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NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
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ACRS Members
ACRS Staff

SUMMARY OF REACTOR COOLANT RELIEF SYSTEMS IN OPERATING U.S. LWRs

Based on previous operating history, the probability of a small break LOCA due to activation of a power-operated relief valve (with its block valve open) is 0.1 per reactor year for B&W PWRs (NUREG-0560). Sixty inadvertent blowdowns have occurred in BWRs. The BWR main steam pressure relief systems do not have block valves. This report contains a general description and operating history of these systems.

John G. Stampelos
ACRS Fellow

Attachments:
1. Summary of PWR Pressurizer Relief Systems
2. Summary of BWR Main Steam Relief Systems

cc: ACRS Fellows

SUMMARY OF PWR PRESSURIZER RELIEF SYSTEMS

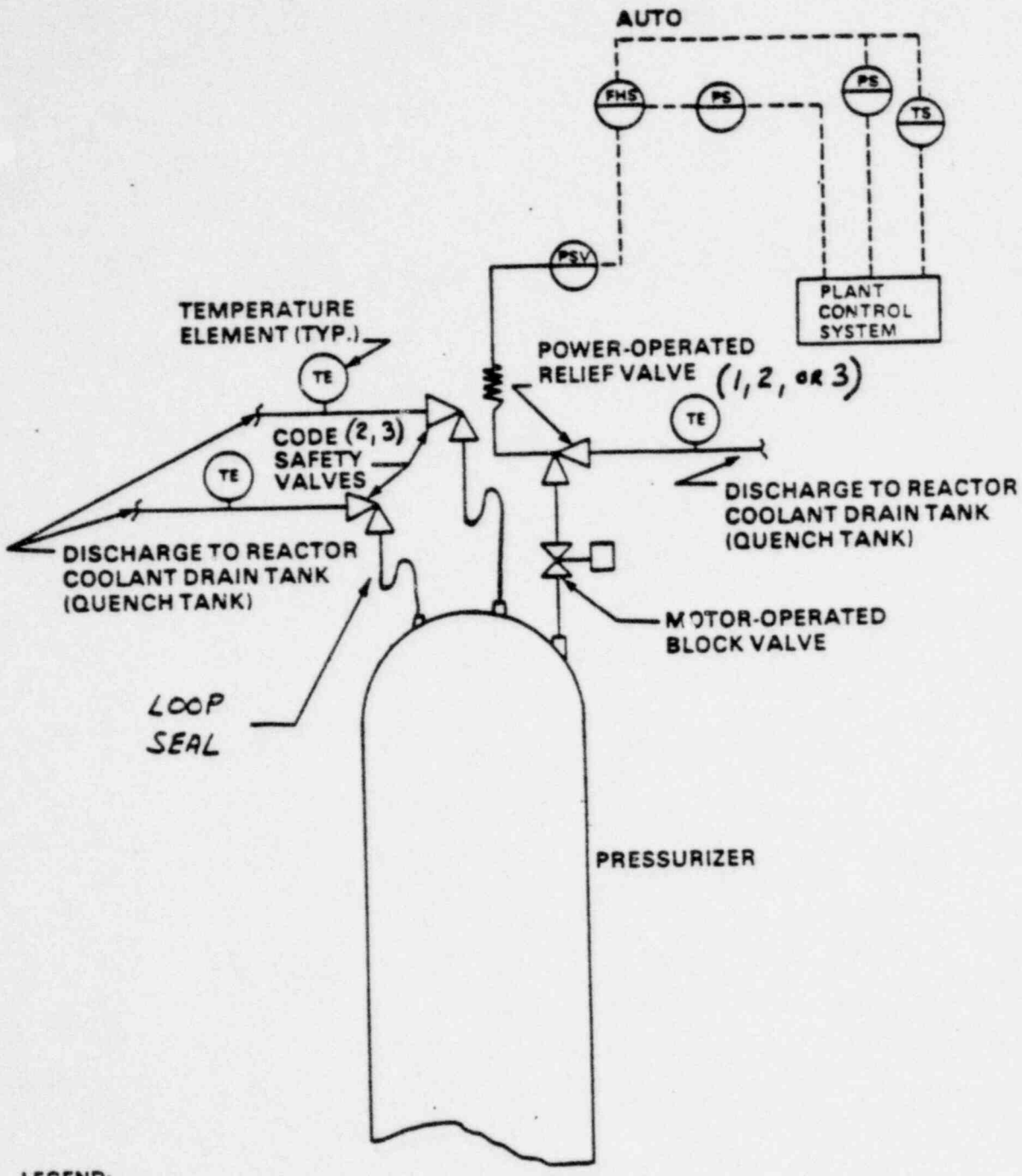
The pressurizer pressure relief system (Figure 1) consists of from two to three spring-loaded backpressure compensated safety valves (Figure 2) and up to three (generally one or two) power-operated relief valves (Figure 3). The safety valves are required for overpressure protection by the ASME Boiler and Pressure Vessel Code. The power-operated relief valve does not contribute to the required relieving capacity of the reactor system but enhances plant availability. The power-operated relief valves limit the lifting frequency of the safety valves and are used to provide overpressure protection during operation at low temperatures. The setpoint of the safety valve is nominally 2500 psig. The setpoint of the power-operated relief valve is nominally 2450 psig.

The safety valves (Figure 2) operate against the force of spring pressure. A water loop seal is provided to minimize valve leakage. The power-operated relief valve (Figure 3) is a pilot-operated valve. This valve can be operated either manually or automatically by a mode selection switch located in the control room. Reactor coolant system pressure from chamber I (in Figure 3) leaks pass the valve disc guide into chambers II, III, and IV. The valve disc (#2) is held shut by this pressure and the force of the valve spring (#4). When actuated, the solenoid lifts the pilot valve disk (#13) which vents the reactor coolant system pressure in chamber II through chamber IV and into the atmosphere. The main valve disc (#2) moves down and opens. A block valve is provided upstream of the power-operated relief valves in case of failure. Leakage of the power-operated relief valves may be indicated by temperature detection on the valves exhaust pipe, valve position indication detectors, and quench tank level and pressure. The position indicator only indicates whether the solenoid is energized. The safety valves do not have block valves.

The operating history of the spring-loaded safety valves has been unremarkable. The history of the power-operated relief valves is summarized in NUREG-0560 for B&W plants (Table 1). A review (NUREG-0560) of the LERs dealing with feedwater types of transients has indicated that three events have occurred in B&W plants in which these valves have stuck open. There has been about 150 occasions in which pressurizer relief valves have actuated in B&W plants yielding a failure rate of 2×10^{-2} per event and a probability of a small break LOCA of about 0.1 per reactor-year if the block valve is not closed. The control circuits for relief valves are currently not single failure proof. A single failure in the control circuits can result in a small break LOCA.

The setpoint pressure of power-operated relief valves has been changed from 2255 psig to 2450 psig because of TMI-2. This should reduce the actuation rate of these valves. The setpoint for the other vendors was around 2450 psig before the TMI-2 experience. The reactor trip setpoint varies from 2300 psig to 2385 psig depending on the vendor.

Attachments:
As stated



LEGEND:

⊖ – PANEL MOUNTED IN CONTROL ROOM
PSV – PRESSURE RELIEF VALVE
FHS – FLOW HAND-ACTUATED SWITCH
PS – PRESSURE SWITCH
TE – TEMPERATURE ELEMENT
TS – TEMPERATURE SWITCH

ADAPTED FROM NUREG-0560

FIGURE 1: TYPICAL PWR PRESSURIZER PRESSURE RELIEF SYSTEM

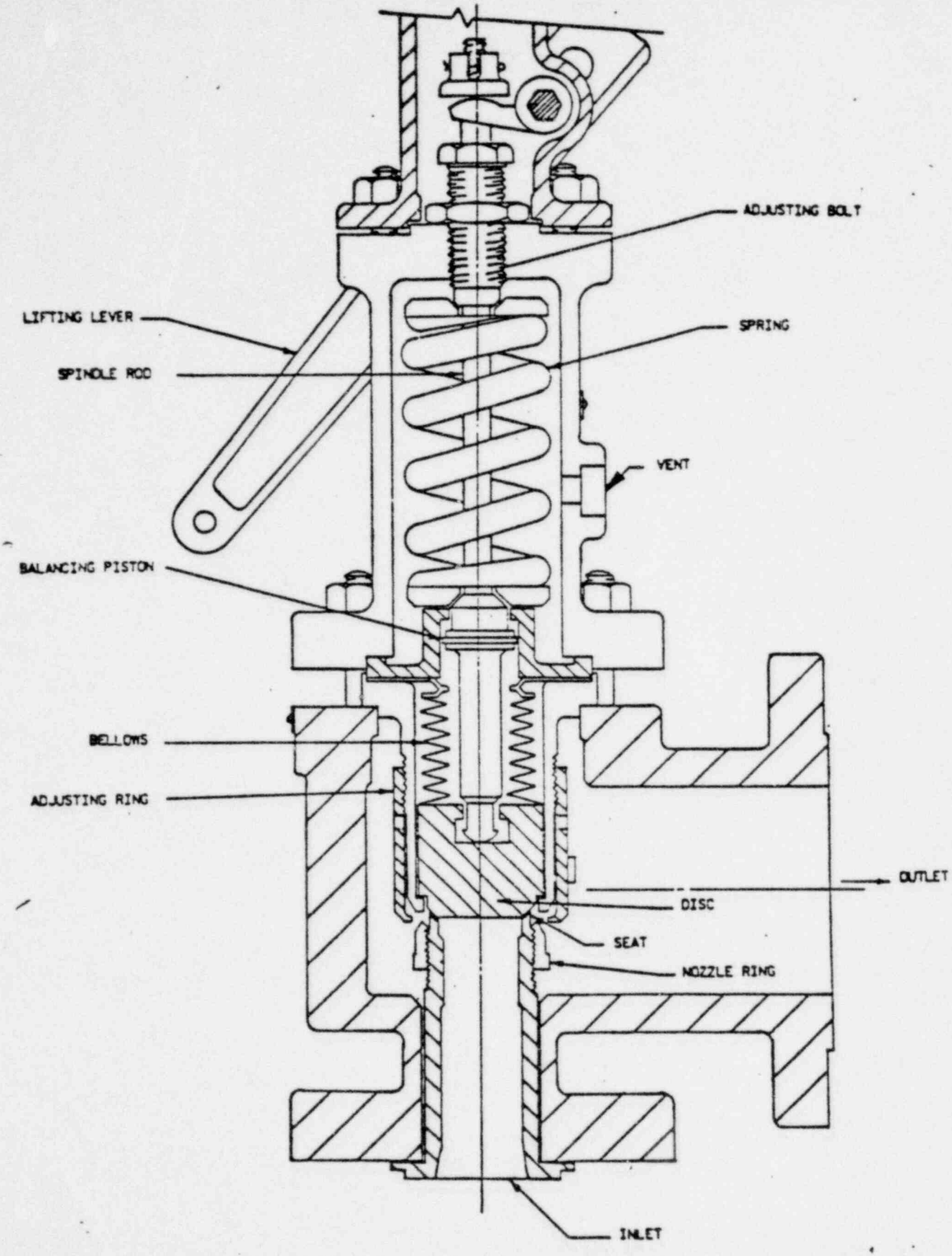
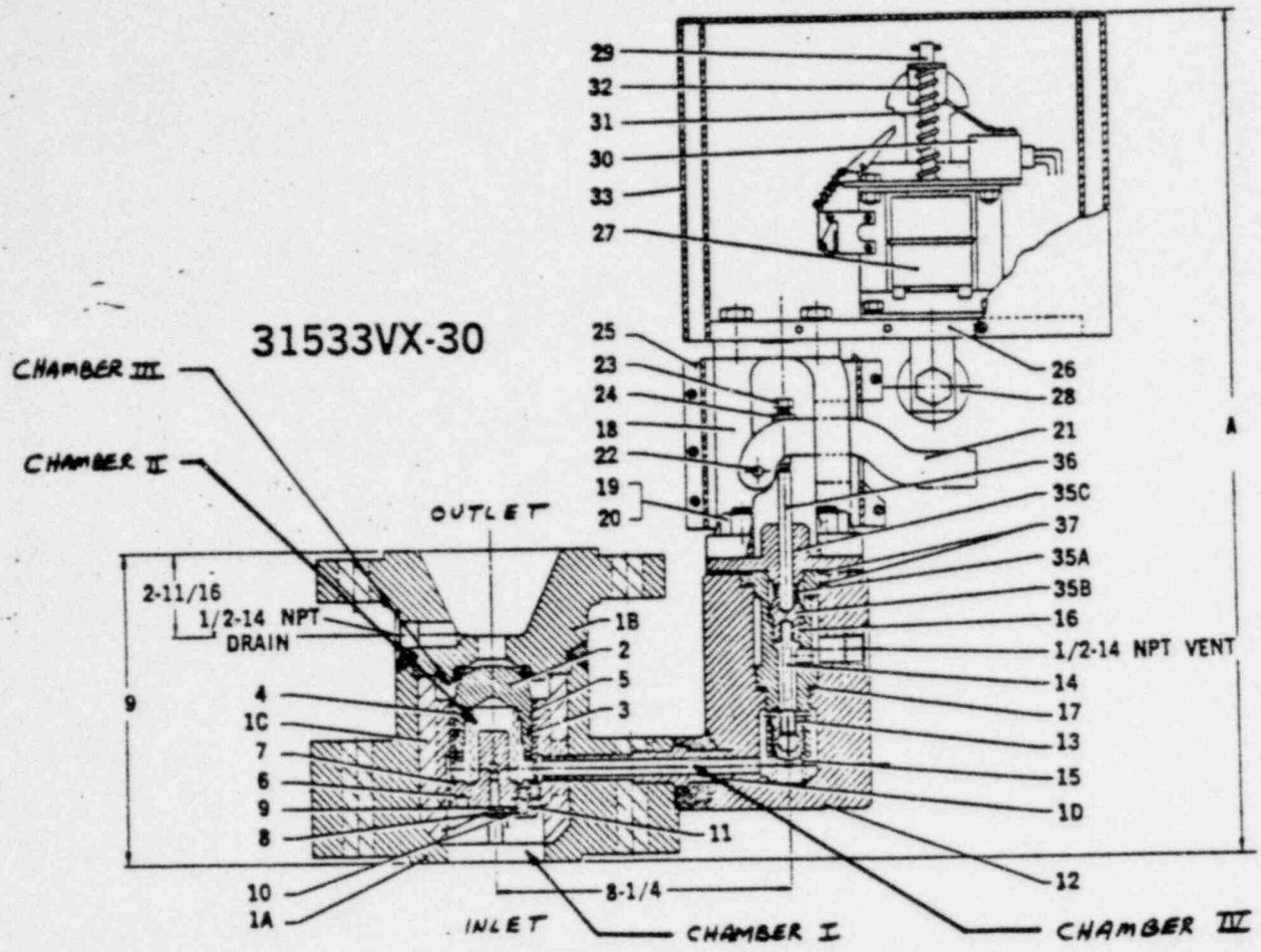


FIGURE 2: TYPICAL PRESSURIZER SPRING-LOADED SAFETY VALVE



PART NO.	MATERIALS
1 Base Assembly	
1A Lower Base	ASME SA182 F316, Stainless Steel
1B Top Flange	ASME SA182 F316, Stainless Steel
1C Cage	ASTM A351 CA15 CF8M
1D Tube Insert	ASME SA182 F316, Stainless Steel
2 Disc	ASTM A565 Gr. 616, Stainless Steel, Condition T
3 Piston Ring	AISI 420, Hardened Stainless Steel
4 Disc Spring	Inconel X-750
5 Guide	AWS-5387 R-CoCr-A
6 Guide Retaining Plug	ASTM A276 Gr. 414, Stainless Steel
7 Guide Gasket	AISI 304, Stainless Steel
8 Lock Screw	AISI 304, Stainless Steel
9 Lockscrew Lockwasher	AISI 410, Stainless Steel
10 Retaining Lockscrew	AISI 304, Stainless Steel
11 Retaining Screw Lockwasher	AISI 410, Stainless Steel
12 Pilot Base	ASME SA182 F316
13 Pilot Disc	ASTM A565 Gr. 616, Stainless Steel
14 Lower Spindle	ASTM A565 Gr. 616, Stainless Steel
15 Pilot Disc Spring	Inconel X-750
16 Pilot Seat Bushing	ASME SB166
17 Seat Bushing Gasket	AISI 304, Asbestos
18 Solenoid Bracket	ASTM A216 WCB, Carbon Steel (Cadmium Plated)
19 Bracket Stud	ASME SA193 Gr. B16

PART NO.	MATERIALS
20 Bracket Stud Nut	ASME SA194 Gr. 4
21 Lever	ASTM A216 WCB, Carbon Steel, (Zinc Plated)
22 Lever Pin	Carbon Steel (Cadmium Plated)
23 Adjusting Screw	AISI 416, Stainless Steel, (Zinc Plated)
24 Locknut	Carbon Steel, (Zinc Plated)
25 Bracket Cover	AISI 302, Stainless Steel
26 Solenoid Plate	AISI C1019, (Zinc Plated)
27 Solenoid	
28 Solenoid Plunger Head	Carbon Steel, (Zinc Plated)
29 Plunger Assembly	
Guide Plate	ASTM A479 TP 430
Spring Guide	Brass Tube
30 Unimax Switch	KBL-7-HB5
31 Plunger Spring	#24 Ga. Music Wire, (Cadmium Plated)
32 Spring Bracket	Carbon Steel, (Zinc Plated)
33 Solenoid Cover	Carbon Steel, (Painted)
34 Spring Cover	Carbon Steel, (Zinc Plated)
35 Bellows Assembly	
35A Bellows	AM 350 Stainless Steel
35B Bellows Piston	ASME SA479 Gr. 316L, Stainless Steel
35C Bellows Flange	ASME SA479, Gr. 316L, Stainless Steel
36 Upper Spindle	ASTM A565, Gr. 616, Stainless Steel
37 Upper Seat Bushing Gaskets	AISI 304, Asbestos

FIGURE 3: TYPICAL PWR PRESSURIZER POWER-OPERATED RELIEF VALVE

TABLE 1 : CODE SAFETY-RELIEF VALVES AND POWER-OPERATED RELIEF VALVES ON PRESSURIZER FOR B&W PLANTS

Valves for B&W Plants	Arkansas 1	Crystal River 3	Davis-Besse 1	Oconee 1	Oconee 2	Oconee 3	Rancho Seco	Three Mile Island 1	Three Mile Island 2
Code Safety-Relief Valves									
Mfg	Dresser	Dresser	Crosby	Dresser	Same	Dresser	Dresser	Dresser	Same
Number	2		2	2		2	2	2	
Type	Spring-loaded	Spring-loaded	Spring-loaded	Spring-loaded		Spring-loaded	same	Spring-loaded	
Model no.	3-31759A	2½ - 31739A	3XM1X6, Type H886	2½ -31739A		2½-31739A		2½-31739A	
Size	3" x 6"	2½" x 6"	4" x 6"	2½" x 6"		2½" x 6"		2½" x 6"	
Relief cap.	311,733 #/hr	311,733 #/hr		311,973 #/hr		317,973 #/hr		280,000 #/hr	
Set press.	2500 psig	2500 psig		2500 psig		2500 psig		2500 psig	
Reseat press. (approx.)	2375	2375		2375		2375		2450	2475
Known malf. (significant)	None	None	None	None		None		None	None
Power-Operated Relief Valves									
Mfg	Dresser	Dresser	Crosby	Dresser	Same	Dresser	Dresser	Dresser	Same
Number	1	1	1	1		1	1	1	
Type	Electromatic	Electromatic	Electromatic	Electromatic		Electromatic		Electromatic	
Model no.	31533VX-30	Same	HPV-ST	31533 VX-30		31533VX-30		31533VX-30	
Size	2½" x 4"		2½" x 4"	2½" x 4"		2½" x 4"		2½" x 4"	
Relief cap.	106,450 #/hr	100,000 #/hr	112,000 #/hr	100,000 #/hr		100,000 #/hr	112,000 #/hr	106,450 #/hr	
* Set press.	2300 psig *		2235 psig *	2300 psig *		2300 psig *		2300 psig *	
Reseat press.						2220 psig		2250 psig	
Malf. date (significant)	9/1/74	None	9/24/77	None	None	June 1975	June 1978	None	3/29/78
cause	Improper venting		Steam pilot valve system			Boric acid crystal buildup, bent lever on pilot valve	Valve leakage		De-energized vital bus
Fail position	Closed (Class 1E)	Closed (1E)	Closed (non-1E)	Closed (non-1E)			Closed (non-1E)	-	
Position Ind.	Yes (Pilot-red/green)	Yes (open-closed)	Yes (on pilot-red/green lights)	Yes (open-closed)			No	Pilot-red green	
Thermocouple ind. and alarm	Yes (computer)	Yes (computer)	Yes (computer)	Yes (computer)			Yes (computer)	Yes	
Thermocouple type and location	Strap-on	Well/~50 ft from valve	Strap-on/ ~1 ft	Strap-on/6 7 ft downstream			Strap-on/40 ft from valve		
Block Valve									
Mfg.	Velan	Dresser	Velan	Westinghouse	Same	Same	Velan		
Type	Motor-operated	Motor-operated	Motor-operated	Motor-operated			Motor-operated	Motor-operated	Same
Fail position	As-is (non-1E)	As-is (1E)	As-is (non-1E)	As-is (non-1E)			As-is (non-1E)	-	
Pos. indication	Yes	Yes	Yes	Yes			Yes	Yes	

SOURCE : NUREG 0560

* SETPOINT PRESSURE RAISED FROM 2255psig TO 2450psig by IE BULLETIN 79-05B

SUMMARY OF BWR MAIN STEAM RELIEF SYSTEMS

The main steam pressure relief system (Table 1) for U.S. BWRs include a total combination of from 6 to 22 safety/relief valves (SRVs), spring-loaded safety valves (SVs), and/or power actuated relief valves (PARVs).

Valve Setpoints

1.	spring-loaded safety valves (SVs)	1225 psig
2.	power actuated relief valves (PARVs)	1130 psig
3.	safety/relief valves (SRVs)	1025-1155 psig*

* depends on the plant and the total number of valves employed in the system

A specific number of PARVs or SRVs, in addition to providing overpressure protection, are utilized in the automatic depressurization system (ADS). The ADS is part of the Emergency Core Cooling System. Generally, the ADS is actuated on the simultaneous receipt of a high drywell pressure, reactor vessel low water level, and indication of output pressure from one low pressure core injection or core spray pump signal.

Most SVs discharge directly to the containment drywell whereas the PARVs and the SRVs discharge to the suppression pool. The pressure relief system valves do not have blocking valves. The safety valves (Table 1) are required to provide overpressure protection by the ASME Boiler & Pressure Vessel Code. The relief system valves have leakage indication and alarms via temperature monitoring devices located near the valve exhaust tail pipes. The older design SRVs have a bellows leakage alarm for their pilot stage.

A typical spring-loaded SV (Figure 1) actuates when reactor coolant pressure exceeds the spring pressure. A typical PARV is shown in Figure 2. Main steam in chamber A passes upward around the disk guide into chamber B. In addition, main steam normally pressurizes chamber C via a clearance space between the main valve disc and disc guide. The main valve spring and the steam pressure in chamber C hold the main valve disc shut. PARV actuation is accomplished by energizing the solenoid in the pilot valve which vents the steam in chamber C to the atmosphere. The subsequent differential pressure (between chamber C and chamber B) forces the main valve disc to drop down and open the valve.

The SRVs are typically of two designs. Most BWR plants employ the older 3-stage SRV design (Figure 3). The main valve disk is held in the closed position by the force of the main valve preload spring and main steam pressure acting on the main valve piston (the chamber behind the main valve piston is pressurized through the main valve piston orifice). The main valve disc opens when the second stage piston moves down allowing main steam pressure to bleed from behind the main valve piston. The second stage piston moves down when main steam pressure is sufficient to move the pilot stage piston disc to the right and pressurize the chamber immediately above the second stage piston. This 3-stage SRV has had a significant number of inadvertent blowdown events (Table 2 and Table 5).

The major cause of spurious openings or failures of the 3-stage SRV to reseat has been excessive pilot valve leakage. The principal strategy to assure that pilot leakage is minimized involves increasing the simmer margin, performing more frequent valve maintenance, and replacement with the new 2-stage SRV design. (The simmer margin is the differential pressure between normal system operating pressure and the valve setpoint.) The new 2-stage design (Figure 4) has an improved pilot section design and no second stage piston.

As of April 12, 1979, twenty 3-stage valves have been replaced with the new 2-stage design and ten more are committed to be replaced. Hatch Unit 1, Fitzpatrick, and two of the reactors at Browns Ferry have replaced some of their 3-stage valves with the new design. There have been no inadvertent blowdowns to date with the new 2-stage design. In addition to the mechanical failures associated with the 3-stage valves, several failures of the pneumatic diaphragm operator have occurred. Excessive heating caused by extended service life and improper thermal insulation were the cause. Yearly diaphragm replacement should correct the problem.

The NRC, as part of its continuing program for monitoring safety/relief valve performance, has requested all BWR licensees to provide an operations and maintenance history for each of their safety/relief valves manufactured by Target Rock Corp. The response of the licensees is due September 16, 1979.

Attachments:
As stated

TABLE 1

BWR TYPE	FACILITY	VALVE COMPLEMENT		
		SAFETY/RELIEF VALVES	SAFETY VALVES	POWER-ACTUATED RELIEF VALVES
2	Nine Mile Point	-	16	6
2	Oyster Creek	-	16	5
3	Dresden 2	1	8	4
3	Dresden 3	1	8	4
3	Millstone 1	6	-	-
3	Monticello	7	-	-
3	Pilgrim 1	4	2	-
3	Quad Cities 1	1	8	4
3	Quad Cities 2	1	8	4
4	Browns Ferry 1	11	2	-
4	Browns Ferry 2	11	2	-
4	Browns Ferry 3	11	2	-
4	Brunswick 1	11	-	-
4	Brunswick 2	11	-	-
4	Cooper	8	3	-
4	Duane Arnold	6	2	-
4	Fitzpatrick	11	-	-
4	Hatch 1	11	-	-
4	Peach Bottom 2	11	2	-
4	Peach Bottom 3	11	2	-
4	Vermont Yankee	4	2	-

SOURCE: NUREG-0462

TABLE 2

Inadvertent Blowdowns Events

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
ns Ferry 1						2	1		2			5
ns Ferry 2						2	1			2		5
ns Ferry 3										3		3
nswick 1										1	1	2
nswick 2							2	1	1			4
per						4						4
esden 2								1				1
esden 3												
ane Arnold												
itzpatrick								3				3
atch 1							1	1	3			5
illstone 1				1			1		1	1	1	5
onticello				1	1					2		4
ine Mile Pt. 1						1*						1
Oyster Creek					1*							1
Peach Bottom 2							3	1	2	1		7
Peach Bottom 3									2		1	3
Pilgrim 1					2	1		1			1	5
Quad Cities 1										2*		2
Quad Cities 2												
Vermont Yankee												
TOTAL	0	0	2	4	2	11	8	10	10	10	3	

*Power Actuated Relief Valve

SOURCE: NUREG-0462 (JULY 1978), UPDATED TO JULY 1979

TABLE 3

Failures to Open Properly on Demand

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
Browns Ferry 1												
Browns Ferry 2												
Browns Ferry 3												
Brunswick 1												
Brunswick 2												
Cooper												
Dresden 2		3*					2*		1*			6
Dresden 3					1*	1*						2
Duane Arnold						1						1
Fitzpatrick												
Hatch 1									2			2
Millstone 1												
Monticello				2				1				3
Nine Mile Point	1*											1
Oyster Creek					1*				1*			2
Peach Bottom 2						1						1
Peach Bottom 3												
Pilgrim 1									2			2
Quad Cities 1								1*	1*	2*		4
Quad Cities 2								1*	2*	1		4
Vermont Yankee						1		1				2
TOTAL	1	3	0	2	2	4	2	4	9	3		

*Power Actuated Relief Valve

SOURCE: NUREG-0462 (JULY 1978), UPDATED TO JULY 1979

TABLE 4

Potential Failures to Open Properly

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
Browns Ferry 1					1							1
Browns Ferry 2												
Browns Ferry 3												
Brunswick 1												
Brunswick 2							1				1	2
Cooper							1	1				2
Dresden 2												
Dresden 3												
Duane Arnold									1	1		2
Fitzpatrick								1				1
Hatch 1								1	1			2
Millstone 1							1				1	2
Monticello												
Nine Mile Point									1*			1
Oyster Creek												
Peach Bottom 2					1	2			1			4
Peach Bottom 3											1	1
Pilgrim 1												
Quad Cities 1												
Quad Cities 2												
Vermont Yankee				2						1	1	4
TOTAL	0	0	0	2	2	2	3	3	4	2	4	

*Power Actuated Relief Valve

SOURCE: NUREG-0462 (JULY 1978), UPDATED TO JULY 1979

TABLE 5

Event Type	Safety/Relief Vavles	Power Actuated Pressure Relief Valves	Total
Inadvertent Blowdowns	56	4	60
Failures to Open	12	18	30
Potential Failures to Open	21	1	22

NOTE: SPRING-LOADED SAFETY VALVES (SVs) ARE NOT INCLUDED IN THIS TABLE BECAUSE THEIR OPERATING HISTORY HAS BEEN RELATIVELY GOOD.

SOURCE: NUREG-0462 (JULY 1978), UPDATED TO JULY 1979

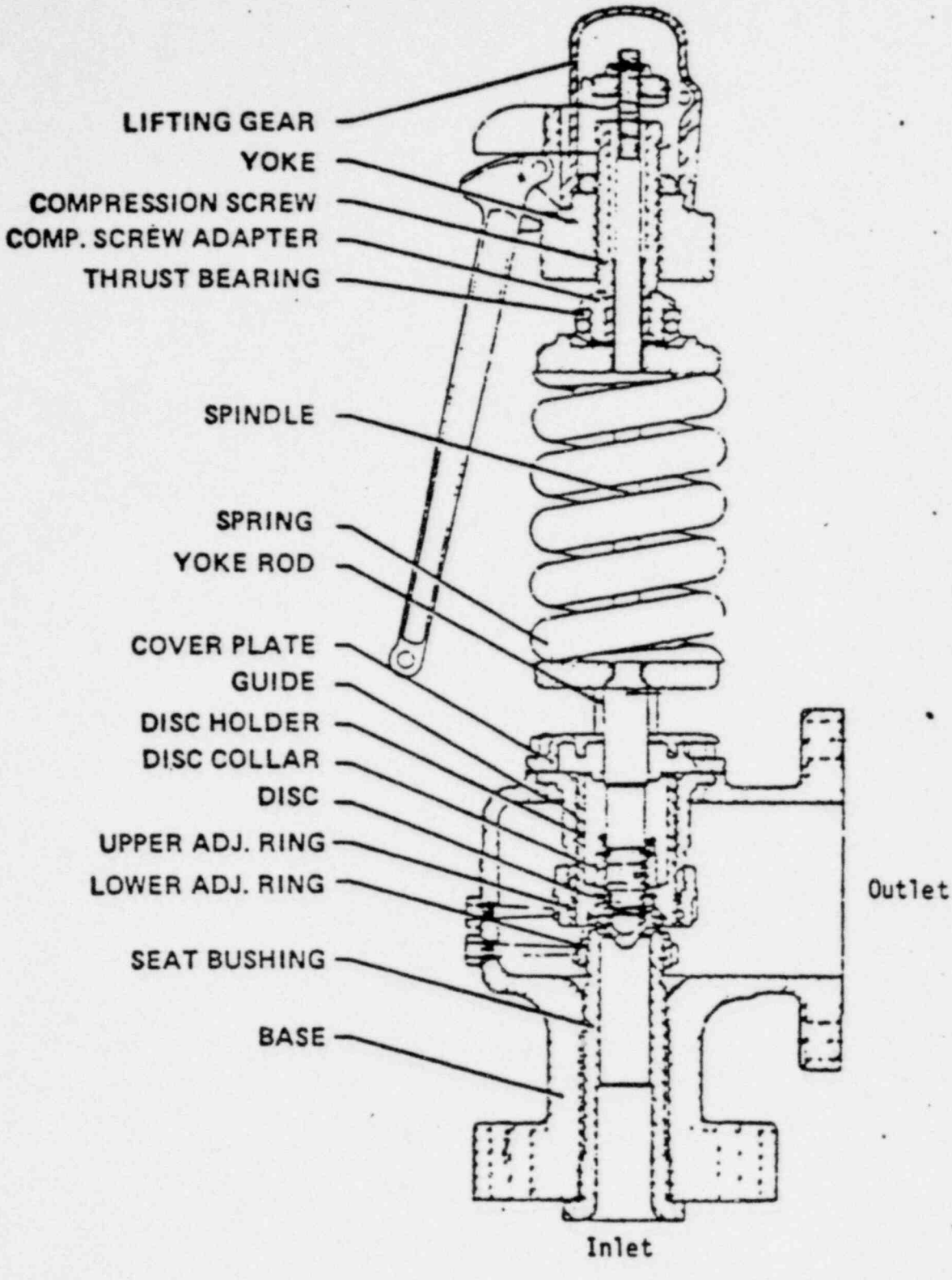


FIGURE 1: TYPICAL BWR SAFETY VALVE

SOURCE: NUREG-0462

SOURCE: NUREG-0462

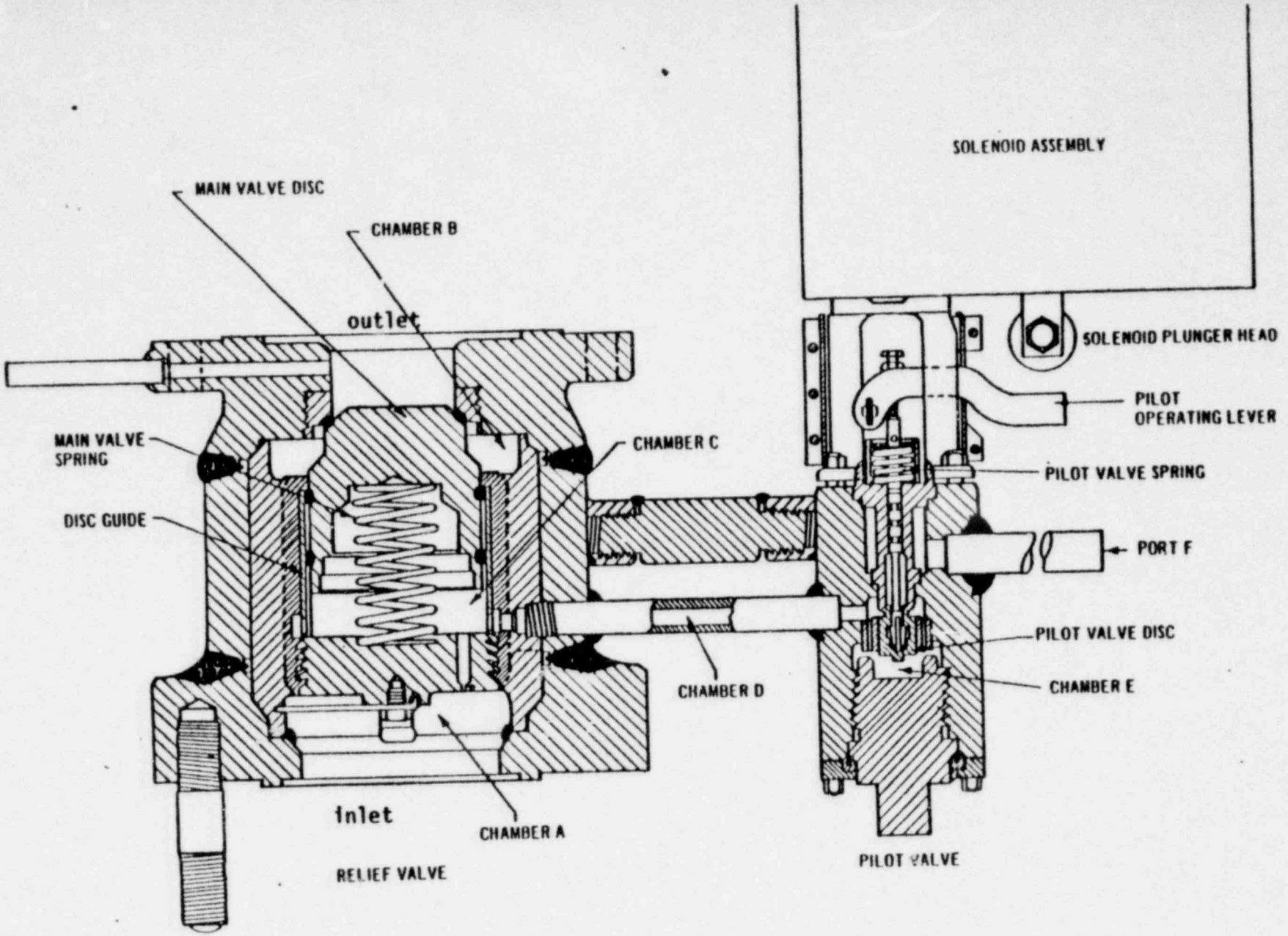


FIGURE 2: TYPICAL BWR POWER ACTUATED RELIEF VALVE (PARV)

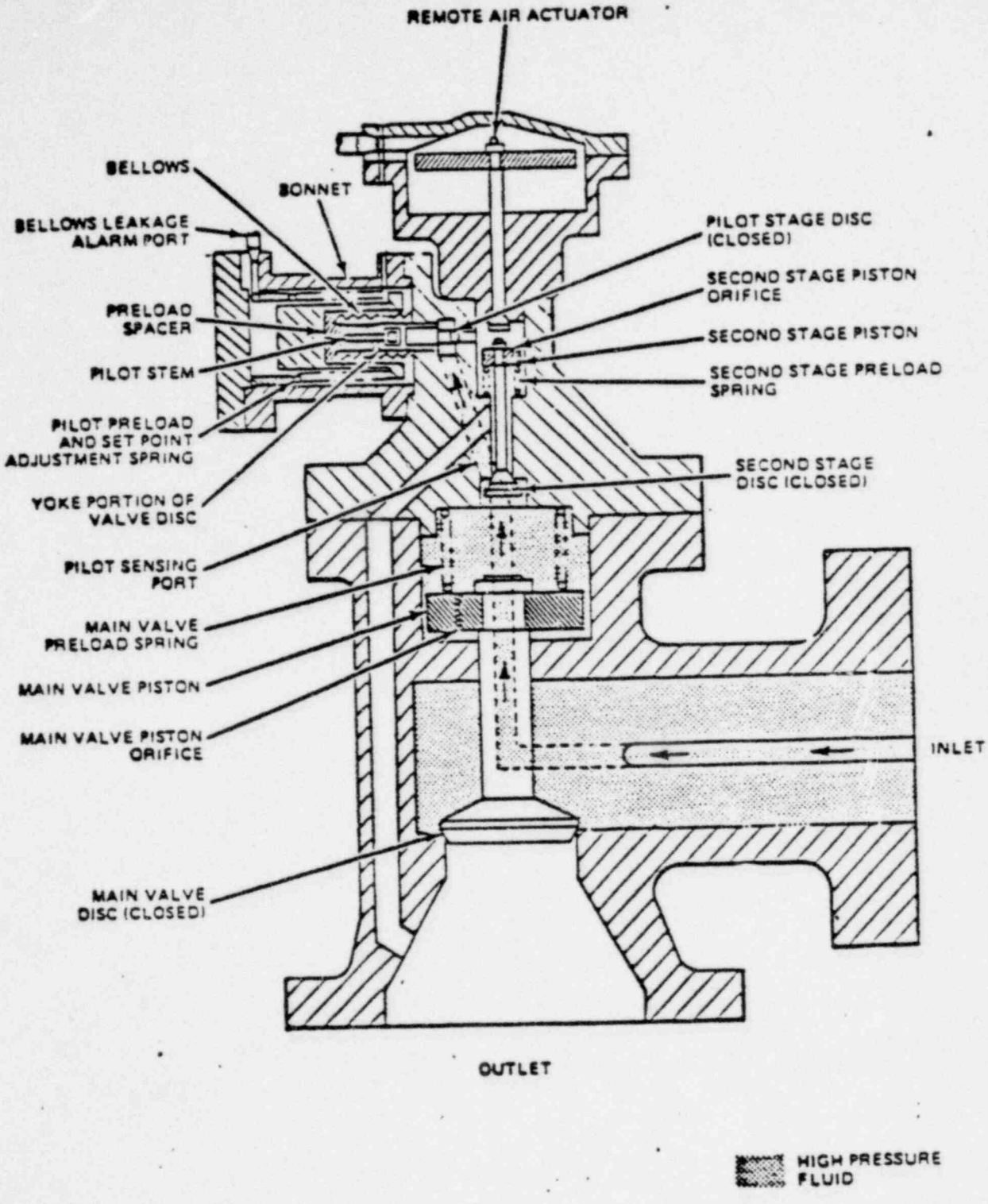


FIGURE 3: 3-STAGE SAFETY/RELIEF VALVE SCHEMATIC (SRV)

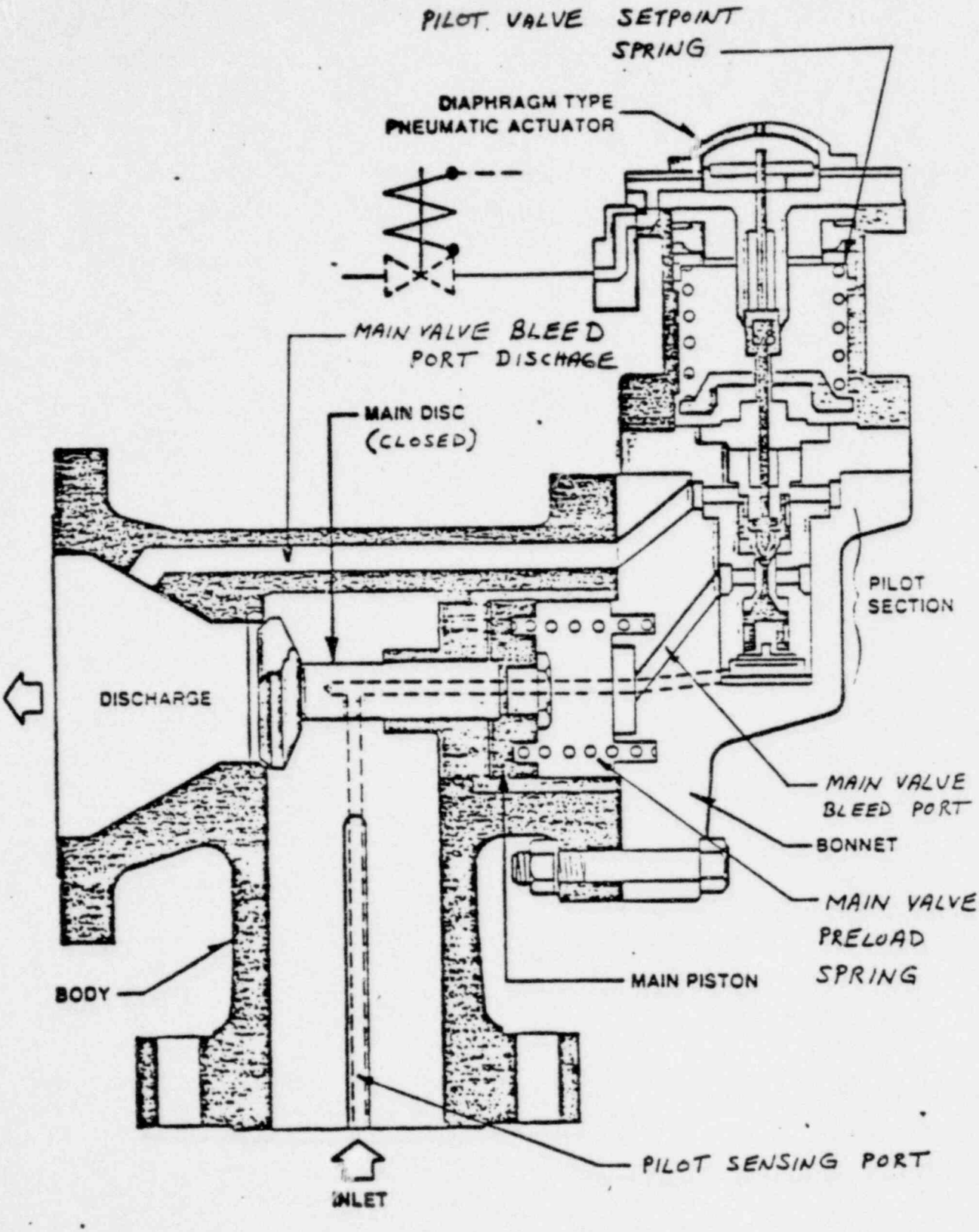


FIGURE 4: 2-STAGE SAFETY/RELIEF VALVE SCHEMATIC (SRV)