

PROCESS SAFETY RELIEF VALVE TESTING - ONE CHEMICAL PLANT'S VIEWPOINT

BY: WARREN WOOLHOLK, SENIOR INSPECTOR & ROY SANDERS,
SUPERINTENDENT OF INDUSTRIAL ENGINEERING

PPG INDUSTRIES, INC., LAKE CHARLES, LA

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By: Warren Woolfolk, Senior Inspector
Roy Sanders, Superintendent Of Industrial Engineering

PPG Industries, Inc. - Lake Charles, LA Complex

FOREWORD

Safety relief valves play a key role in protecting property and personnel during process upsets in petrochemical plants. These valves must be properly tested and repaired at sufficient intervals to ensure their reliability.

Lake Charles PPG Industries' Louisiana complex manufactures chlorine, caustic soda, vinyl chloride, ethyl chloride, muriatic acid and a line of organic solvents on a 600-acre site. Some of the raw materials, intermediates and finished products are corrosive. Owing to the corrosive and sometimes fouling nature of some of these substances, we have had to keep a watchful eye on our safety relief valves.

We believe that if a chemical plant handles corrosives and fouling substances, a periodic, in-depth examination of new and existing safety relief devices is required. Furthermore, we recommend that each safety relief valve be tested under a volume of fluid sufficient to allow the safety valve to fully "pop."

SL 105225

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INTRODUCTION

In 1974, we assigned a technical employee to determine how effectively the existing Safety Relief Valve (SRV) Program was operating. His assignment was to define the resources required to ensure proper installation, testing and recordkeeping. The job originally was only temporary, but now is permanent. We also now have two full-time, factory-trained mechanics maintaining our 2,800-plus safety relief valves.

While revising our program, we found that a substantial number of our safety valves were not giving us the required protection, that our first test facilities were inadequate, that sufficient spare parts were not available and that our recordkeeping was insufficient.

During the past nine years, we found that due to design limitation, certain new valves were unreliable when exposed to corrosive substances. Expertise on new safety valves could be obtained from manufacturers, but we soon learned that the corrosive problems and user-oriented problems were not well documented.

Our proof testing indicated that all the effort spent sizing safety valves and engineering the system to give adequate protection was of little value if it was not followed by an adequate inspection and maintenance program using established, realistic inspection frequencies. Our inspection frequencies are set by class of service and are adjusted to fit recent data. A combined, cooperative effort of PPG experts in loss prevention, corrosion engineering, inspection, operations and maintenance was necessary to develop a viable inspection and repair program.

OUR FIRST TEST FACILITIES

The safety relief valve test stand employed before 1975 basically was a clampdown table with a 1/4" tubing from a compressed air cylinder. There was insufficient energy in such a small volume of compressed gas to properly activate the valve. Pops, if any, were very short. The abrupt pops caused erratic behavior of the test gauges; hence, accurate readings were difficult to obtain, as indicated in Figure 1. Our definition of a "pop" is the rapid opening of the valve with its associated audible report.

SRV TESTS
UNDER LIMITED VOLUME & FLOW

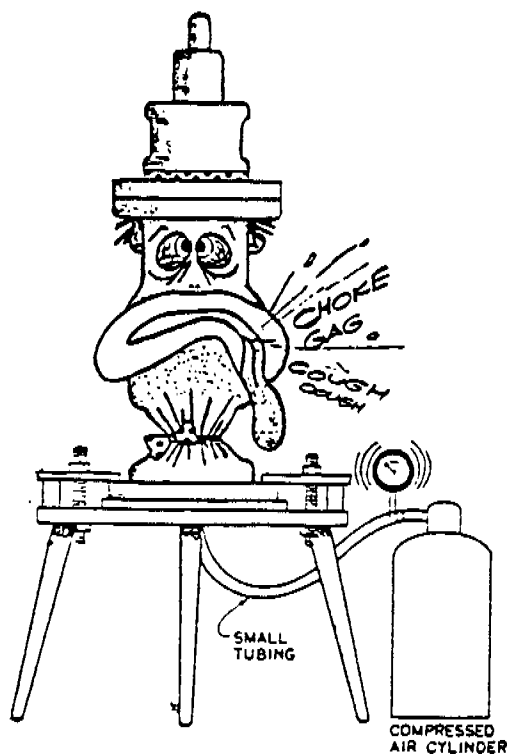


FIGURE 1

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In order to get any response from most safety relief valves on a low-volume test facility, the blowdown rings were adjusted to the top position or to the position for the longest blowdown. Consequently, this involved the lowest reseating pressure. Before returning the valve to its intended service, the blowdown rings were supposed to be readjusted for a standard reseating pressure. Re-adjusting was done according to charts furnished by the manufacturers.

The previously employed blowdown ring setting method is subject to error having serious consequences. Figure 3 shows the normal position of the blowdown ring. If the mechanic making the adjustment miscounted and moved the blowdown rings too low, the safety valve could fail to obtain a full lift or it could chatter instead of pop. Chattering -- a rapid opening and closing of a safety relief valve -- can drastically reduce the capacity of the valve. Chattering can result in destruction of the safety valve or adjacent equipment. If the blowdown ring inadvertently was left in the uppermost position, then reseating pressure (blowdown point) could be low enough to allow escape of more material than desired during an emergency situation.

Such limited-volume testing most often failed to yield a distinct pop. Most valves only hissed with a rapid simmer. In our experience, safety valve simmer, instead of an actual pop, misaligns the internal parts on some safety relief valves, resulting in leakage. The simmer point seldom is the same pressure as the actual popping pressure. Most safety relief devices will simmer at 90-95 percent of the popping point. Test facilities that do not have adequate volume increase the danger of setting valves at simmer pressure instead of pop pressure. In other words, the valves could be set 5-10 percent too high. In cases where faulty springs exist, potential errors of 20 percent or greater have been observed.

Low test volume below the seats of the safety valve results in rapid pressure release. This condition allows the full force of the valve's spring to slam the reworked seats together with enough force to damage the fine finish of the lapped seats.

Since we were not satisfied with our test equipment, our first approach was to ask safety valve manufacturers the requirements for a good safety valve test facility. The responses varied. Some were vague. Manufactured test stands were appraised, but had only slight variations of our existing test facility. We needed to look further.

A too-large test vessel would be overly costly in compressed air and mechanics' time. A too-small vessel may not meet the ASME code statement: "Test fixtures and test drums, where applicable, shall be of adequate size and capacity to insure representative pop action and response to blow-down adjustment."¹ It seemed that if we were to have a proper test stand, we should experiment and design one. We tested salvaged pressure vessels of various sizes to determine the minimum volume necessary to properly evaluate SRV's.

Our experiments led to the conclusion that a three-standard-cubic-foot test tank would give a representative pop action of a safety valve with a normal blowdown ring setting up to and including one with an "L" orifice area. The range of safety valves equipped with an "M" orifice up to and including a "T" orifice would require a tank with a minimum of 15 standard cubic feet. The limited test volume required special blowdown considerations for larger vessels.

We also understood that our vessel design should not have a choke between the tank and the safety valve. To compensate for the air leakage from simmering, we found it necessary to have considerable flowing air supply as well as the static accumulated test volume. We have a 4,000 SCFM supply.

The need for substantial testing media volume is real for testing SRV's exposed to corrosive or fouling chemicals. We feel an SRV test stand that does not have enough volume for a full "pop" of the SRV is inadequate.

Certain rupture disc manufacturers claim that if a reverse buckling rupture disc is installed between the pressure source and the SRV, then on-site SRV testing can be accomplished without removing the SRV. In our opinion, this type testing using a small tubing and pressured cylinder to pressurize the small volume between the disc and the SRV is inadequate, as we discovered on our original test stand.

OUR TEST FACILITIES

The major components of our test facility are three pneumatic tanks, complete with a high-volume air supply, quick-assembly clamps and accurate gauges. Figure 2 shows the major components of our testing system. A description of the other equipment in the test shop would go beyond the intent of this paper.

The three pneumatic vessels are a 3.3-standard-cubic-foot tank at 500 psi, a 4.4-standard-cubic-foot tank at 3,000 psi, and a 15-standard-cubic-foot tank for safety relief valves having inlets larger than three inches in diameter. Each of the vessels is mounted solidly to the test table and each can be connected to one or more high-quality test gauges.

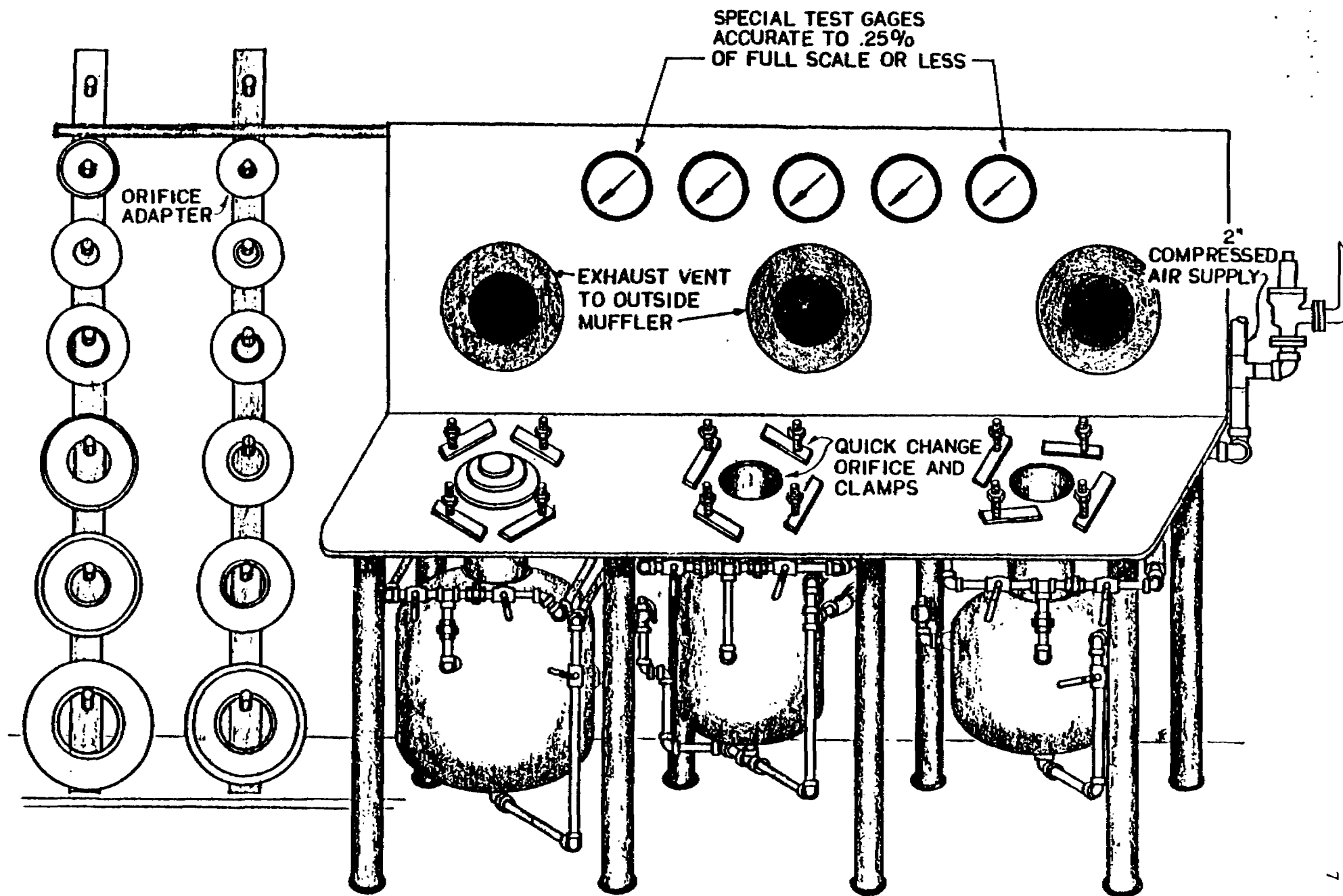


FIGURE 2

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OBSERVATIONS WHEN TESTING SRV'S IN PLANTS HANDLING CORROSIVES

Our education really began when this ample-test-volume SRV facility was put into service in 1975. For the first time, a measurable lift was observed on the valve stems when the safety valves were popped on the test stand. All moving parts were lifted free and floated down to reseat on a test medium of approximately 85-95 percent of the valve set pressure. This method eliminated possible misalignment of moving parts within the valve and reduced the probability of hammering out the finely lapped seats. SRV's now could be popped many times without any damage to the seating area. Pressure rise and fall now was gradual, thus making gauge readings accurate. The blowdown adjusting rings did not have to be repositioned to achieve the required pop action. This eliminated the error of leaving the blowdown ring too high or over-adjusting it too low.

Once our test facility having amply accumulated air volume and adequate air flow was put into use, we found that many variables not observable on our old test facility became detectable. Safety relief valve parts, defective due to corrosion, wear or incorrect machining, were found using the high-volume test stand. Such defective parts could result in an unbalanced flow across the safety valve seats. This lack of equilibrium could cause the valve's internal parts to cock and bind in the guiding area. A full lift could not be achieved at design overpressure while testing certain safety valves having defective parts. We also observed that defective parts caused misalignment that could result in leakage after the test.

Springs weakened during service or those too weak for the set pressure led to early simmer and excessive blowdown (reclosing pressure) of safety relief valves.

We could not compensate for the excessive blowdown by lowering the adjusting ring, even until a chatter occurred. Early simmers, such as 20-30 percent the actual popping point, could not be corrected. When limited-volume test facilities were used, such factors could cause mechanics to erroneously set a valve 20-30 percent too high, by adjusting to the simmer point instead of the actual popping point.

If a safety valve had been inadvertently supplied with a spring too strong for its popping pressure, the valve would exhibit a short blowdown. The valve possibly could chatter in service, and would not fully lift at the required overpressure. The short blowdown could not be compensated for, nor could the valve be made to achieve full lift at required overpressure.

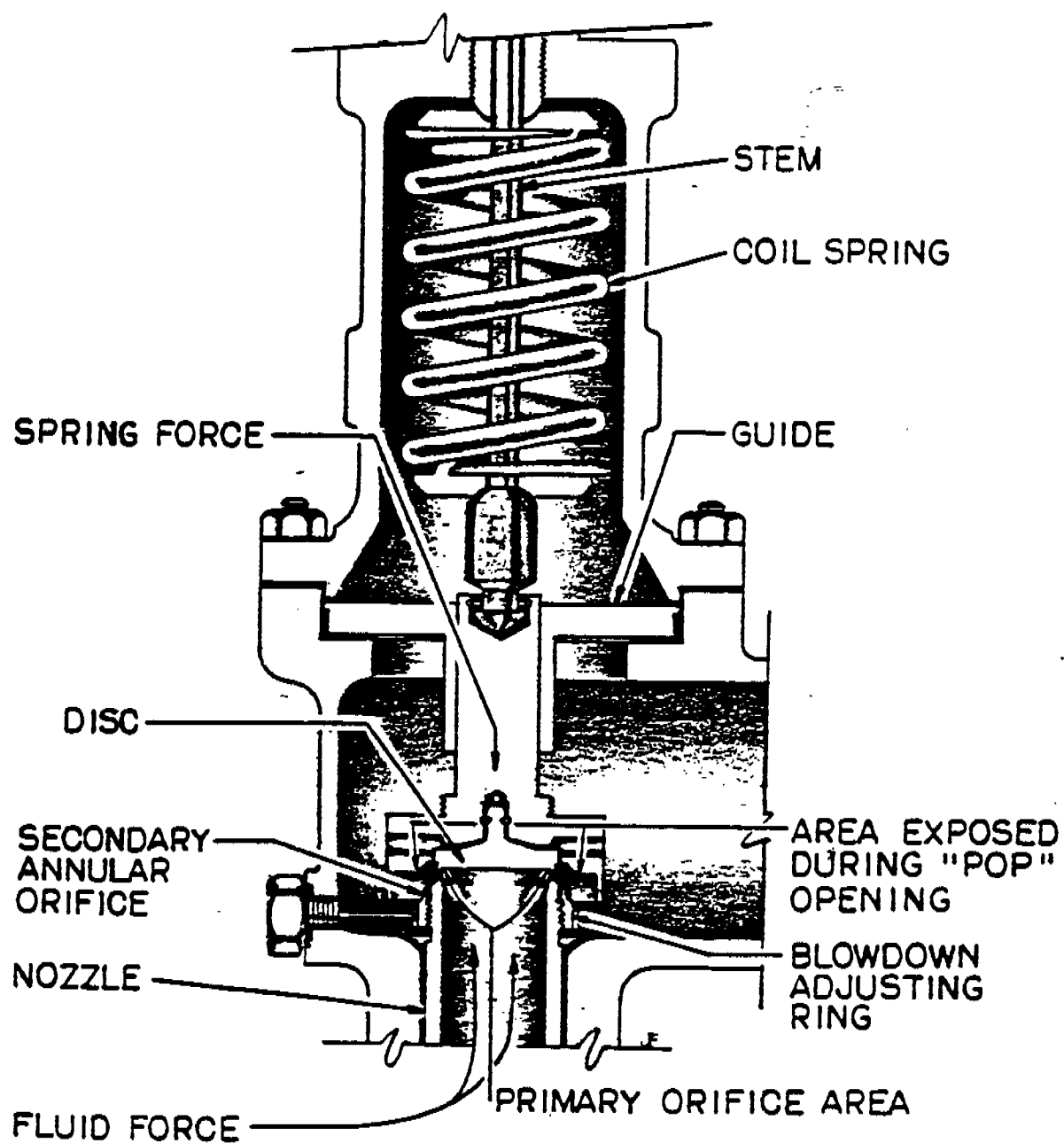
Another observation we made showed that moving the adjusting ring (blow down ring) down from the "test position" to the field-adjusted position caused a change in the set pressure in many valves.

Our conclusion is that no substitute exists for an adequately designed test facility. This also implies that field testing is of limited value for safety relief valves which are protected by reverse buckling rupture discs, especially in a plant that processes corrosives.

DESIGNS OF SAFETY RELIEF VALVES

Safety relief valves are rather sensitive instruments, which operate at a point of equilibrium between two opposing forces. Prior to valve opening, the force of the confined pressure acting over the nozzle area is balanced by the spring force and weight of the floating parts. As the pressure rises in the system and

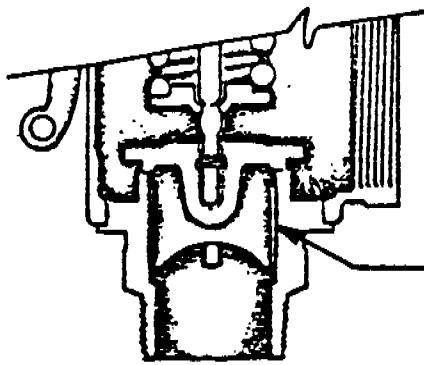
FIGURE 3
SRV JUST BEFORE POPPING



at the moment just before the "pop," the fluid pressure is exposed to a significantly greater area, as shown in Figure 3. This greater area with the same fluid pressure amplifies the force. Almost instantly, the valve snaps open. It is essential that there are no hindrances in the internal parts to interfere with this snap action. Any such hindrance can cause a malfunction. Hindrances occurring in the guiding area of the valve may be caused by corrosion of the metal parts, galling of the metal parts, product solidification in the guides, pieces of trash or rupture disc, use of incompatible lubricants, and so forth. Guides must be machined to close tolerances to ensure proper valve operation. The guides must be obstruction free and must remain so throughout their expected service life. During safety valve repair and testing, the guides should receive the same degree of attention as the seats.

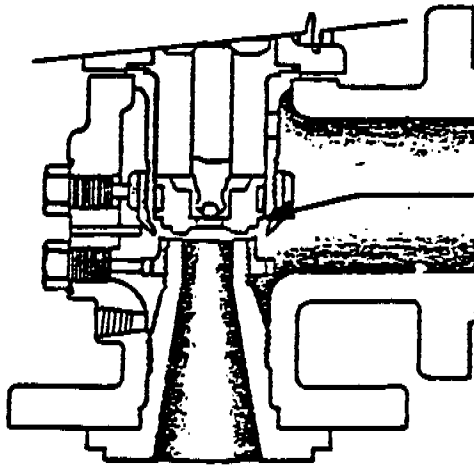
During our early safety relief valve testing investigations, we found that corrosion in valves' guiding areas was the most common cause of late pops. Typically, our mechanics had been trained to give a great deal of attention to the seats of the SRV's to prevent leakage, but had not been alerted properly to the importance of the guiding areas. We found that the guiding areas of the SRV's should be cleaned, polished and lubricated during each repair.

When specifying safety relief valves for use in areas where corrosive substances such as chlorine (Cl_2) or hydrochloric acid (HCl) are handled, the design of guiding areas is important. Typical process safety valve designs are wing-guided, cage or disc-guided, or upper stem-guided. We recommend using only upper stem-guided valves in corrosive services. We recommend an "O" ring seated upper stem-guided valve where temperature conditions permit.



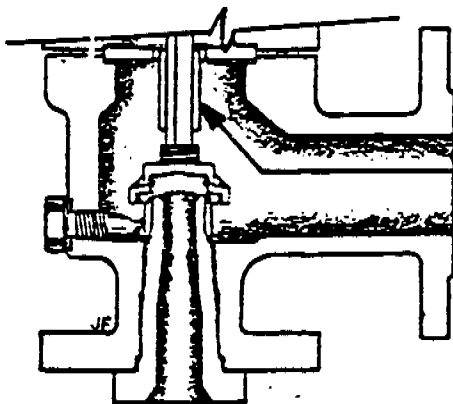
SIGNIFICANT AREAS FOR
CORROSION BETWEEN GUIDES
AND NOZZLE WITHIN THE
CORROSIVE OR FOULING MEDIA

WING GUIDED SRV



SIGNIFICANT AREAS FOR
CORROSION AROUND THE DISC
AND UNDESIRABLES CAN BE
INJECTED INTO VALVE GUIDES

CAGED OR DISC GUIDED SRV



GUIDE AREA NOT IN CONTACT
WITH CORROSIVE MEDIA. THE
GUIDES ARE ALSO NOT EXPOSED
TO DIRECT IMPINGEMENT

UPPER STEM GUIDED SRV

The upper stem-guided safety valve offers several advantages over the wing-guided and cage or disc-guided types in minimizing the effects of corrosion in the guiding area. Figure 4 gives a comparison of these devices.

The most significant advantages for using an upper stem-guided safety valve are:

1. Most upper stem-guided valves have the guides located high in the valve body, usually above any entrained fluid level. In this location, the guides are not subjected to direct exposure or impingement of the product.
2. Compared to the area of the disc, the area of the guides is low and thus has minimum exposed surface area which can corrode or upon which fouling media can collect. This design allows less resistance to opening with minimum corrosion or fouling.
3. The upper stem-guided safety relief valve is adaptable to a bellows, which will isolate the guiding area from the discharge stream.

HANDLING SRV'S ON MAJOR PROJECTS

New safety relief valves for all new installations should be removed and tested during the pre-operation stage. On two recent multi-million dollar projects, we found that more than 30 percent of new safety relief valves would not function within ASME code² tolerances. Needless to say, having new valves that would not work surprised us.

We assumed that the safety relief valves were properly set by the manufacturer. However, after the manufacturer has set and sealed a safety valve to his satisfaction, he has limited control over the handling and storing of the safety valves. Many construction projects require that the constructor install safety valves in order to assure proper location and fit. This requirement means that the safety valves are exposed to the environment of the construction site. Rough handling, mud, rain, sandblasting, painting, chemical exposure from adjacent plants, and so forth frequently are encountered. It would be unfair to the manufacturer to assume that the installed valve in a new plant is in the same condition it was when it was sealed and shipped. These valves should be removed and retested immediately before start-up. If the plant site does not have adequate test facilities and trained mechanics, some SRV manufacturers have mobile shops that permit the valves to be retested at the plant site. Our procedures require all safety valves to be removed and shop-tested prior to start-up.

TESTING AND REPAIR PROCEDURES

Our testing procedure may vary from other industry practices in that we rely on adequate volume testing and that we pay considerable attention to the guides. We also specify that safety relief valves be lubricated in the guides and threaded parts, as well as at pressure points. Our safety relief valves first are tested when they are received, and the appropriate data is recorded.

The safety valve then is disassembled, sandblasted and painted. During assembly, all defective parts are replaced or reconditioned to manufacturer's specifications. Metal seats are lapped to the desired flatness. All moving and pressure-bearing parts, including the guides, are lubricated. Lubricants are selected to be

compatible with products and in-service temperatures. Improper lubricants or lubricants improperly applied can cause problems. The lubricant, applied to the guiding surfaces in a thin, uniform coating, not only reduces friction and galling, but acts as a barrier to corrosive media. Caution must be used to prevent excessive lubricants from being applied to the guides. Reliability is greatly enhanced by lubricating the guiding surfaces of safety valves.

Upon assembly the valve is tested and set to the correct set pressure (including cold set adjustment if required). The blowdown is set. On any bellows-type valve or conventional valve exposed to back pressure, the valve is back-pressure tested.

A tag made of sheet lead is stamped and attached to the valve to indicate location number, set pressure and date of test. All openings that could allow entry of foreign elements are sealed so that the valve is protected en route to the user or during storage.

Table No.1 lists the steps of our repair procedure.

TABLE 1

SRV TESTING STEPS



1. Prepare vessel for valve removal
2. Tag valve for removal
3. Pretest POP pressure
4. Sandblast and paint
5. Reassemble and lubricate
6. Final set and blowdown
7. Document on paper
8. Reinstall valve

TESTING FREQUENCIES

The testing frequency of a chemical plant's relief devices should be based upon careful observations and not conflict with the authority having jurisdiction over such matters. In chemical plants that process or handle corrosives, similar services may require different test frequencies between valve sites, due to differing environmental conditions.

In general, PPG's test frequencies range from six months to three years. Our present testing guidelines for new installations are shown in Table 2.

These are general guidelines of PPG Lake Charles complex. They are adjusted as test history is compiled for actual operating conditions.

Other chemical manufacturers should consult state laws, local ordinances, insurance company regulations, and so forth, before establishing test frequencies.

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TABLE 2GENERAL GUIDELINES FOR FREQUENCY OF TESTING

These are general guidelines based on operating conditions in the Lake Charles complex. Dirty, fouling or highly corrosive services require special attention and the test frequency should be adjusted to meet these higher demands.

1. BOILER VALVES PER STATE LAW (Louisiana law requires a once-per-year test for boilers below 400 psi. The test frequency is unspecified for boilers rated above 400 psi. PPG tests its high-pressure boiler SRV's once every two years.)
2. PROCESS STEAM VALVES OUTSIDE PROCESS AREA - TWO YEARS.
3. POSITIVE DISPLACEMENT PUMPS OR COMPRESSORS - ONE YEAR.
4. VESSELS PROCESSING CORROSIVE CHEMICALS AS CL_2 AND HCl - ONE YEAR.
5. PROCESS VESSELS WITH HEAT SOURCE - ONE YEAR (including stills, kettles, hot oil coolers, low pressure refrigerated storage, etc.)
6. STORAGE VESSELS WITH NO HEAT SOURCE - CLEAN SERVICE - TWO YEARS.
7. INSTRUMENT AIR MANIFOLDS WITHIN DEHUMIDIFIED CONTROL ROOMS - THREE YEARS.
8. LUBRICATING RELIEF VALVES ON ENCLOSED SYSTEMS (such as compressors, turbines, generators) - THREE YEARS.

RECORDKEEPING - THE TRUE TEST OF YOUR PROGRAM

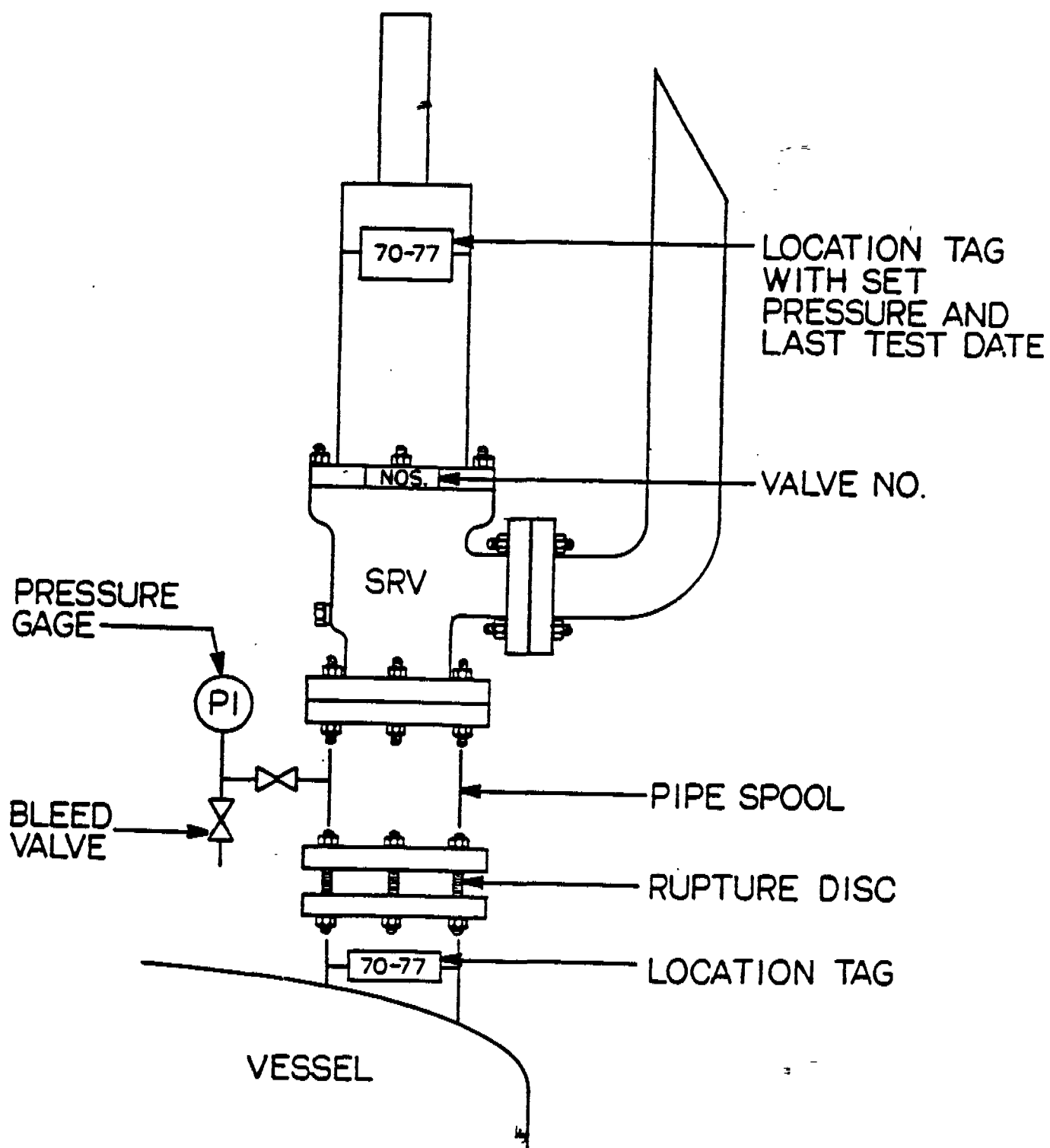
In a chemical complex that has a large number of safety relief valves, accurate records are necessary to ensure that safety relief valves will function when required. Because testing is expensive, it also is economically prudent to not needlessly test every relief device on a rigid inflexible set of guidelines. Tests should be based upon service history.

In order to handle our needs, we found it necessary to use a dual numbering system, a computer and computer-generated reports. Each location and safety relief valve is assigned a specific number.

The equipment number is unique to the safety relief valve and is retired when the valve is retired. Our equipment number records include information on the manufacturer, model number, serial number, type of construction, orifice size, spring rating, and inlet and outlet nozzle sizes and ratings. Spare safety valves are a must to handle plant needs; this type numbering aids in locating spares.

The second number we use is the location number. Each potential site of over-pressure is assigned a location number. The vessel or pipeline flange also is identified as well as the safety relief valve intended for or installed on that location (see Figure 5).

Location number records include a description of the location, the temperature, set pressure, product, presence of a rupture disc, and so forth. One of our department's circulated reports - - the Safety Valve Inspection Schedule - - is location oriented. This report is issued to operations supervisors every two months.

FIGURE 5

The Safety Valve Inspection Schedule gives the service, location, frequency of inspection, last test date, last test results (satisfactory, changed, or unsatisfactory), the correct set pressure, back pressure, operating temperatures, and number of each safety valve. This schedule automatically flags valves due for testing.

A second report also can be generated. It shows the conditions of the last 10 tests, including whether the safety relief valve passed or failed the pre-test, the presence of plugging material in the vessel nozzle, the condition of a rupture disc if one is present, and the condition of valve components.

If the report indicates trouble, then we have not done enough. When the report gives satisfactory test data, we think our program is working. Over the past nine years, we have reduced the out of tolerance performance safety relief valves to one-tenth of our 1975 experiences. We are still trying to improve.

Literature Cited

1. American Society Of Mechanical Engineer's (ASME) Boiler and Pressure Vessel Code, Section VIII, Part UG 136-d-5.
2. ASME Section VIII, Part UG 134-e-1.