Reliability Testing of Pressure Relief Valves

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ABSTRACT

Following a brief description of pressure relief valves, this paper presents as-found set point test results for pressure relief valves that have been in process or utility system service. The paper examines the reliability of the relief valve to open at set pressure as a function of several key parameters, including time in service, fluid, size, and valve design (vendor). Although it may be that steam and water service valves are affected adversely by service conditions, this analysis is focused primarily on clean air/gas service. The probable correlation between fluid cleanliness and reliability is not being made, but will be considered in future studies. Valves that discharge outside allowable ASME tolerances are evaluated to determine possible causes of the deviation. Three failure case studies are presented. A final summary of test results indicates that valve reliability is not a strong function of time in service for the one-to-five year operating periods investigated. Additionally, this data set indicates that less than one percent (0.96%) of all valves pop tested at greater than 1.4 times tag set pressure.

BACKGROUND

The current study was initiated to determine the existing condition of relief valves removed from service at the time of recall or retest. The information gained may be used to perform a risk assessment or to adjust test frequency. Since seat leakage and low popping pressure are conservative failures, the frequency of high pop pressure and the occasional stuck valve are of most interest.

NOMENCLATURE

ASME – the American Society of Mechanical Engineers

Bench Testing – the practice of pressurizing the inlet of a relief valve that has been removed from the field. Relieving pressure and seat tightness are tested. The as found values are compared to initial (new) tested values.

Blow down – the difference between popping pressure and reseating pressure typically expressed as a percent of set pressure.

BPVC – Boiler and Pressure Vessel Code overseen by the ASME Section VIII of the code applies to pressure relief valves**.**

NBIC – National Boiler Inspection Code is a national standards board that accredits organizations for repair and alteration of pressure relief devices. The national board provides a certificate and VR stamp to those they accredit to repair pressure relief valves.

Popping pressure – applies to relief valves in steam, air and gas service. The value of increasing pressure which moves the disc rapidly off the nozzle or seat causing the valve to pop.

Pressure relief valve – a spring loaded pressure relief device designed to open and relief excess fluid pressure and to re-close after normal system conditions have been restored.

Reseat pressure – or closing pressure is indicated when the valve disc comes back to rest on the nozzle or seat.

Risk based decisions – those made to bench test/maintain relief valves based on assessment of risk. Risk assessment involves a study of probability of unacceptable failure and the significance or consequences of failure (risk = probability x consequence).

Safety valve – a pressure relief valve actuated by inlet pressure by rapid opening or pop action and refers typically to steam or gas service

Safety relief valve – a pressure relief valve actuated by inlet pressure by rapid opening or pop action. Used for liquid, steam or gas.

Set Pressure – the pressure at which the pressure relief valve was intended to lift, pop or relieve system pressure. Typically is indicated on the attached tag for ASME section VIII valves.

Used relief valve – a relief valve that has been in the field, installed in a piping system for some period of time.

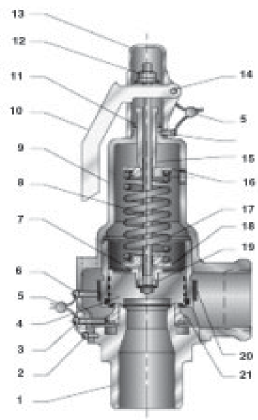
Valve reliability – the probability that a valve is able to perform it's required and intended function under design conditions for a stated period of time or for a stated demand

TYPES OF PRESSURE RELIEF VALVES

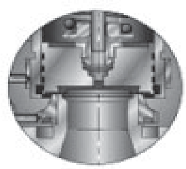
One basic type of pressure relief valve (PRV) is the simple spring-loaded mechanical device that is designed to relieve or discharge gas, liquid, or steam above its “set pressure”. Another type of valve is the pilot operated relief valve, where “pilot” refers to the method of actuation not the relief action itself. According to reference 3, other PRV types include temperature-actuated valves and power actuated valves.

Figure 1 provides an example of conventional spring-loaded relief valve cross sections. The major components are labeled. A pressure relief valve is designed to open at a predetermined set pressure and allow excess pressure to exit the closed system. In most cases, the pressure relief valve will close when pressure is less than a predetermined set point as when the system has returned to normal operation. The main pressure retaining components are shown in the next figure. An adjustment screw is tightened against the spring to increase set pressure. Figure 2 provides a basic view of the force balance between pressure developed in the throat area A1 and spring force acting on top of the disc.

No.	Part Name
1	Nozzle
2	Body Set Screw
3	Warn Ring Set Screw
4	Disc
5	Wire and Seal
6	Guide Set Screw
7	Retainer Nut
8	Stern
9	Body
10	Lever
11	Jam Nut
12	Lift Nut
13	Cap
14	Lever Pin
15	Cap Set Screw
16	Compression Screw
17	Spring
18	Spring Step
19	Stem Retainer
20	Guide
21	Warn Ring
22	Seat



Model 6010



Model 6021

Figure 1. Relief Valve Cross Section

Shown in Figure 3 is a cross section of a typical hard seat and soft seat spring-loaded relief valve. Hard or metal seated valves utilize flat lapped nozzle and seat to provide a tight seal of system fluid until the relief pressure is obtained. Elastomeric (soft rubber) seats would be used when a low fluid leak rate is necessary or when handling a corrosive fluid. Process fluid temperature and pressure will be limiting factors when using soft seated valves over hard seats. The balanced pressure relief valve, Figure 4 compensates for a back pressure that may exist on the discharge side of the valve disk (the outlet). Valves are balanced with bellows or pistons. The bellows or piston in effect seals the discharge side of the valve from the spring and disk. Consequently, pressure developed in the discharge piping will not add to spring pressure on the disc and will therefore cause the lift pressure to change.

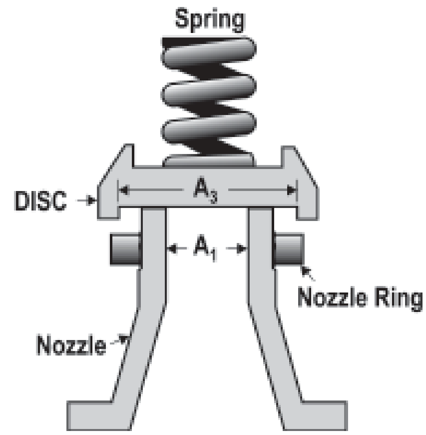


Figure 2. Force Balance On Disc

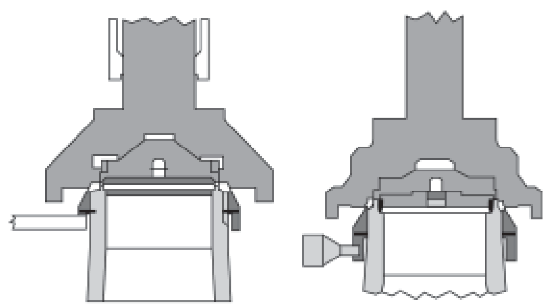


Figure 3. Types of Seat

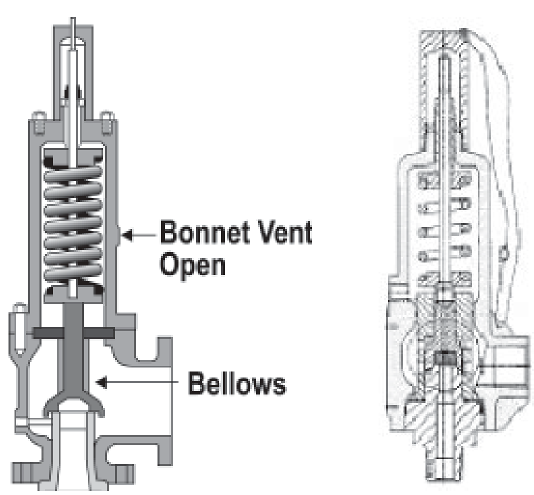


Figure 4. Balanced Relief Valve

As discussed in vendor literature, pilot relief valves use a smaller pilot valve to control system pressure above the piston or diaphragm chamber. Since spring pressure holding the disc seated to the nozzle is reduced by help from system pressure, large springs and housings (castings) are not required. There are other advantages to pilot operated relief valves including low seat leakage near set pressure, separate control for set pressure and blow down. Also advantageous is limited system fluid loss due to better control of valve lift/duration during an overpressure event.

TEST FACILITY

This valve repair/test shop supports a complex of chemical processes, service, heating and boiler steam, service air, nitrogen, argon, oxygen, breathable air, and incompressible fluids as well. It is considered a requirement for relief valve mechanics to be ASME qualified "VR" valve repairmen. All parts replacement, repairs and test records are stored in a permanent and retrievable electronic file format. Periodically, VR shop mechanic records are reviewed by an ASME-approved NBIC inspector. At present, a three-year recertification is required for repair shops.

Mechanics input test data including the as-received pop pressure, blow down, ASME set pressure and as-left pop pressure for both new and used. New valves are tested to verify vendor listed set pressure prior to installation in the facility. To be in compliance with engineering specifications, each valve must have a metal tag attached indicating its location in the plant and the next test date. Current pressure protection policy is that all new pressure relief valves arriving on plant will be tested to verify and document set pressure before field installation. Tags make it easy for operators to verify that systems have up to date protection. Tags also assist in planning outages for the purpose of removal and retest.

When a new or used valve is received in the shop, each item is checked for evidence of physical damage, corrosion, and deposits. The manufacturer, model, and serial number are recorded as well as the end-user contact. Large valves are lifted to the inspection test stand by chain hoist. Valves are first tested in the as-arrived or as-found condition following the external visual inspection. Test pressure is increased on the test stand until the valve lifts or "pops". This activity simulates field performance. If a valve fails test, then tear down and further parts inspections occur. Typically, a valve will fail test because it lifts above or below the ASME tolerance on tagged set pressure (setpoint). Another mode of failure is seat leakage when holding test pressure at 90% of set pressure. The seat must be tight as indicated by no flow of bubbles or bulging of tape at the outlet. All parts are cleaned, either mechanically or chemically. In some cases, parts will be replaced, lapped to ensure a leak-tight seal, or machined if seat and nozzle have experienced chemical or mechanical deformation An automatic lapping machine is used to flatten the lap blocks. These special lapping blocks are used to hand-work the seats and nozzles flat, removing scratches and minor defects with very fine 1800 grit compound. The shop's flexible hose hydrostatic test stand is used to test hoses prior to use and for pop testing small water service valves.

PLANT PRESSURE RELIEF VALVE POPULATION

The site maintains 5000 pressure relief valves in various fluid services. Fluid services include air and gas, water, acids, caustics, oil, and steam at pressures from 2 inches water to 34.5 MPa (5000 psig). The majority are air/gas with set points from 0.34 – 1.72 MPa (50-250 psig) with greater than half having less than 1" IPS inlet. The entire population includes 1240 air valves, 1320 liquid, 163 steam, and 1040 gas relief valves including argon, helium, nitrogen, oxygen, and freon.

New Valve Testing or Pre-installation Tests

When new valves are purchased for a project or to replace one already in the field, this site requires that they be tested and tagged. Even though they arrive directly from a valve vendor stamped and sealed, all are tested. Once a valve is tested, registered and tagged, it can be sent to the customer for installation. Registration guarantees that the valve will be returned to the shop for retest at the engineering specified interval.

Used or In-Service Valve Tests

Mechanics test each valve as received from the field and input the last test date, initial first pop lift pressure, average of the next three lifts and the general overall condition as-arrived. Failure on the test stand can mean failed low; they leaked before reaching pop pressure. Valves can also fail high, that is at least >1.05 times set pressure. ASME specifications allow for +/- 3% tolerance of set point for Section VIII Code compliant relief valves and slightly higher for non-code valves in certain pressure ranges.

During each valve test, the initial pop pressure is recorded as well as an average of the next three. In most cases, clean air/gas valves relieve very close to their stamped set point following this exercise although the first pop may be as much as 20-50% higher than stamped pressure.

Blowdown is defined as the difference between actual popping pressure and actual reseating pressure stated as a percentage of set pressure (ref. 3). For example, if a pressure relief valve has 20% blowdown on a setpoint of 0.7 MPa (100 psig), the actual blowdown in standard pressure unit is 20 psig. That means the valve opens at (ideally) 100 psig and reseats or closes at 80 psig. This valve may be protecting a system that operates at 90 psig. If all happens as designed the system, vessel, or component will be protected if our valve actually lifts at 100 psig. The actual blowdown is important because too short will cause a rapid valve opening and closing (seat chatter). As an example, if the valve opened at 100 psig and reseated at 96 psig, not enough product can be discharged during the overpressure event. This will cause pressure to build to the setpoint of 100 psig again in a short time. Too long of a blowdown, for example lifting at 100 psig and reseating at 50 psig, will cause expensive loss of product and the cost to pump the system back to the operating pressure of 90 psig.

DATA PRESENTATION – GRAPHS CHARTS

Data was tabulated in spreadsheets to look for trends by comparing vendors, years of service, system pressure, test pressure/set pressure and initial versus average pop pressure. The following charts are annotated to indicate what was concluded from the data. Chart 1 and Table 1 provide a summary of pre-installation test results on 560 new valves.

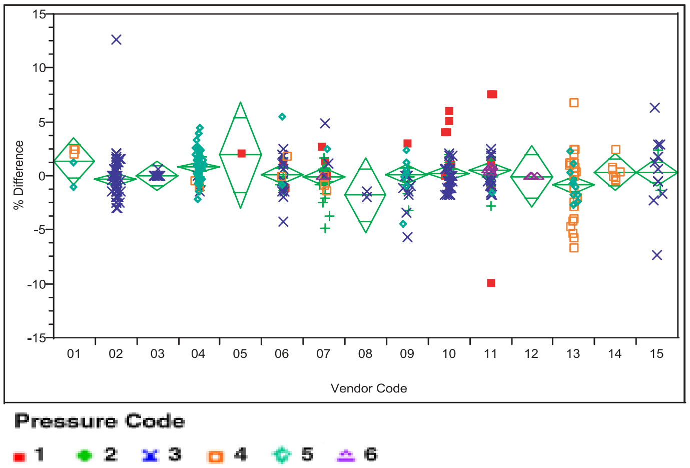


Chart 1. New Valve Pre-Installation Tests

Analysis of Difference from ASME Section VIII Limits by Vendor Code
% Difference is 100 [Test Pressure – Stamped Pressure]/stamped pressure

Pressure Code	Min(Stamped SP (MPa/psig))	Max(Stamped SP (MPa/psig))
1	0.515/75	0.689/100
2	0.759/110	1.03/150
3	1.10/160	1.38/200
4	1.52/220	1.72/250
5	2.07/300	2.76/400
6	10.3/1500	37.9/5500

Table 1. Results of New Valve Tests

SUMMARY									
ASME Section VIII Pressure Relief Valves - As-arrived Test Data for New Valves from Stores									
Source: SRS-PEVT Study, Joe Weber, BSRI, April 2002									
%Rejected	Rejected for	Vendor	Population	Rejected	High Pop	%Over Set[1]	%Over Limit[2]	Set Pressure [3]	Service
4.6	leaking	a	9	2	1	10.0	4.3	35	steam
4.3	high pop	b	13	0	0	0.0	0.0		air
2.5	low pop	c	85	1	1	13.0	9.7	175	steam
1.1	stamped wrong	d	108	21	4	4.5	1.5	350	air
0.5	no seal	e	1	0	0	0.0	0.0		na
0.4	wrong valve	f	55	9	2	5.5	2.5	400	liquid
0.4	bad lever	g	41	5	2	6.7	3.3	165	steam
0.4	no oxygen clean report	h	2	0	0	0.0	0.0		air
14.2	total (70/560)	z	40	6	1	24.0	20.0	165	steam
		k	1	0	0	0.0	0.0		steam
		y	66	4	4	6.0	3.0	100	air
[1] Actual SP - Stamped SP/ Stamped SP*100,		m	54	6	1	27.0	24.0	75	air/liquid
maximum overpressure of High Pop valves		m	14	7	3	10.0	3.0	80	steam
		n	1	0	0	0.0	0.0		na
[2] Actual SP - Allowable high SP/ Stamped SP*100		o	3	0	0	0.0	0.0		air
ASME limit of +/- 3% on >70 psig set		p	3	0	0	0.0	0.0		liquid
		r	38	7	1	6.8	4.0	250	liquid
[3] Set pressure of rejected high pop (psig)		s	8	0	0	0.0	0.0		air
		x[4]	18	2	1	6.3	1.2	175	air
[4] ASME Section IV			560	70	21	6.3	4.0		
						average	average		
na - not available									

Notes and Summary on Pre-installation Results

The specification limit for section VIII valves is +/- 2 psi up to 70 psig set points (not shown) and +/- 3% of set pressure above 70 psig. Mean diamonds indicate no significant difference in average test pressure from stamped set pressure assuming a normal distribution.

It can be seen that about four percent of new relief valves pop outside the upper ASME limit. Several pop at pressure higher than 20 percent of set pressure. It is likely that these particular new relief valves if not pre-installation tested would have in service lifted at +120% of the expected value. Current data suggests that if we want to be sure of the as-installed condition, we must test to verify. For many installations, systems, or services it may be acceptable risk and most cost effective not to test. By statistical analysis a number of manufacturers models are predicted to exceed the upper spec limit by less than 0.15% or 1500 parts per million. Others would exceed the upper limit with 2% of valves, while another vendor would provide a total number outside upper and lower limits of 7%.

- 2.5% of valves tested at 5% or more below the stamped set pressure
- 3.8% of valves tested at greater than 1.05 times the stamped set pressure
- 0.5% of valves tested at greater than 1.12 times the stamped set pressure

Notes on Used Valves

- 3% of valves popped below the ASME lower spec limit of -3%
- 25% popped at greater than the ASME upper spec limit of + 3%
- 5% of valves popped at greater than 20% above the ASME limit

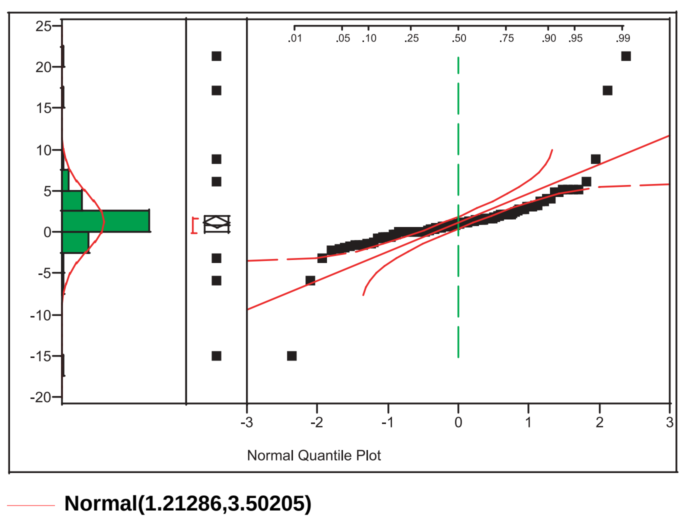


Chart 2. Distribution of % Difference from Setpoint for In-Service Valves 100 [TP-SP]/SP All Vendors, All Service with Set Points Greater Than 70 psi

This chart illustrates the distribution of test data on a normal distribution plot. The x-axis is sigma and y-axis is 100 Dp/P. The distribution is not exactly normal as there are many outliers. The non-normal distribution makes it difficult or risky to project with confidence what fraction of a population would fall outside ASME tolerance (+/- 3% for >70 psig).

Chart 3 portrays used valve data by vendor. Also shown is the mean line with uncertainty limits. Except for Vendor 4 and 9, there appears to be no slope or significant trend toward greater Dp/P with increased time in service. The data includes all sizes, all service, and all pressure ranges.

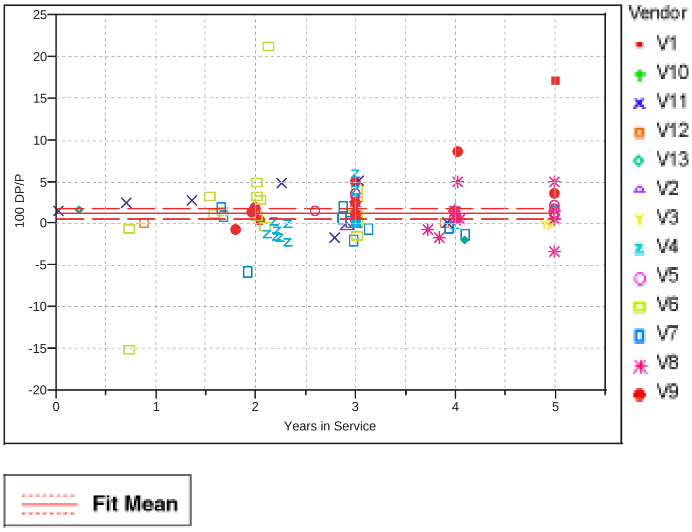


Chart 3. 100 [TP-SP]/SP versus Years in Service and Vendor, Valve Set Points Greater than 70 psig All Services, All Vendors, Used Valves

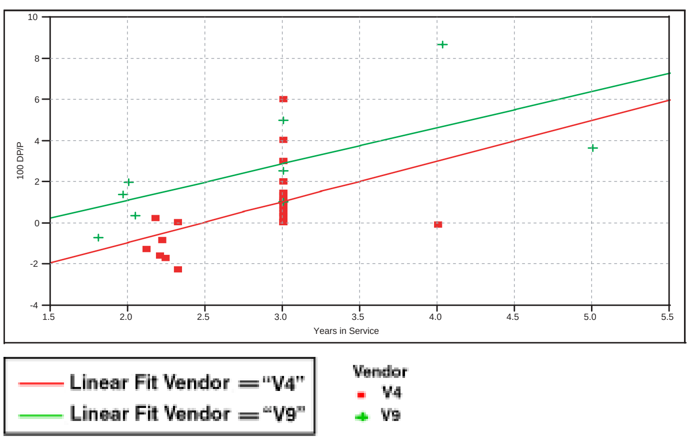


Chart 4. Plot of 100 [TP-SP]/SP By Years in Service Used Valves with Metal-To-Metal Seats Vendors 4 and 9

After looking closely at the data, two different vendor valves (V4, V9) provided significant trend lines. The trend line for V9 shows an approximate 7% increase from set pressure within the first five years of service. It is not known at this time if the range in data was due to valve design or environment.

A Note on Soft Seated and Hard Seated (Metal-to-Metal) Seats

A recent relief valve performance analysis by ExxonMobil Research concluded that extension of their inspection (test) interval from one to two years for clean gases did not produce an increase in overpressure amount or frequency. The paper stated that further testing would be pursued to determine if longer intervals between inspection were possible. The data suggest that the maximum elastomer set may be reached in less than two years. Elastomer (plastic, rubber, Teflon etc) set is considered to be the main reason for "sticking" during valve lift and higher test pressure on first pop (Palluzi 2003).

In the plot shown above, V4 and V9 are both hard seated valves, that is they have metal-to-metal lapped seats to seal fluid pressure. Soft seats were not present in the valves shown above.

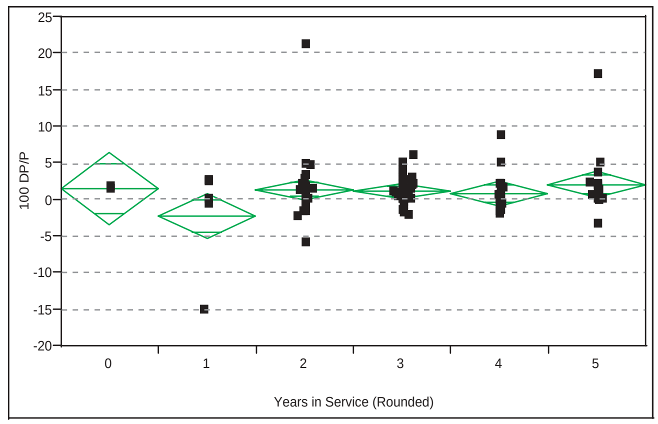


Chart 5. 100 [TP-SP]/SP By Years in Service (Rounded Down) with Mean Diamonds, Used Valves

This plot shows valve data by rounded-down years in service. All vendors, all services, all pressure ranges are included. In this case, the mean diamonds indicate that there is not a real difference in the observed data (mean DP/P) across increasing years in service. More data may provide further insight, but the data to date does not suggest that shorter test frequencies would yield better test results and consequently less risk.

Mean Diamonds

The upper and lower points of the diamond drawn at zero through five years service, indicate the 95% confidence interval for the mean or average value of 100 Dp/P. DP is defined as test pressure (TP) minus set pressure (SP). Basically we would like to know if one age group is the same as another age group, in other words are their averages the same or significantly different. The middle bar in the diamond indicates the mean, x-bar, or the average of each group. If the horizontal bars within the diamond overlap with those in other diamonds, then the mean values of the two groups are the same. In other words there is no significant difference in the average value of the two groups when the straight bars inside the diamonds overlap or coincide with straight bars in the other diamonds.

In Chart 6, we are looking for a trend toward a higher or lower ratio when viewed by pressure range. It can be noted that the lowest pressure range includes the most scattering of data. This is due to the fact that ASME Section VIII tolerance for set pressure is +/- 2 psi for set pressures up to 0.483 MPa (70 psig). Consequently, valves set at 16 psig might vary from 14 to 18 psig and be within tolerance. An acceptable TP /SP in the latter case would be 18/16 or 1.13. A valve set at 4 psig could be as much as 6/4 with TP/SP of 1.5. The remaining set of data shows the ratio TP/SP to be centered between 0.9 and 1.1 which is plus or minus 10% of set pressure. No strong function of pressure range is indicated here.

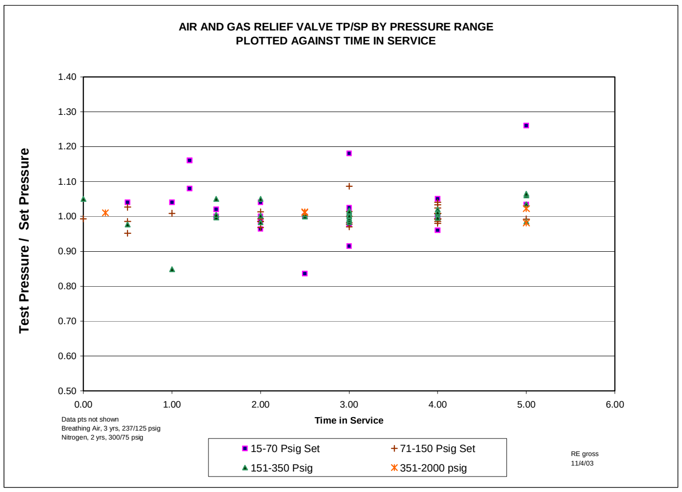


Chart 6. Air and Gas Service All Pressure Ranges Used Valves

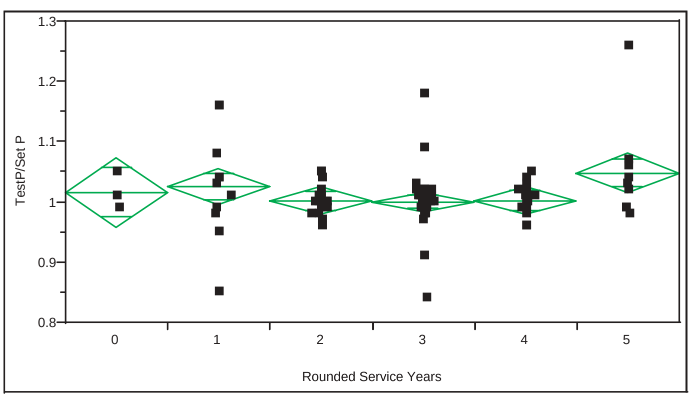


Chart 7. Analysis of Test P/Set P and Rounded Down Years Air and Gas All Pressures

The mean diamonds indicate that there is no statistical difference from TP/SP = 1 within the first four years of service. There could be slight increase in test pressure at five years but the data are not conclusive. Several valves test as much as 20+ % over set pressure. Reasons for the over pressure might include different valve design, set pressure range, size, and environmental or field conditions (e.g., heat and vibration). Additional data may provide further insight, but the data to date does not suggest that shorter test frequencies yield better test results or less risk of exceeding set pressure by more than 10%.

Vendor 8 has two out of three TP/SP's significantly over 1.10. Vendors V1 through V7 are well behaved. What we conclude from Chart 8 is that there is no significant difference in the mean values of the ratio TP/SP for eight different vendor's valves. More data and further study in 2004 is warranted.

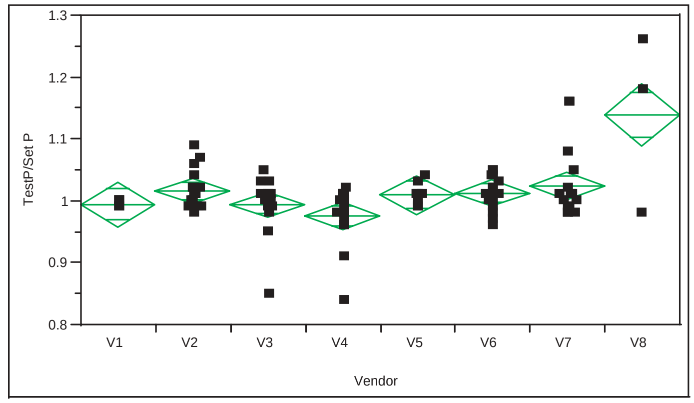


Chart 8. Test P/Set P by Vendor Air and Gas

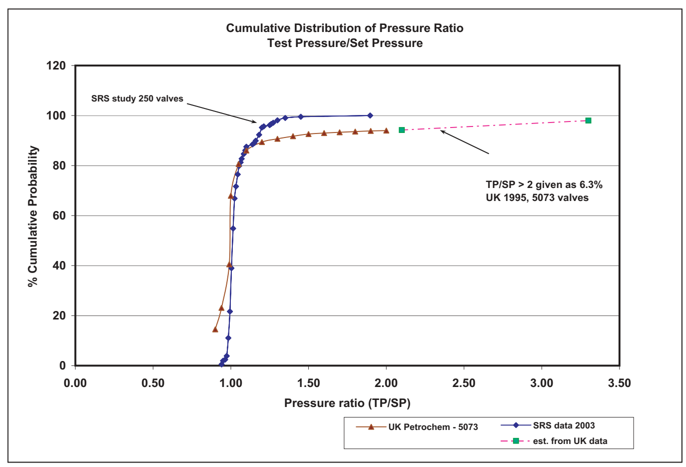


Chart 9. Probability Density Trace of Pressure Ratio for All Services, All Vendors, Time in Service, and All Sizes of Valves

In Chart 9 a comparison of probability density traces from the referenced UK study (Smith, 1995) and the current SRS study is portrayed. Up to the ratio 1.1, these curves are very similar. It is not known at this time whether the SRS curve will flatten out as more data is accumulated.

From this probability density trace, it can be seen that approximately 90+ percent of valves bench tested within 0.9 to 1.2 times the expected value of set pressure. There is a 10 percent chance that a valve will relieve at greater than 20% over set pressure, and less than one-half percent probability that any valve, any service, any vendor or size will relieve at greater than 150% of set pressure after being in service for up to five years. Additional Statistical Analysis revealed that our current test data does not fit normal, log-normal, exponential or Weibull distributions well which leaves us without confidence limits on our conclusions.

To be able to provide 95% confidence limits to conclusions, we chose Distribution-Free Tolerance limits analysis.

Analysis

Assuming that Pressure Ratio does not follow a normal distribution, the tolerance limits state that we can be 95.0% confident that 98.57% of the distribution lies below 1.9. This interval is computed from the largest data value. Also, the tolerance limits state that we can be 95.0% confident that 97.7% of the distribution lies below the ratio 1.45. These results can be used to help understand the inherent "risk" involved in PRV performance over time, effectiveness of the inspection/test process, and impact of increased time in service.

CONCLUSIONS

1. TP/SP is not a strong function of time in service for the one-to-five year operating periods investigated.
2. There seems to be little correlation between Vendor, TP/SP and up to five years in service.
3. There seems to be little correlation between Pressure range, DP/P and time in service.
4. An increasing trend may be developing with two vendors, DP/P and time in service.
5. No trend evident for Air/Gas vendors, TP/SP, and up to five years in service.
6. Two specific manufacturers and model Air/Gas valves assessed do not trend toward large TP/SP versus time at least up to five years.

FURTHER STUDY

- Continue collecting data to develop trends.
- Segregate data by hard and soft seat design.
- Correlate other influences such as indoor/outdoor service, fluid cleanliness, or seat conditions to reliability
- Investigate high temperature effects (75-80 degrees C). Earlier studies (Aird, 1982) noted that an almost linear increase in lift pressure over time after soaking at 80 degrees C.
- Identify those valves using different elastomer seats and evaluate in further studies.
- Correlate as-found conditions of valve seats to failure rate.

ACKNOWLEDGEMENTS

Scott Williams, *ME Department University of South Carolina.* Reviewed test data and created a spreadsheet; performed preliminary graphing and trend analysis.

Mike Clark and James Fulmer, *Qualified ASME valve repairmen.* Perform 1200 valve tests per year and record test data.

Stephen Harris Ph.D, *Statistical Consulting.* Reviewed the raw data and helped define independent variables; provided statistical analysis of the final data.

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APPENDIX A
KNOWN FAILURES—CASE STUDIES

Case 1. 125 psig Nitrogen Valve In Service for Two Years

It is readily noticed in Figures 5 and Figure 6 that this valve was installed out in the weather and not protected by a rain cap or provided corrosion resistant parts under the bonnet. When the valve shop tested this valve, it popped loose at 237 psig set point. The valve was dismantled and the spring retaining washers were found rusted to the valve stem preventing free motion of the valve stem.

Figure 5. Nitrogen Valve

Figure 6. Nitrogen Valve with Bonnet and Lifting Lever Removed; Totally Dismantle

This nitrogen service valve was repaired with new parts, and provided a rain shield to prevent water from entering the bonnet.

Case 2. Reciprocating Air Compressor Second Stage Relief

Figure 7 is a disassembled spring loaded relief used on a reciprocating air compressor second stage. The cold set pressure is 125 psig. The valve was removed from the second stage discharge piping. Shown are the valve housing, spring, retainers, disc, nozzle, stem, and manual exercise handle.

Figure 7. Disassembled Compressor Relief

The failure was excessive leaking by the seat. Seat damage occurs typically because shock pulses of the high pressure piston lift the disc off the seat. After a large number of cycles, a hammering effect begins to develop as the disc and seat fret against each other. Figure 8 is of the disc, disc holder and spindle. The holder shows galling marks on its outer diameter indicated by the silvery vertical slashes seen. The disc can be seen as having an indentation matching the nozzle seat. The depression is approximately 1/64 inch deep. A new disc will be flat across or may even be dished out (convex).

Figure 8. Compressor Relief Disc and Spindle

Inspection of the exercise handle, stem, and spring reveals an impression left in the spring adjustment screw by the manual actuation lever working back and forth. Possibly, the velocity/acceleration of the discharge piping of the reciprocating compressor caused the handle to oscillate with sufficient force to decrease the spring tension holding down on the valve disc. These valves are typically subjected to both vibration and elevated temperature. Both of which have been shown in the past to promote early failure and increase or decrease from cold set pressure (Aird, 1982).

Case 3. Leaking Conventional Steam Valve

Figure 9. Steam Valve on the Test Stand

This valve is a conventional spring-loaded 4 x 6 inch 100 PSIG Steam valve from a process area. The valve was disassembled on the test stand after failing test. Failure mode was excessive leakage at holding pressure. By procedure, the valve must be able to hold tight at 90% of set pressure. Mechanics place duct tape across the discharge flange and if the tape bulges during the holding test, the valve fails this test.

Figure 10 is a picture of the valve disc after disassembly. The bellows indicates that this is a balanced pressure relief. Outlet port conditions do not affect the set pressure.

Figure 10. Valve Disc After Disassembly

The discoloration in Figure 11 indicates that the valve was leaking by in service causing a hot spot. Typically this condition also causes the seat to be "cut" or eroded by the steam. Eventually the erosion causes a deep enough groove in the seat to be quite noticeable.

Figure 11. Closeup of the Disc Seating Area

Figure 12. Steam Valve Seat After Rework

The seat area here has been lapped true and flat. When mated with a similarly refurbished nozzle surface factory performance will be expected.

Figure 13. Steam Valve Disc Before Lapping
Steam Valve Nozzle as Seen After Disassembly in the As Arrived Condition

Rust discoloration around the nozzle area is an indication that the valve was leaking in service. Surface finish on the nozzle is not cut appreciably, but is more than likely not flat as steam leakage can lead to slight warping of this critical area.

Figure 14. Steam Nozzle After Cleaning, Polishing and Lapping

The like-new condition seen will provide for a tight metal-to-metal seal between the nozzle and disc. The valve will now hold tight near set pressure and will not sizzle during operation. The flat mating surfaces will also promote a good lift off or pop when set pressure is reached.