant to sticking open. Upgrading the PORVs, operators, or control components to safety-grade status could each effect a reduction in PORV failures. A new PORV design from Target Rock and improvements incorporated in the new Crosby/Garrett design may provide higher reliability, but neither has been in service long enough to provide long-term operating experience.

BV reliability could best be enhanced by upgrading them to safety-grade status, where more rigorous testing, diagnostics, and maintenance are required. The QA normally applied to maintenance on safety-grade components may reduce the incidence of maintenance-induced failures. A summary of EPRI-recommended testing, diagnostic, and maintenance practices is contained in Appendix E.

The most common mechanical failure mechanism for PORVs appears to be degradation of the seat/disk interface or other internal parts by high-pressure steam and/or water. No reported events mentioned boron incompatibility as contributing to PORV or BV failure. However, an event that involved a stuck-open PORV occurred at Oconee 3 in June 1975. The causes of the failures given in the sources of information reviewed included: (1) heat expansion, (2) boric acid crystal buildup on the valve lever (on the exterior of the valve), (3) rubbing of the lever against the solenoid brackets, and (4) bending of the solenoid spring bracket. This was the only reported event that specifically mentioned boric acid crystals. No events found listed boron incompatibility with PORV materials as a cause of failure.

Internal leaking was the most common failure mode apparent from this study. Of the seven failure-to-close events, four occurred at B&W units and were considered to be serious challenges to safety (especially the TMI-2 event).

Most PORV BV failures involved torque switch failure or misadjustment. Proper coordination of valve packing adjustment, operator maintenance, and setup of motor-operator torque switches, limit switches, and torque-bypass limit switches would considerably enhance MOV reliability. A more thorough analysis of MOVs is contained in Ref. 7.

9. REFERENCES

1. Letter, James P. Knight, Washington, D.C., to Guy A. Arlotto, "RES Assistance on Generic Issue No. 70 — PORV and Block Valve Reliability (July 1985).

2. *PWR Safety and Relief Valve Test Program-Valve Selection/Justification Report*, EPRI NP-2292, Electric Power Research Institute, Palo Alto, Calif., December 1982.

3. W. W. Weaver, "Estimating Failure-to-Close Probabilities for Pressurizer Valves," NUREG/CR-0027, *Proceedings of the International Meeting on Thermal Nuclear Reactor Safety*, American Nuclear Society, February 1983.

4. *LER Summary Report on Valves*, Report EGG-EA-5125, NUREG/CR-1363, Vol. 1, June 1980.

5. *Reliability/Availability Data Collection and Analysis System*, Report NPGD-TM-378, Babcock and Wilcox, Lynchburg, VA, 1981.

6. R. J. Borkowski et al., *The In-Plant Reliability Data Base for Nuclear Plant Components: Interim Report — The Valve Component*, NUREG/CR-3154, December 1983.

7. W. L. Greenstreet, *Aging and Service Wear of Motor-Operated Valves in Nuclear Power Plants*, NUREG/CR-4234, June 1985.

8. E. G. Silver, *The 21/55 Data Base Users' Manual*, NUREG/CR-4011, July 20, 1984.

Appendix A

DATA BASE SEARCH PARAMETERS

Source	Search strategy	Gross number of events	Number of events after screening
NOAC-RECON	Keywords: VALVES, MAIN COOLING SYSTEM, REACTOR COOLANT, REACTOR PWR, "PORV," "POWER OPERATE" + "PILOT"	185	110 PORV 32 BV
NOAC-SCSS	System: Pressurizer; PORV and BV Failures	363	74 PORV 22 BV
NPE	NSSS: CE, B&W, and W System: RCS Component: safety/relief valve, control valve	202	78 PORV 12 BV
NPRDS[a]	NSSS: CE, B&W, and W System: RCS Component: pressure relief valves, pressure control valves	78	13 PORV 0 BV

[a]No specific PORV (motor-operated) BV events could be obtained from NPRDS because the structure of the NPRDS does not permit searching by component function, that is, PORV or PORV BV. A compilation of MOV failure data taken from NPRDS is contained in Reference 7.

Appendix B

EVENT TABLES

Table B.1. B&W PORV events — mechanical failures

Plant	Event date	Description/failure cause	Severity	PORV Manufacturer/ model No.	Utility valve I.D.	Corrective action
ANO-1	9/74	PORV lifted and stuck open; pilot vent line design faulty	F	Dresser/31533VX-30	PSV-1000	Redesign location where the 1/2-in. vent line joins the 4-in. PORV discharge pipe
	11/8/79	Leaks; wear of internals.	D	Dresser/31533VX-30		Lapped pilot and main seat
	1/8/80	Bad disk seat	D	Dresser/31533VX-30		
Crystal River 3	6/23/79	Seat leak at mating surfaces	D	Dresser/31533VX-30		Lapped and rebuilt
	11/22/85	PORV failed to open on demand, and another PORV transferred open	F			
Davis-Besse	9/24/77	PORV lifted nine times; pilot stem failed; close relay missing	D	Crosby/HPV-SN		Repairs made
	10/77	Pilot stem clearance problem	D	Crosby/HPV-SN	RC-2A	
	5/15/78	Broken valve stem	F	Crosby/HPV-SN	RC-2A	Stem and bonnet were replaced
	10/26/79	Pilot valve and main disk leaking	D	Crosby/HPV-SN	RC-2A	Lapped pilot and main disk replaced all gaskets
	2/18/82	Leaks through	D	Crosby/HPV-SN	RC-2A	Replaced internals
	6/9/85	PORV failed to close on third actuation; failure cause undetermined	F	Crosby/HPV-SN	RC-2A	Pending
Oconee 1	2/3/75	Leaks; manufacturing and/or installation error	D	Dresser/31533VX-30		Lapped
	10/9/76	Limit box failure	D	Dresser/31533VX-30		Replaced limit box
	1/19/77	Scarred valve seat	D	Dresser/31533VX-30		Lapped
	7/21/77	Leaks past seat, worn disk	D	Dresser/31533VX-30		Replaced disk
	10/4/77	Seat scarred	D	Dresser/31533VX-30		Lapped
Oconee 2	11/73	Pilot leakage	D	Dresser/31533VX-30	2RC-66	
	5/26/77	Leaks; abnormal wear on seat of main valve and pilot	D	Dresser/31533VX-30		
	8/23/78	Leaks; trash under seat	D	Dresser/31533VX-30		Cleaned and repaired
	4/29/79	Worn seat	D	Dresser/31533VX-30		
	7/1/82	Valve seat and disk scratched, leaks past seat	D	Dresser/31533VX-30	2RC-66	Lapped the valve seat and disk
	11/22/83	Carbon buildup on coil contacts (coil located on the valve)	F	Dresser/31533VX-30	2RC-66	Cleaned the coil contacts

Table B.1. (continued)

Plant	Event date	Description/failure cause	Severity	PORV Manufacturer/ model No.	Utility valve I.D.	Corrective action
Oconee-3	6/74	Vent failed to open	F	Dresser/31533VX-30	3RC-66	
	2/5/75	Leaks	D	Dresser/31533VX-30		Lapped
	6/13/75	Vent failed to open; boric acid buildup; bent lever on pilot valve	F	Dresser/31533VX-30	3RC-66	Valve repaired
	7/20/76	Leak; seat worn badly	D	Dresser/31533VX-30		Repaired
Rancho Seco	6/11/78	PORV and BV leaking	D	Dresser/31533VX30	PV-21511	Replaced PORV and the disk' seat was lapped on the block valve
	9/19/83	Position indicator weight caused pilot valve to open, opening PORV	F	Dresser/31533VX30	PV-21511	Position indicator was removed, and a different method of position indication was used
TMI-1	8/31/82	PORV internals corroded	F	Dresser/31533VX30	RC-RV2	Installed spare, PORV was refurbished
	2/11/83	PORV internals rusted and pitted; traces of sulfur on internals; pilot valve disk was stuck; main valve disk was stuck closed	F	Dresser/31533VX30	RC-RV2	Refurbished PORV (from 8/31/82 event) was re-installed
TMI-2	3/28/79	PORV stuck open	F	Dresser/31533VX-30	RC-R2	
[a]	6/23/79	PORV leaked	D	Dresser/31533VX		Lapped seat and rebuilt valve

[a] No plant identification available.

Table B.2. B&W PORV events — control failures

Plant	Event date	Description/failure cause	Severity	Corrective action
Crystal River 3	11/75	Stuck solenoid	F	
	2/26/80	Power supply was lost; PORV open due to a faulty circuit design in the NNI; PORV could not be closed	F	
	6/3/82	Position indicator was out of tolerance	D	Preamplifier was recalibrated
Davis-Besse	9/24/77	Missing seal-in relay caused PORV to cycle 9 times, then stick open	F	PORV was reworked; seal-in relay installed(?)
Oconee 2	8/73	Wiring error	F	
	5/12/82	Hook-up wire blocked control relay contact	F	Rerouted hook-up wire
	2/21/84	Coil contacts had carbon build-up	F	Cleaned coil contacts
Rancho Seco	3/20/78	Operator changing a light bulb dropped light bulb and shorted out NNI power; PORV disabled	F	
TMI-2	3/28/78	Loss of power to PORV actuation channels	F	
	9/78	Failed to open	F	

Table 8.3. W PORV events — mechanical failures

Plant	Event date	Description/failure cause	Severity	PORV Manufacturer/ model No.	Utility valve I.D.	Corrective action
Beznau	8/20/74	Stuck open; fractured valve yoke	F			
Callaway 1	12/17/84	Excessive PORV leakage; BVs had to be closed	D	Garrett/straight through or Copes-Vulcan D-100-160		
Connecticut Yankee	1977	PORVS were deteriorating causing excessive leakage and loss of operability	D	Crosby		Replaced Crosby valves with Copes-Vulcan air-operated valves
	3/12/83	Seat leakage; disk cracked	D	Copes-Vulcan/ D-100-160	PR-570	Disc welded and machined to fit
Cook 1	1/24/84	Seat leakage; cause unknown	D	Masoneilan/ 38-20771	NRV-151	Replaced plug, stem, packing, seat ring and gasket; reset stroke
Farley 2	4/26/81	PORV seat leakage; PORV was isolated	D	Copes-Vulcan/ D-100-160	445 A	PORV repaired when plant conditions permitted
Ginna	6/19/83	PORV lifted but leaked on reseat; seated after pressure reduced	D	Copes-Vulcan/ D-100-160	430	Valve was cycled open, then shut
Indian Point 2	1/19/81	Opening times were 2.5 s longer than permitted	D	Copes-Vulcan/ D-100-160	PCV-456	
Kewaunee 1	9/19/75	Gasket failed	D	Masoneilan/ 38-20721	PR-2A	Replaced gasket and lapped valve seat
	6/10/76	Valve will not operate; bent stem	F	Masoneilan/38-20721	PR-2B	Installed new valve internals
	1/22/77	Valve will not open; diaphragm failed	F	Masoneilan/38-20721	PR-2B	Replaced diaphragm
	8/6/83	Seat leakage; wear	D	Masoneilan/ 38-20721	PR-2A	Replaced stems, plug, seat and gaskets
	12/5/84	Seat leakage; incorrect installation	D	Masoneilan/38-20721	PR-2A	Replaced plug stem, seat ring and gaskets

Table B.3. (continued)

Plant	Event date	Description/failure cause	Severity	PORV Manufacturer/ model No.	Utility valve I.D.	Corrective action
McGuire 1	1/3/82	PORV seat leakage; BV was closed	D	Control components/ drag valve	NC-32	PORV repaired during 2/82 outage
	4/2/82	PORV seat leakage; BVs were closed	D	Control components/ drag valve	NC-34	PORV repaired
	12/22/85	PORVs out-of-calibration and fail to open	F			
North Anna 1	3/80	PORV failed to actuate	F			
	11/82	PORV was mechanically "blocked" in the open position; the steel "block" fell out and left valve closed	F		PCV-1456	A more substantial "blocking" device was to be designed and provided
	9/21/84	Seat leakage; improper adjustment of valve stem	D	Masoneilan/ 38-20721	1RCPCV-1456	24 stem threads showing; screwed down 6 threads and leaking stopped
North Anna 2	6/24/80	Cocked bearing in valve operator; PORV inadvertently opened and then failed to close; maintenance unknowingly cocked the bearing; the event was attributed to an inadequate procedure	F	Masoneilan/ 20,000 series	PCV-2456	The cocked bearing was corrected and the spring pressure readjusted
Point Beach 1	3/15/76	Valve leaked through; plug and seat cut	D	Copes Vulcan/ D-100-160		Remachined and lapped plug and seat; reinstalled with new gaskets
	4/18/77	Stem out of adjustment; valve leaked	D	Copes Vulcan/ D-100-160		Adjusted valve stem downward
	6/25/77	Valve leaked through; cage and plunger worn	D	Copes Vulcan/ D-100-160		Remachined cage and plunger, repacked valve
	7/2/83	Seat leakage; degraded cage and plug	D	Copes-Vulcan/ D-100-160	1-431C	Installed a new plug, cage, gaskets, and packing

Table B.3. (continued)

Plant	Event date	Description/failure cause	Severity	PORV Manufacturer/ model No.	Utility valve I.D.	Corrective action
Robinson 2	4/18/79	PORVs had long stroke times; scored valve stems	D			
	4/29/83	PORV failed during testing; galling of plug to cage	D	Copes-Vulcan/ D-100-160	RC-455C	All damaged components were replaced
Salem 1	6/81	PORV leakage due to steam cutting of valve cage	D	Copes-Vulcan/ D-100-160	1 PR1	The valve cage was replaced
	1/5/82	PORV leaking through	D	Copes-Vulcan/ D-100-160	1 PR1	
	1/7/82	PORV would not open in manual	F	Copes Vulcan/ D-100-160	1 PR2	PORV disassembled and awaiting parts
Salem 2	6/22/80	Foreign material or drystroking caused valves not to reseat	D	Copes-Vulcan/ D-100-160		Parts were refurbished
	5/15/81	PORV leakage caused by galling of the plug	D	Copes-Vulcan/ D-100-160	2 PR1	PORVs were modified by installing plugs of a different material
	6/18/81	PORV seat leakage; generic problem	D	Copes-Vulcan/ D100-160	2 PR2	PORV was isolated
	7/9/81	Valve leaked through	D	Copes-Vulcan/ D-100-160	2 PR2	Scheduled for repair during next refueling outage
	1/21/83	PORV seat leakage; generic problem	D	Copes-Vulcan/ D-100-160		The PORV plugs were scheduled for replacement
	7/25/84	PORV failed to reset during test, BV slow to close	D	Copes-Vulcan D-100-160	2 PR2	
Sequoyah 1	10/26/81	PORV leaked due to improper adjustment of stem coupling	D	Masoneilan/ 20,000 series	1-PVC-68-340A	Stem coupling was readjusted
	4/21/83	PORV leakage	D	Masoneilan/ 20,000 series	1-PVC-68-340	PORVs scheduled for replacement
	9/12/83	Valve failed to open; leaking through; valve not fully closed	F		PCV-68-340	PORVs scheduled for replacement during 12/83 refueling outage
Sequoyah 2	11/9/83	PORV leakage; crack in valve seat	D	Copes-Vulcan D-100-160	2-FCV-68-340	Valve vendor replaced seat

Table B.3. (continued)

Plant	Event date	Description/failure cause	Severity	PORV Manufacturer/ model No.	Utility valve I.D.	Corrective action
Summer 1	10/20/82	PORV seat leakage; steam impingement on seat	D		PCV-445A PCV-445B	Valve scheduled for repair
	2/17/83	PORV seat leakage	D		PCV-445B	
	4/10/84	Seat leakage; cage deformed; design error	D	Copes-Vulcan/ D-100-160	PCV-444B	Heavy wall cage spacer and new trim assembly were installed
	7/3/84	Seat leakage; cage deformed	D		PCV-445B	
Surry 1	1/26/82	Leaking PORV and BV	D	Copes-Vulcan/ D-100-160		
	10/2/82	Leaking diaphragm	D		PCV-1455C	PORV was overhauled
	2/4/83	PORV would not cycle	F		PCV-1455C	
Zion 1	1/20/76	Seat leakage	D	Copes Vulcan/ D-100-160	PCV-455C	Install new plug, stem, cage, spacer, gasket, and diaphragm
	7/22/84	Seat leakage; wear plus possible radiation damage	D	Copes-Vulcan/ D-100-160	PCV-455C	Lapped in plug and seat; repacked, set stroke
Zion 2	12/18/83	Seat leakage; wear	D	Copes-Vulcan/ D-100-160	PCV-456	Replaced valve stem, stem assembly seat, and gaskets; repacked valve; set stroke and preload
a	3/23/75	Plug scored, cage frozen; valve would only stroke 1/4 in., frozen open	F	Copes-Vulcan/ D-100-160		Installed new stem, plug, cage, and gasket
a	3/23/75	Bonnet leak; plug scored, cage frozen; valve frozen shut	F	Copes-Vulcan/ D-100-160		Installed new stem, plug, cage, and gasket
a	7/7/75	Seat leakage; cage fits tight	D	Copes-Vulcan/ D-100-160		During outage, replaced stem and disc assembly; cage reconditioned
a	1/14/76	Seat leakage	D	Copes-Vulcan/ D-100-160		Seats relapped - valve still leaks; scheduled for repair net outage

[a] No plant identification available.

Table B.4. W PORV events — control failures

Plant	Event date	Description/failure cause	Severity	Corrective action
Connecticut Yankee	8/13/79	PORV and BV opened due to failure of pressure controller	D	
	2/4/80	PORV actuated due to dirty contacts	D	
	4/3/81	Pressurizer pressure controller malfunction; PORV and BV opened	D	A connector was reinstalled properly
	11/1/83	Loss of control air; filter leak	F	Isolated leak, incorrect O-ring was installed, correct O-ring was then installed
	11/28/83	Loss of control air; filter leak due to worn threads	F	Replaced entire filter canister
Cook 2	1/8/83	PORV emergency air actuation system failure; allowed PORV to drift closed during test	F	Regulators were readjusted to a higher pressure to ensure the valves would remain open
	7/3/83	Lack of air supply for PORVs due to administrative error	F	Air supply was restored
	10/8/83	PORVs drifted closed; air supply regulator set low	D	Regulator adjusted to a higher pressure
Farley 2	2/17/83	PORV controller failure; defective driver card	F	Installed new card

Table B.4. (continued)

Plant	Event date	Description/failure cause	Severity	Corrective action
Ginna	5/6/80	Both PORVs inoperable; DC power switches in the "off" position	F	
	1/25/82	PORV stuck open due to faulty pilot solenoid valve	F	Solenoid valve was replaced
Indian Point 2	1/19/81	Opening time 2.5 seconds long; nitrogen supply valve closed	D	Nitrogen valve reopened
McGuire 1	4/3/81	PORV actuation setpoint set too low	F	Pressure was reduced
	3/26/82	PORV position indication light failure	D	Socket contacts were adjusted to contact bulb, and the socket will be replaced
	6/5/82	PORV position indication lost due to pinched cable at limit switch	F	The wire and conduit were repaired
McGuire 2	4/1/83	Low pressure signal to PORV; air trapped in pressure transmitter	F	Transmitter was bled
North Anna 1	3/78	PORV failed to open; pressure interlock not jumpered out; procedure error	F	Revised procedure
	12/31/80	PORV nitrogen supply low due to frequent cycling during preparation for refueling	D	Design and modifications have been undertaken
	3/18/81	PORV tanks leaked	F	Both PORV nitrogen low-temperature overpressurization systems were repaired

Table B.4. (continued)

Plant	Event date	Description/failure cause	Severity	Corrective action
North Anna 1 (continued)	10/7/81	PORV nitrogen supply low	F	A temporary nitrogen supply was used
	5/10/82	PORV nitrogen supply low	F	A design study has been completed and the system will be modified
	5/19/82	'A' PORV declared inoperable; two days later 'B' PORV was found to be inoperable for an indeterminant time; nitrogen isolation valve closed for indeterminant time	F	
	5/19/82	PORV nitrogen supply low	F	Manual blocks were installed on both relief valves
	5/25/82	PORV nitrogen supply low	F	A design study has been completed and the system will be modified
	6/82	PORV would have opened 20.5 psi above limit; pressure transmitter drifted low	D	Transmitter was recalibrated
	12/7/82	PORV nitrogen supply low	F	Nitrogen relief valve was repaired
	12/11/83	PORV nitrogen supply accumulator relief valve failed	F	Nitrogen relief valve was removed, inspected, and reinstalled

Table B.4. (continued)

Plant	Event date	Description/Failure cause	Severity	Corrective action
North Anna 2	8/80	Nitrogen supply low	F	Nitrogen tanks recharged
	8/14/80	PORV nitrogen supply low	F	Gas supply recharged; design changes expected
	9/2/80	Low nitrogen due to high plant usage	F	Nitrogen supply tanks recharged; recommended actions have been proposed to fix entire nitrogen supply system
	11/2/80	PORV nitrogen supply low	F	Future corrective actions will be based on the investigation in progress
	6/20/81	PORV nitrogen supply low	F	Repairs to reduce leakage have been made
	8/6/81 & 8/17/81	PORV nitrogen supply low	F	A full nitrogen tube truck was ordered and used to repressurize the tanks
	3/8/82	PORV nitrogen supply low	F	Gas supply tanks refilled
	5/16/82	PORV nitrogen supply low	F	A design study has been completed, and the system will be modified
	5/26/82	Stroke times were 2.4 s long; improper setting of nitrogen pressure regulator	D	Regulator readjusted
	6/5/82	PORV nitrogen supply low	F	A design study has been completed, and the system will be modified

Table B.4. (continued)

Plant	Event date	Description/failure cause	Severity	Corrective action
North Anna 2 (continued)	7/10/82	PORV nitrogen supply low	F	A design study has been completed, and the system will be modified
	8/20/82 & 8/28/82	PORV nitrogen supply low three times on 8/28/82	F	A design study has been completed, and the system will be modified
	10/82	Acoustic monitor failed	D	Passive channel put in service; action channel to be repaired during a subsequent outage
	1/8/83	Lost valve position indication for PORVs	D	Maintenance performed on a remote valve indicator for solenoid valve SV-2551A
	4/6/83	PORV nitrogen supply low	F	A design study has been completed, and the system will be modified
	5/15/83	PORV nitrogen supply low	F	Regulators were reset
Point Beach 1	6/28/83	No position indication; circuit breaker was open	D	Closed circuit breaker
Point Beach 2	9/25/82	Valve in instrument air line closed; PORV was inoperable	F	Instrument air line opened; bad procedure

Table B.4. (continued)

Plant	Event date	Description/failure cause	Severity	Corrective action
Robinson 2	11/4/83	PORV failed to meet required cycle time; limit switches misadjusted	D	The limit switch was repaired and a small leak on the operating diaphragm was repaired
	12/15/84	Both air and nitrogen to PORVs were isolated; system drawings and procedures in error	F	
Salem 2	3/1/82	POP valves were closed, which rendered both PORVs inoperable	F	Valve reopened and operator was counseled
	1/22/83	POPS declared inoperable due to excessive leakage	F	Problem investigated during current outage
	1/26/83	PORV control air system failed; surge caused excess flow check valve to close	D	Control air system was returned to normal lineup; the vent was restored
	8/30/83	POPS valve failed to demonstrate operability due to problems with valve position indicator	D	The controls of the PORVS have been modified to function as POPS valves
San Onofre 1	6/18/81	PORV controller settings caused cycling during transients	D	PORV control was placed in manual mode; will repair automatic controller
Sequoyah 1	4/21/83	Valve failed to open; failed coil in ASCO Model LB831654 solenoid	F	Scheduled for repair at first outage
	4/2/84	PORV bistable alarm lights miswired	F	Both PORVs on both units were rewired

Table B.4. (continued)

Plant	Event date	Description/failure cause	Severity	Corrective action
Sequoyah 2	4/2/84	PORV bistable alarm lights miswired	F	Both PORVs on both units were rewired
Summer 1	6/6/83	PORV nitrogen supply pressure regulator drifted (PCV-445A-RC)	F	The limit switches and the regulator were adjusted
	7/7/83	PORV nitrogen supply pressure regulator drifted (PCV-44B-RC)	D	Nitrogen supply header pressure control regulator was replaced
	8/31/83	Possible inadvertent opening of PORV upon loss of power	D	Design needs to be corrected
Surry 1	10/2/82	Low back-up air pressure	F	Air bottles were replaced
	2/9/83	Both PORV control air supplies were degraded	D	Replaced backup air bottle for one PORV, and emergency air bottles were replaced for the other
	2/11/83	Instrument air check valve installed backwards	D	Check valve reinstalled correctly
Surry 2	5/27/80	Accumulators for both PORVs were vented, and the instrument air source was isolated; PORVs inoperable	F	
	5/21/81	Due to a wiring problem the pressure inputs to the PORVs were eliminated	F	

Table B.4. (continued)

Plant	Event date	Description/failure cause	Severity	Corrective action
Turkey Point 4	11/28/82	Overpressure mitigating system failed to operate; pressure transmitter isolation valve closed	F	
Zion 2	6/18/80	Accumulators for both PORVs were vented and the instrument air source was isolated; PORVs inoperable	F	Changed procedures to block open PORVs during integrated leak rate test
[a]	2/26/75	Air line to PORV leaking	D	Installed new air hose on air operator

[a]Plant identification not available.

Table B.5. CE PORV events — mechanical failures

Plant	Event date	Description/failure cause	Severity	PORV Manufacturer/ model No.	Utility valve I.D.	Corrective action
Calvert Cliffs 1	7/6/79	PORV failed to seat after test	D	Dresser/31533VX-30	RC-402-ERV	The pilot valve stroke was adjusted
	10/18/80	Set pressures adjusted incorrectly by manufacturer (both valves)	D			Lift pressures were readjusted
	3/1/81	PORV leaked due to low RCS pressure	D			RCS pressure was increased and PORV stopped leaking
Calvert Cliffs 2	8/22/77	Leak	D	Dresser/31533VX-30		Cleaned
Millstone 2	12/29/83	PORV seat leakage; foreign material on seat	D	Dresser/31533VX-30	2-RC-404	The valve was successfully flushed
Palisades	Early 1972	PORV seat leakage (all PORVs)	D	Dresser/31533VX-30		PORVs were disassembled, lapped, and the connecting piping modified to reduce stresses on the valve body
	8/30/80	PORV leakage, PORV pilot was held open by the solenoid plunger; plunger spring slipped	F		1042B	The spring guide was brazed back onto the guideplate
St. Lucie 2	4/28/83	Possible failure of PORV pilot solenoid valve	D			PORV was retested with dummy signal to pilot valve and PORV operated normally
	5/14/83	PORV position indication magnet lost magnetism due to high temperatures	D	Garrett/Angle Valve	1475	The magnet was replaced
	5/23/83	PORV position indication magnet lost magnetism due to high temperature	D	Garrett/Angle Valve	1474	The magnet was replaced
	6/3/83	PORV position indication magnet lost magnetism due to high temperature	D	Garrett/Angle Valve	1475	The magnet was replaced
	7/4/83	PORV position indication magnet lost	D	Garrett/Angle Valve	1474	The magnet was replaced
[a]	7/22/76	Seat leakage	D	Dresser/31533VX		Replaced disc, guide, rings
[a]	11/28/79	Pilot valve and main valve seating surface cut	D	Dresser/31533VX-30	1-ERV-404	Replaced pilot and main valve discs
[a]	1/25/80	Pilot valve and main valve seating surfaces cut	D	Dresser/31533VX-30	1-ERV-402	Replaced pilot disc and lapped main valve disc
[a]	12/9/80	Valve lifted, failed to reseat tightly; seat leakage	D	Dresser/31533VX		Lapped seat and reinstalled

[a]Plant identification not available.

Table B.6. CE PORV events — control failures

Plant	Event date	Description/failure cause	Severity	Corrective action
Calvert Cliffs 1	1/80	PORV actuated on erroneous signal; bumping of pressure transmitter cabinet	D	This over-pressure protection circuitry was disabled, and PORV actuation was a function of the RPS during normal operation
	7/16/81	PORV actuated on erroneous signal; bumping of pressure transmitter cabinet	D	A mechanical stop was installed to protect the transmitter
	4/26/83	While troubleshooting, a short circuit caused loss of control power to PORV; short circuit due to technician error	F	Control power was restored
Calvert Cliffs 2	1/18/81	PORV opened due to pressure transmitter failure	F	
	2/3/83	PORVs opened when two RPS channels were inadvertently de-energized	D	Wiring error corrected
	8/24/84	Override handswitches were in the "override" position and PORVs would not open	F	The procedure has been changed to require operator verification
Ft. Calhoun 1	12/20/78	Defective procedure; technician pulled recorder fuses which opened both PORVs; operator closed PORVs	D	BVs closed; design changes considered so that removal of recorder fuses will not disable PORVs

Table B.6. (continued)

Plant	Event date	Description/failure cause	Severity	Corrective action
Maine Yankee	11/83	PORVs may not actuate due to single relay failure under LTOP procedures	D	Design modifications initiated
Palisades	9/71	PORV opened; technician de-energized the RPS breakers, which de-energized the feed to the PORV pilot valve solenoids	F	Closed BV, corrected non-standard drawing notation
	11/23/81	Licensed operator error (Administrative); valves were declared operable without following procedures	D	Procedures will be reviewed
	8/13/83	PORVs do not provide LTOP when shutdown cooling system isolation valves are open	D	The LTOP system will be evaluated and modified as necessary to allow PORV opening
St. Lucie 1	3/23/81	PORV acoustic flow position indicator was inoperable	D	A spare transducer and cable were installed
St. Lucie 2	4/24/83	Pressure transmitter was erroneously isolated by unidentified personnel	F	A valve lineup was performed to ensure no further instrumentation was isolated

Table B.7. PORV BV Events

Plant	Event date	Description/ failure cause	Severity	Valve manufacturer/ model No.	Utility valve I.D.	Motor operator manufacturer/ model No.	Corrective action
ANO-2 (B&W)	6/79	Failed torque switch; BV failed to close	F		MV-32196	Limitorque/ SMB-00	The switch was replaced
Beaver Valley 1 (W)	4/28/81	BV operator limit switch damaged; bent pinion gear and shaft	F		MOV-RC-535	Limitorque	Replaced limit switch
Calvert Cliffs 1 (CE)	11/3/81	BV packing leak	D		RC-403-MOV		Backseated valve; valve was repacked during subsequent refueling outage
Connecticut Yankee (W)	8/13/79	BV and PORV opened as a result of the pressurizer pressure controller	F		MOV-569		Operator overrode the open signal
	2/80	BV opened on spurious signal from pressure controller; dirty contacts	F		MOV-569		
	4/3/81	BV and PORV opened spuriously; pressurizer pressure controller connector came loose	F		MOV-569		The connector was reinstalled
Crystal River 3 (B&W)	9/27/83	Torque switch failed; BV failed to close	F		RCV-11	Limitorque	Replaced torque switch
Cook 1 (W)	1/20/86	BV packing leak	D	NMO-151			Valve was repaired
McGuire 2 (W)	4/27/83	BV packing leak, eye bolts failed	D	Borg Warner	2NC-31B	ROTORK	Repairs are scheduled for 6/83

Table B.7. (continued)

Plant	Event date	Description/ failure cause	Severity	Valve manufacturer/ model No.	Utility valve I.D.	Motor operator manufacturer/ model No.	Corrective action
Millstone 2 (CE)	6/10/79	Body-to-bonnet seal failed	D	Velan/SA-182	2-RC-405		The valve gasket and spacer ring were replaced
	9/28/81	Body-to-bonnet seal ring leakage	D	Velan/SA-182	2-RC-403	Limitorque/ SMB-000	Replaced seal ring
	12/6/81	BV motor operator electrical failure due to torque switch	F	Velan/SA-182	2-RC-403	Limitorque/ SMB-000	Motor torque switch and geared limit switch assemblies were replaced
	3/4/82	BV body-to-bonnet joint leaked until RCS temperature and pressure raised	D	Velan/SA-182	2-RC-403	Limitorque/ SMB-000	
	7/82	BVs suffered packing leakage	D	Velan	2-RC-403 & 2-RC-405		Replaced seal ring
	3/1/83	BV leakage into containment	D		2-RC-405		
North Anna 1 (W)	11/19/82	BV control cable connections loose; BV could not be opened	F	MOV-1536			Loose connection tightened
Oconee 1 (B&W)	12/19/73	M.O. failure; valve stuck open	F		RC-4		Override thermal O/L to close valve
Robinson 2 (W)	11/30/81	BV operator did not receive proper PM; BV failed to close	F	Velan/3-6M58SM		Limitorque/ SMB-000-5	Valve repaired under vendors direction
	6/25/83	BV packing leak	D		RC-536		Scheduled for repacking at cold shutdown
Salem 2 (W)	7/25/84	BV slow to close; broken wire in the valve operator circuit	D	Velan	2 PR 6	Limitorque	Readjusted
San Onofre 1 (W)	6/4/85	BV failed to close fully; actuator diaphragm leaked, part of diaphragm was missing	D	Anchor Darling	CV-530		Actuator diaphragm was replaced

Table B.7. (continued)

Plant	Event date	Description/ failure cause	Severity	Valve manufacturer/ model No.	Utility valve I.D.	Motor operator manufacturer/ model No.	Corrective action
Sequoyah 2 (W)	11/10/81	BV position limit switch gear broken; BV position could not be verified	D		2-FCV-68-333		Limit switch was replaced
	3/27/82	BV operator torque switch setting too low for operational conditions; BV would not close	F		2-FCV-68-333	Limitorque	Torque switch setting was increased
Summer 1 (W)	10/1/82	BV would not reopen after test; packing too tight; overtorque on opening	F		MVG-8000A		Stem packing was replaced
	10/10/82	BV packing leak	D		MVG-8000C		Packing was replaced
	12/16/83	Packing leak	D		MVG-8000A		Valve packing was replaced
Surry 1 (W)	1/26/82	BV would not close completely; required manual assistance	D	Velan	MOV-1536	Limitorque	BV was cycled satisfactorily at cold shutdown; however, torque switch was replaced
	6/18/82	BV would not close completely either remotely or manually; BV was closed by overriding the torque and limit switches	D		MOV-1536		
St. Lucie 1 (CE)	4/16/81	BV packing adjusted too tight; BV would not close	F	Velan	MV-1403		Packing gland adjusted and maintenance cautioned
	8/2/81	BV would not close due to failed limit switch; excessive leakage through packing	F		MV-1403		Loose electrical connection was tightened
	2/26/82	BV would not shut	F	Velan/P35036-2	MV-1403		Closed manually in 57 min
Turkey Point 3 (W)	12/30/84	BV would not close completely; faulty torque switch	D	Velan	MOV-3-535		Torque switch was replaced

Table B.8. PORV events — design/fabrication failures

Plant	Event date	Description/ failure cause	Severity	PORV manufacturer/ model No.	Utility valve I.D.	Corrective action
Ginna (W)	5/79	Valves had incorrect discharge coefficient (C_v = 42 instead of C_v = 50)	D	Copes-Vulcan/ D-100-160		Copes-Vulcan was expediting delivery of properly sized internals; scheduled for installation during the next cold shutdown so that valves could be isolated
Indian Point 2 (W)	8/78	Newly installed valves had incorrect discharge coefficient (C_v = 38.5 instead of C_v = 50)	D	Copes-Vulcan D-100-160		During the 1979 refueling outage, the existing valve trim sets were removed and replaced with the proper trim sets
Indian Point 3 (W)	8/78	Newly installed valves had incorrect discharge coefficient (C_v = 38.5 instead of C_v = 50)	D	Copes-Vulcan D-100-160		During the 1979 refueling outage, the existing valve trim sets were removed and replaced with the proper trim sets
Prairie Island 1 (W)	2/80	Discovered in 11/80 that additional conax fitting required to meet environmental qualification for PORV	D	Copes-Vulcan D-100-160		Ordered material; scheduled repair for planned outage
Prairie Island 2 (W)	2/80	Discovered in 11/80 that additional conax fitting required to meet environmental qualification for PORV	D	Copes-Vulcan D-100-160		Ordered material; scheduled repair for planned outage
Salem 2 (W)	8/80	Limit switches on PORV were not seismically and environmentally qualified	D	Copes-Vulcan D-100-160		Limit switches were to be replaced at next cooldown with qualified limit switches

Appendix C

HUMAN ERROR EVENTS

Table C.1. Human error events

Table	Plant	Event date	Description
		Operators	
2	Rancho Seco	3/20/78	Operator dropped light bulb — shorted NNI power
4	Cook 2	7/3/83	Lack of air supply for PORVs due to administrative error
4	Ginna	5/6/80	Power switches off
4	Indian Point 2	1/19/81	N_2 supply valve closed
4	North Anna 1	3/78	PORV failed to open; pressure interlock not jumpered out; procedure error
4	North Anna 1	5/19/82	N_2 supply valve closed
4	Point Beach 1	6/28/83	Circuit breaker open
4	Point Beach 2	9/25/82	Instrument air line valve closed-faulty procedure
4	Salem 2	3/1/82	POP valves were closed, which rendered both PORVs inoperable
6	Palisades	11/23/81	Licensed operator error (administrative) — valves were declared operable without following procedures
		Maintenance/I&C	
1	Oconee 1	2/3/75	Possible installation error
2	Crystal River 3	6/3/82	Position indicator out of tolerance
2	Oconee 2	5/12/82	Hookup wire blocked contacts

Appendix C

Table C.1 (continued)

Table	Plant	Event date	Description
2	Rancho Seco	3/20/78	Operator changing a light bulb dropped light bulb and shorted out NNI power; PORV disabled
3	Kewaunee 1	12/5/84	Seat leakage; incorrect installation
3	North Anna 1	9/21/84	Seat leakage; improper adjustment of valve stem
3	North Anna 1	11/82	PORV was mechanically "blocked" in the open position; the steel "block" fell out and valve closed
3	North Anna 2	6/24/80	Cocked bearing in valve operator; PORV inadvertently opened and then failed to close; maintenance unknowingly cocked the bearing; the event was attributed to an inadequate procedure
3	Salem 2	6/22/80	Foreign material or dry stroking caused valves not to reseat
3	Sequoyah	10/26/81	PORV leaked due to improper adjustment of stem coupling
4	Connecticut Yankee	4/3/81	Mis-installed connector
4	North Anna 2	5/26/82	Improper regulator adjustment
4	Point Beach 2	9/25/82	Valve in instrument air line closed; PORV was inoperable; bad procedure
4	Robinson 2	12/15/84	Both air and nitrogen to PORVs were isolated; system drawings and procedures in error
4	Sequoyah 1 and 2	4/2/84	PORV indicating lights miswired
4	Surry 1	2/11/83	Instrument air check valve installed backwards

Appendix C

Table C.1 (continued)

Table	Plant	Event date	Description
6	Calvert Cliffs	1/80	PORV actuated on erroneous signal; bumping of pressure transmitter cabinet
6	Calvert Cliffs 1	4/26/83	While troubleshooting, a short circuit (due to technician error) caused loss of control power to PORV
6	Calvert Cliffs 1	7/16/81	PORV actuated on erroneous signal; bumping of pressure transmitter cabinet
6	Ft. Calhoun 1	12/20/78	Technician pulled recorder fuses which opened both PORVs; Operator closed PORVs; defective procedure
6	Palisades	9/71	PORV opened; technician deenergized the RPS breakers, which de-energized power supply to the PORV pilot valve solenoids; nonstandard drawing notation
6	St. Lucie 2	4/24/83	Pressure transmitter was erroneously isolated by unidentified personnel
7	Robinson 2	11/30/81	BV operator did not receive proper PM; BV failed to close
7	St. Lucie 1	4/16/81	BV packing adjusted too tight; BV would not close
7	Summer 1	10/1/82	BV would not reopen after test; packing too tight; overtorque on opening

Appendix D

PORV MANUFACTURERS INTERVIEW SUMMARY

Four PORV manufacturers were contacted and asked to informally respond to a list of questions provided by NRC. The four manufacturers are:

Dresser Industrial Valve Operations	Alexandria, LA
Copes-Vulcan	Lake City, PA
Target Rock Corporation	East Farmingdale, NY
Crosby Valve and Gage Company	Wrentham, MA

Each was visited and interviewed on an informal basis to obtain their response on questions related to PORV manufacturing, installation, testing, maintenance, and operation.

This Appendix contains the questions from the NRC and a summary of the responses from the personnel contacted at each facility. The responses do not necessarily reflect individual corporate policy, but are the result of interviews conducted in an informal, conversational manner.

1. Since 1971, are PORVs constructed to Section III of the ASME Boiler and Pressure Vessel Code? Prior to the introduction of the 1971 Edition of Section III of the Code, were PORVs constructed to codes and standards such as the Draft ASME Code for Pumps and Valves and ANSI B31.1.0?

COPES-VULCAN: Copes-Vulcan PORVs are constructed to ASME Section III pressure-retaining requirements. Prior to 1971, Copes-Vulcan used ASME pump and valve code.	CROSBY: Older versions (HPV-SN) were built to ASME Section III requirements; these are the only PORVs Crosby built for nuclear units. Crosby has a new design (a modified Garrett design) but none have been ordered.	DRESSER: PORVs are constructed to ASME Section III pressure-retaining capabilities but not to Code relieving capacity requirements. Prior to 1971, Dresser PORVs were built to 1968 Article 9 Code.	TARGET ROCK: Yes; Target Rock did not make any PORVs prior to 1971. All have been constructed to ASME Section III Code.

2. Are PORVs Code stamped? If they are not code stamped, what is the reason for not stamping?

COPES-VULCAN: All Copes-Vulcan PORVs for nuclear application are N-stamped ASME Section III, Class I.	CROSBY: Crosby PORVs are code stamped.	DRESSER: Dresser PORVs are N-stamped as pressure boundary. All pre-1971 PORVs are not N-stamped; AEs (NSSS) did not require it in specs.	TARGET ROCK: All PORVs supplied by Target Rock to date have been N-stamped: Bellefonte, Sequoyah, Watts Bar, Midland are also qualified to IEEE-382 (1972), -323 (1974), and -344 (1975).

3. Are PORVs constructed to Seismic Category I requirements?

COPES-VULCAN: Copes-Vulcan supplies Seismic Category I if the customer requests it; Copes-Vulcan provides calculations for seismic design. They have run IEEE qualification tests for certain customers.	CROSBY: Old design had no seismic requirements specified by utility/-NSSS. New design is qualified to Seismic Category I requirements.	DRESSER: Dresser PORVs were not constructed to Seismic Category I requirements; NSSS did not ask for it.	TARGET ROCK: Midland and TVA valves were all qualified to Seismic Class I requirements.

4. Are PORVs constructed in accordance with a Quality Assurance Program in conformance with 10 CFR 50, Appendix B?

COPES-VULCAN: Nuclear PORVs (ASME Section III) are constructed to 10 CFR 50 Appendix B when specified by customer.

CROSBY: Crosby has a QA program in conformance to 10 CFR 50, Appendix B. All nuclear PORVs are constructed to these requirements.

DRESSER: Since 1971, Dresser has applied QA requirements meeting 10 CFR 50 Appendix B.

TARGET ROCK: All Target Rock nuclear PORVs are constructed in accordance with 10 CFR 50 Appendix B requirements.

5. Are the design features of PORVs for nuclear service identical to those for nonnuclear service? If not, describe the differences.

COPES-VULCAN: Nuclear PORVs are identical to similar relief valves in other service. Nuclear units have material traceability, NDE, etc. to meet QA requirements and ASME Section III. Design features and materials meet ASME requirements.

CROSBY: Old version — nuclear and fossil designs are the same except for class H insulation for solenoid. New version — unique design for nuclear use — not used in fossil units due to cost.

DRESSER: The basic design and principle of operation is the same for Nuclear PORVs and commercial-grade PORVs. Nuclear valves have material traceability, NDE, etc. to meet QA requirements and ASME Section III. Most nuclear PORVs have a bellows in the pilot valve to preclude packing leakage to environment.

TARGET ROCK: The design features are similar; however, most non-nuclear service valves are subjected to higher temperatures, and as such utilize different materials.

6. Are there differences in the construction of PORVs for nuclear service compared with the construction of PORVs for non-nuclear service other than that associated with the Quality Assurance Program that is in conformance with 10 CFR 50, Appendix B?

COPES-VULCAN: Nuclear PORVs are identical to similar relief valves in other service. Nuclear units have material traceability, NDE, etc. to meet QA requirements and ASME Section III. Design features and materials meet ASME requirements.

CROSBY: Old version — nuclear and fossil designs are the same except for class H insulation for solenoid. New version — unique design for nuclear use — not used in fossil units due to cost.

DRESSER: The basic design and principle of operation is the same for Nuclear PORVs and commercial-grade PORVs. Nuclear valves have material traceability, NDE, etc. to meet QA requirements and ASME Section III.

TARGET ROCK: Nuclear service valves are qualified to IEEE standards as stated above in #2. PORVs for non-nuclear service receive the same QA program (10 CFR 50, Appendix B) as nuclear service valves.

7. What modifications have been made to PORVs since they have been used in nuclear service? Were these modifications made because of nuclear service?

COPES-VULCAN: Copes-Vulcan experienced minor problems with early units (mid 60s) with trim parts — came out with a "quick-change" trim and resolved problem. No significant modifications made for conditions unique to nuclear service. Copes-Vulcan feels that ASME material requirements limit improvements in nuclear PORVs. They believe they can make a better PORV with newer materials but Code does not allow use of new materials, so nuclear designs are essentially unchanged.

CROSBY: New version — since acquiring the Garrett design, Crosby modified the bonnet joint gasket configuration and the pilot valve seat design to provide better sealing.

DRESSER: PORVs at Oconee and TMI were equipped with heavier springs to allow use down to 50 psi versus nominal 2300 psi design operating pressure; an improved latching device for bottom plug was added on -2 and -3 models. Otherwise no other significant design changes.

TARGET ROCK: Only modifications are to assure compliance with IEEE requirements (#2 above) requires radiation-resistance solenoid insulation. (Supercritical fossil applications are actually tougher valves than nuclear service other than solenoid.)

8. Are any future modifications anticipated for PORVs used in nuclear service?

COPES-VULCAN: No future modifications are planned due to Code restrictions (see #7 above) and diminishing nuclear market.

CROSBY: No modifications planned at this time.

DRESSER: Dresser has developed an improved PORV design to meet IEEE-382, but no prototypes have been made or tested yet; no demand for Environmentally Qualified valves from utilities. Dresser is presently redesigning commercial version of Electromatic — mostly for simpler maintenance and better reliability (fewer parts).

TARGET ROCK: No modifications are planned; present Target Rock nuclear PORV is considered by Target Rock to be superior to other designs.

9. Is there feedback from utilities, architect engineers, or nuclear steam system manufacturers with respect to operational or maintenance problems of PORVs?

COPES-VULCAN: Some early units experienced gasket problems, but Copes-Vulcan resolved these problems long ago. No other feedback from utilities. They rarely hear from AEs or NSSS suppliers.

CROSBY: Utilities — little feedback except occasionally through field service personnel or sales representatives. AEs — no feedback. NSSS — some feedback during start-up phase of plant operation, but little after that.

DRESSER: Utility feedback is variable; they don't always get the complete story on problems that occur, as they (Dresser) hear of problems long after they occur. Some utilities communicate regularly; others are never heard from. AE firms do not order PORVs, hence no feedback. Dresser interfaces with NSSS suppliers on new reactors — they specify valve.

TARGET ROCK: Operational or maintenance problem feedback (if any) comes from utilities. AEs and NSSSs are out of the picture by the time the PORV is operational. Target Rock deals with utilities mostly in spare parts and maintenance.

10. Are you requested by utilities to perform maintenance on PORVs?

COPES-VULCAN	CROSBY	DRESSER	TARGET ROCK
COPES-VULCAN: Copes-Vulcan has a force of service engineers who do perform field maintenance when requested.	CROSBY: Occasionally called in on back-fit jobs, but not on older PORV versions.	DRESSER: Dresser has a field service group that is frequently called to work on PORVs, but at a test facility (like Wyle). They rarely go to plant to work on valves.	TARGET ROCK: On occasion, mostly during start-up to make sure valve is ready for service after handling during shipping, storage, inspection, construction installation, and hookup. Target Rock has experienced cases where valve was shipped in sealed, clean condition only to find valve installed with loose or missing parts, dirt, etc. which has compromised all QA applied by Target Rock to assure unit meets specifications.

11. Do you know if utilities perform maintenance on the PORVs in accordance with your recommendations as the manufacturer?

COPES-VULCAN	CROSBY	DRESSER	TARGET ROCK
COPES-VULCAN: Copes-Vulcan has no feedback from utilities concerning use of Copes-Vulcan procedures/maintenance manuals supplied with valve.	CROSBY: Crosby offers in-house or on-site training for utility personnel for repair and maintenance. They provide all maintenance manuals and procedures for PORVs. They have only experienced one case where utility did not follow Crosby procedures.	DRESSER: All utilities are given Dresser maintenance procedures and should base their maintenance procedures on the Dresser Manual.	TARGET ROCK: Utilities are provided maintenance instructions as part of the contract, but work to date, however, has been conducted by Target Rock personnel.

12. Do you know if utilities utilize replacement parts for PORVs other than those supplied by the original manufacturer of the PORV?

COPES-VULCAN: Copes-Vulcan knows of only a few utilities that have purchased non-Copes-Vulcan parts, but only on other in-plant valves, not PORVs. Pressure boundary parts must be NPT stamped anyway and Copes-Vulcan can provide these. Some "pirate" manufacturers have produced inferior parts (per Copes-Vulcan) but Copes-Vulcan knows of none used in nuclear plants or PORVs.

CROSBY: Crosby has experienced no problems with "outside" replacement parts for PORVs at domestic plants — utilities use vendor-supplied parts.

DRESSER: Dresser knows of no cases where non-Dresser parts were used in their valves.

TARGET ROCK: For N-stamped valves, no; they (utilities) don't normally hold an N-stamp to make parts for PORVs.

13. Are you aware of any indications of boron induced failures or incompatibility with PORVs?

COPES-VULCAN: Copes-Vulcan has not heard of any cases of boron-induced failure or incompatibility of PORV materials with boron.

CROSBY: In 1974 or 1975, Davis-Besse PORV (old Crosby design) had some boron precipitate build-up in discharge passages of pilot valve — it was cause of valve sticking open. Seat leakage through a relatively cold valve caused precipitation. No problems experienced on new units to date.

DRESSER: Dresser has observed no cases of boron-induced failures in their PORVs; but field service personnel only see valves at test facility, where it has been cleaned and decontaminated for shipping and testing.

TARGET ROCK: Target Rock has no information regarding boron-induced failure of their PORVs.

14. Does orientation, location or nuclear service operating environments/operations of the PORV in the reactor coolant system present a concern from your viewpoint as a PORV manufacturer?

COPES-VULCAN: Some piping configurations in nuclear plants (a "U" bend before PORV) cause water to collect in bend. When PORV lifts, relatively cool water passes through valve followed by two-phase steam/water at higher temperatures and supersonic velocity. Such conditions seriously stress valve internals and can lead to leakage. Problem is generally plant-specific.

CROSBY: Crosby designs valve to specifications. Most specs call for "upright" orientation, so no problems with orientation.
<u>Location</u> — valve should be located to see either full steam pressure (loop seal) or water (<300°F) with a loop seal configuration. If there is a loop seal that permits water greater than 300°F to collect, when the PORV is operated, the two-phase water/steam flow through the valve can wire-draw the seat. On the other hand, a loop seal that upon operation introduces cool water first, then progressively hotter water, then steam, can place high thermal stress on valve. Preferred location is with no loop seal so only steam passes through valve.

DRESSER: Dresser PORV is designed to operate in specified system and environmental conditions. In early years, some utilities operated valves in environmental temperatures higher than specified by NSSS, but this is no longer a problem. (Mostly affected safety valves, not PORVs.) The construction practice of "jacking" piping into place to mate with PORV has caused problems in the past.

TARGET ROCK: PORV orientation is important for Target Rock units. Target Rock prefers a mounting that positions solenoid about 10° below horizontal (or better) to allow water to collect in bonnet, which keeps solenoid cooler than if mounted vertically upward. Other nuclear service conditions are not considered a problem.

15. To what extent have human factors considerations, such as procedures and maintenance practices, affected PORV failures?

COPES-VULCAN: No experience or feedback regarding human factors.

CROSBY: Only one case Crosby knows of — maintenance people did not read Crosby procedure. Have heard of cases where "generic" procedures were used on PORVs — with consequential problems.

DRESSER: Dresser field service personnel stated that they rarely see cases of mismaintenance; only recalled one instance of a valve damaged by poor maintenance.

TARGET ROCK: Since there is no periodical maintenance required on Target-Rock PORVs, there is little chance of human error in normal operation. Most problems occur during construction and start-up phase (see #10).

16. What are the failure mechanisms of the PORVs?

COPES-VULCAN: Galling, disk/seat leakage (thermal transients), seat cutting from two phase flow.

CROSBY: Human-induced mismaintenance — cases where "generic" procedures were used on PORVs — with consequential problems.

DRESSER: Observed failure mechanisms have been: pilot leakage (rare), pilot bellows leakage (rare), seat leakage, pin corrosion (rare), binding of solenoid bearings.

TARGET ROCK: Target Rock considers seat/disc "wire drawing" as most common.

17. What are the failure modes of the PORVs?

COPES-VULCAN: Leakage mostly — no cases of stuck open or closed.

CROSBY: In the case of human-induced mismaintenance — the valve stuck open.

DRESSER: Observed failure modes have been seat leakage, failure to operate (solenoid burned out or insufficient power to operate solenoid).

TARGET ROCK: Seat/disc "wire drawing" causing seat leakage.

18. Is the control system for the PORV supplied as part of the PORV overall system?

COPES-VULCAN: Copes-Vulcan does not provide control systems.

CROSBY: Crosby does not provide control systems for nuclear PORVs.

DRESSER: Dresser has not supplied PORV controls for PWRs; they do supply them for commercial applications.

TARGET ROCK: Not on nuclear applications.

19. Do you know if utilities use control systems that are supplied by other than the PORV manufacturer?

COPES-VULCAN: Controls usually provided by NSSS supplier.

CROSBY: Controls usually provided by NSSS supplier.

DRESSER: PWR utilities have PORV controls generally designed by NSSS supplier and supplied by NSSS.

TARGET ROCK: Nuclear utilities usually have their PORV controls designed by NSSS and/or AE.

20. To what extent would upgrading of control systems for PORVs to safety-related status provide an increase in the reliability and operability or PORVs?

COPES-VULCAN: Copes-Vulcan had no comment.

CROSBY: No comment — Crosby does not provide control systems for nuclear PORVs.

DRESSER: On PWRs, only portion of PORV Dresser would have to upgrade would be the solenoid - possibly use a redundant (dual) solenoid design. Dresser has not provided nuclear PORV controls.

TARGET ROCK: Target Rock has no opinion — feels their valve as supplied is extremely reliable. Designation of safety-related would have no effect on design — they are already ASME Section III and IEEE qualified; also Seismic Category I.

21. To what extent would upgrading of PORVs to safety-related status provide an increase in the reliability and operability of PORVs?

COPES-VULCAN: Upgrading PORV itself would not effect any change in design or materials — valve would be the same.	CROSBY: New version Crosby PORVs meet IEEE-323, 344, & 382 standards for safety-related components. Crosby feels that new version (modified Garrett design) is extremely reliable.	DRESSER: Possible improvement using redundant solenoid — but in their experience, solenoids have not failed very often.	TARGET ROCK: Little difference in safety-related valves; Target Rock feels their PORV is reliable as is.

22. To your knowledge, are your installation, operating and preventive maintenance instructions followed?

COPES-VULCAN: Copes-Vulcan has no feedback on this subject.	CROSBY: Yes in most cases; see #15 above.	DRESSER: Yes.	TARGET ROCK: Installation procedures — see #10. Operating and preventive maintenance instructions are generally followed — occasionally Target Rock provides special instructions if asked by utility.

23. Give a brief description of the level of equipment qualification that has been performed on your PORVs. Please list the standards, such as IEEE-323, IEEE-344, etc. to which you have qualified your PORVs and the approximate dates of completion of your Environmental Qualification program.

COPES-VULCAN: Although PORV as a whole has not been tested in IEEE-323, various supplied components are qualified — limit switches, solenoid valves, etc. Some actuators are qualified, but they were used in other nuclear systems, not PORV.

CROSBY: Crosby PORVs (new version) meet IEEE-323, 344 and 382 standards.

DRESSER: No Environmental Qualification has been done on PORVs from Dresser — was never part of specification.

TARGET ROCK: The Target Rock PORV has been qualified to IEEE 323-1974, 344-1974, and 382-1972 and 1980. The Target Rock Solenoid Valve Qualifications are directly applicable to the Target Rock PORV, and in addition, the PORV was subjected to a separate qualification program for B&W.

24. Of the PORVs you have supplied, were any purchased specifically to perform safety-related "active" functions; that is, they must open and/or close under normal, upset, and faulted conditions?

COPES-VULCAN: Only one AE specified the PORV as safety-related — it was for a foreign plant. No domestic plants have specified a safety-related PORV from Copes-Vulcan.

CROSBY: All new version PORVs supplied perform "active" functions and meet safety-related requirements (see #21).

DRESSER: None.

TARGET ROCK: The valves supplied to TVA were required to perform safety-related functions.

25. Do you, as a PORV manufacturer, have any suggestions or recommendations regarding the use of PORVs for safety-related service in PWRs? Do you feel they are suitable for this type of service?

COPES-VULCAN: Copes-Vulcan has better materials available for PORVs, but Code and E-Specs do not allow use. Same materials have been used in PORVs for years. See #7.

CROSBY: Correct maintenance is key to PORV reliability — Crosby feels most problems come from mismaintenance.

DRESSER: Dresser suggests use of Environmentally Qualified solenoids or redundant solenoids; otherwise no changes. They feel their valves have operated satisfactorily and are suitable for nuclear service. Operating conditions are not significantly different from commercial units.

TARGET ROCK: Target Rock feels that more frequent testing while in service will result in higher reliability. The Target Rock valves are designed specifically for this service and will not suffer deleteriously when subjected to frequent testing.

Appendix E

SUMMARY OF EPRI-RECOMMENDED TESTING, DIAGNOSTIC, AND MAINTENANCE PRACTICES FOR PORVs AND BVs

- Use of a planned maintenance/refurbishment program based on detailed, written procedures which are either furnished by the valve manufacturers or written by the plant maintenance personnel based on manufacturers' guidelines.

- Bench testing to verify operability and leaktightness of the valves before they are reinstalled on the pressurizer to permit deficiencies to be corrected without affecting plant availability. Note that the bench testing should simulate as-installed valve conditions (e.g., valve orientation, valve body temperature) as close as practicable.

- Engineering tracking and evaluation of valve failures at the plant and applicable experience at other plants in order to identify required modifications to achieve more reliable performance.

- Performance of valve surveillance tests based on the requirements of ASME Section XI, Subsection IWV. This periodic exercising during plant shutdowns permits valve operational deficiencies to be identified in a manner which minimizes the impact on plant operations.

NUREG/CR-4692
ORNL/NOAC-233
Dist. Category AN, RM

Internal Distribution

1. H. E. Trammell
2. J. R. Merriman
3. J. R. Buchanan
4. G. T. Mays
5. D. M. Eissenberg
6. W. L. Greenstreet
7. A. P. Malinauskas
8-10. J. W. Cletcher II
11-16. G. A. Murphy
17. H. D. Haynes
18. D. Hendrix
19. ORNL Patent Office
20. Central Research Laboratory
21. Document Reference Section
22-33. Laboratory Records Department
34. Laboratory Records (RC)
35-37. Nuclear Operations Analysis Center
38. J. A. Getsi

External Distribution

39-41. J. R. Zahorsky, Crosby Valve Company, 43 Kendrick Street, Wrentham, MA 02093
42-44. Vito Liatonio, Target Rock Corporation, 1966 East Broadhollow Road, East Farmingdale, NY 11735
45-47. N. E. Matson, Copes-Vulcan Inc., P. O. Box 577, Lake City, PA 16423-0577
48-50. Steve Danielson, Dresser Industries, P. O. Box 1430, Alexandria, LA 71309-1430
51. S. P. Carfagno, Franklin Research Center, 20th & Race Streets, Philadelphia, PA 19103
52. B. M. Morris, Division of Engineering Technology, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, 5650 Nicholson Lane, Rockville, MD 20852
53-55. J. P. Vora, Division of Engineering Technology, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, 5650 Nicholson Lane, Rockville, MD 20852
56. V. P. Bacanskas, Franklin Research Center, 20th & Race Streets, Philadelphia, PA 19103
57-59. W. S. Farmer, Division of Engineering Technology, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, 5650 Nicholson Lane, Rockville, MD 20852
60. F. C. Cherny, Engineering Issues Branch, Office of Research, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555
61-63. R. Kirkwood, Engineering Issues Branch, Office of Research, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555
64. C. Michelson, ACRS, 20 Argonne Plaza, Suite 365, Oak Ridge, TN 37830
65. Office of Assistant Manager for Energy Research and Development, Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN 37831
66-67. Technical Information Center, Department of Energy, Oak Ridge, TN 37831
68-327. Given distribution as shown in NRC categories AN and RM.

NRC FORM 335 (2-84) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

SEE INSTRUCTIONS ON THE REVERSE

1 REPORT NUMBER (Assigned by TIDC, add Vol No., if any)
NUREG/CR-4692
ORNL/NOAC-233
Dist. Category AN, RM

2 TITLE AND SUBTITLE
Operating Experience Review of Failures of Power Operated Relief Valves and Block Valves in Nuclear Power Plants

3 LEAVE BLANK

4 DATE REPORT COMPLETED

MONTH	YEAR
July	1987

5 AUTHOR(S)

G. A. Murphy
J. W. Cletcher II*
*PAI, Incorporated

6 DATE REPORT ISSUED

MONTH	YEAR
August	1987

7 PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)

Oak Ridge National Laboratory
Post Office Box Y
Oak Ridge, Tennessee 37831

8 PROJECT/TASK/WORK UNIT NUMBER

9 FIN OR GRANT NUMBER
B0828

10 SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)

Division of Engineering Technology
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

11a TYPE OF REPORT
Topical

b PERIOD COVERED (Inclusive dates)

12 SUPPLEMENTARY NOTES

13 ABSTRACT (200 words or less)

This report contains a review of nuclear power plant operating events involving failures of power-operated relief valves (PORVs) and associated block valves (BVs). Of the 232 events identified, 103 involved PORV mechanical failure, 91 were attributable to PORV control failure, 6 events involved design or fabrication of the PORVs, and 32 events involved BV failures. The report contains a compilation of the PORV and BV failure events including failure cause and severity. The events are identified as to plant and valve manufacturer. An assessment of the need to upgrade PORVs and BVs to safety-grade status concludes that such action would improve PORV and BV reliability. The greatest improvement in reliability would result from using newer, more reliable PORV designs and improving testing, diagnostics and maintenance applied to PORVs and BVs, particularly the BV motor operator. A summary of interviews conducted with four PORV manufacturers is also included in the report.

14 DOCUMENT ANALYSIS – a. KEYWORDS/DESCRIPTORS

Valves, maintenance, degradation, failure mode, failure cause, operating experience, relief valves, aging, service wear

b. IDENTIFIERS/OPEN-ENDED TERMS

15 AVAILABILITY STATEMENT
Unlimited

16 SECURITY CLASSIFICATION
(This page)
Unclassified
(This report)
Unclassified

17 NUMBER OF PAGES

18 PRICE