INTRODUCTION TO OVER PRESSURE PROCTECTION

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Introduction

Overpressure protective (OPP) devices are part of both transmission and distribution systems in the natural gas industry. Safety codes and current state, local, and federal regulations require the installation of overpressure protection devices each time a pressure reducing station is installed that supplies gas from any system to another system with a lower maximum allowable operating pressure (MAOP).

This paper will provide a systematic review of the overpressure protection regulations and devices that meet the regulations. Advantages and disadvantages of each method and the devices used in each method will be discussed.

The primary methods of overpressure protection in the gas industry are: reliefs, monitoring regulators, working monitors, shut off valves/automatic shut offs.

Code Review

The Pipeline and Hazardous Materials Safety Administration (PHMSA) an agency within the U.S. Department of Transportation (DOT) is the federal agency responsible to oversee and enforce the Pipeline Safety Regulations (Title 49 CFR Parts 190-199).

Overpressure protection regulations for natural gas industry are found in 49 CFR Section 192. In Subpart D-Design of Pipeline Component, the design criterion is laid out.

192.195- Protection against accidental overpressuring.
192.199- Requirements for design of pressure relieving and limiting devices.
192.201- Required capacity of pressure relieving and limiting devices.
192.203- Instrument, control and sampling pipe and components.

The maintenance and inspection of the overpressure protection devices is covered in Subpart M-Maintenance.

192.739-Pressure limiting and regulating stations: Inspection and testing.
192.741-Pressure limiting and regulating stations: Telemetering or recording gauges.
192.743-Pressure limiting and regulating stations: Capacity of relief devices.

State and local codes normally come directly from or are interpolations of 49 CFR 192 or ASME B31.8 Sections: 805.217, 841.126, 841.126, 845.1, 845.36.

Interruption of Code

The design and installation of overpressure protection systems need to be designed and installed to prevent a single event causing an overprotection incident to the piping system that it is protecting. OPP system capacity should be the largest capacity requirements of the maximum anticipated volumes. This requirement is independent of the four primary design methods of protection mainly: reliefs, monitoring regulators, working monitors, shut off valves/automatic shut offs.

The maintenance and inspection of the existing pressure limiting and regulating stations must be inspected and tested at intervals not exceeding 15 months but at least once each calendar year. During this inspection the mechanical condition of the devices, set point verification, capacity verification, installation, and design perimeters should be verified. Capacity verification can be done either physically or calculated. Once it has been calculated, it only needs to be checked when changes have occurred within the overpressure system.

Types of Over Pressure Protection

Relief Devices

Relief incorporates a device to vent the gas to atmosphere in order to maintain the pressure below the MAOP. Relief is the most common form of OPP. The most common forms of reliefs are relief valves and rupture disc.

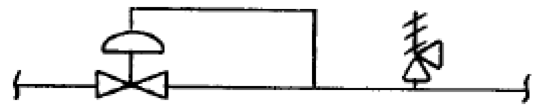

Fig. I Relief Schematic-simple regulator and relief valve setup that is common used at gate stations, farm taps and other pipeline facilities

Minimum relief device capacity for the failed regulator(s) should be the maximum total flow at the differential pressure between the inlet and outlet of the regulator(s), the inlet pressure is the upstream line MAOP and the outlet pressure is the downstream MAOP.

There are three basic types of relief valves: spring/direct acting type, pilot-operated relief valve, and internal relief.

Spring/Direct acting are the simplest and oldest form of relief valves. A basic principle is that the pressure of the media has to overcome the physical pressure exerted by a spring or buckling pin on the seating disc. When system pressure reaches the set point pressure, the disc will lift and allow the media to flow out through the valve. When pressure in the system drops below the set point, the valve will return to the closed position. The spring load is adjustable to vary the set point pressure.

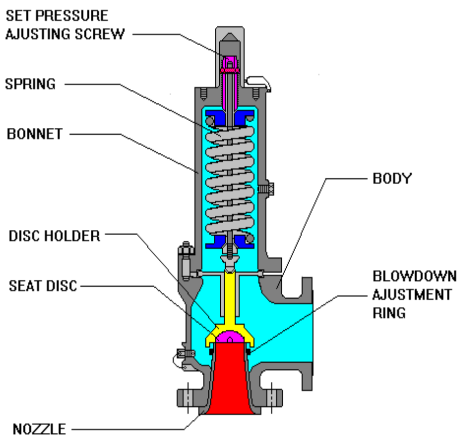

Fig. II Spring/Direct Acting, Relief Valve -simple spring type relief valve

A buckling pin/rupture pin relief valves operate under the same principle. The pin is engineered to buckle at an exact set point from an axial force applied by the system media pressure acting on the seat disc. Once it buckles the media flows through the open valve. It must be manually reset once the pin has buckled.

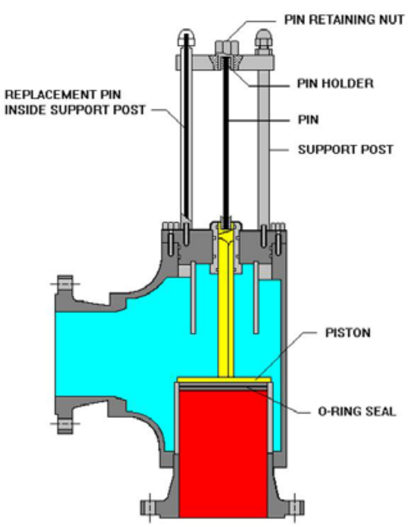

Fig. III Spring/Direct Acting, Relief Valve-example of a buckling pin type of relief valve

The pilot operated relief valves have the most accuracy but are also the most complicated. Pilot operated pressure relief valves consist of a main valve with piston chamber containing a seat disc and a pilot. Under normal operating conditions the pilot allows system pressure into the piston chamber loading the piston and keeping the disc seat closed. When the set pressure is reached, the pilot actuates to shut off the piston chamber and simultaneously vents the piston chamber. This causes the seat disc to open. Adjustment to the set point is done through the pilot.

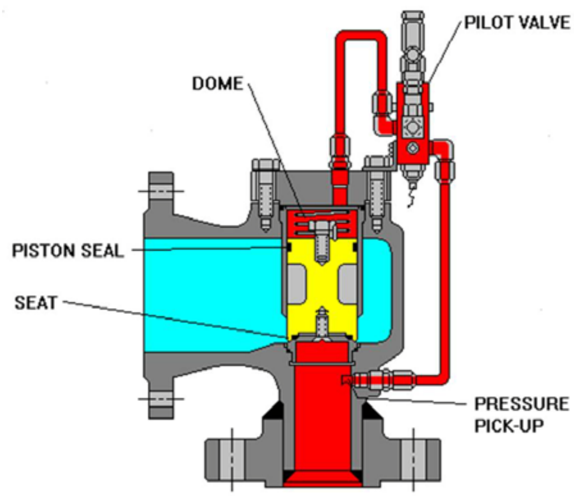

Fig. IV Pilot Operated Relief Valve- has two basic pilot types snap acting pilots and modulating pilots

Internal relief valves are used in low pressure applications in distribution systems. This is due to them providing adequate protection for the low pressure systems. Internal relief uses a relief valve built into the regulator to provide protection. If the pressure builds too far above the setpoint of the regulator, the relief valve in the regulator opens up, allowing excess pressure to escape through the regulator vent.

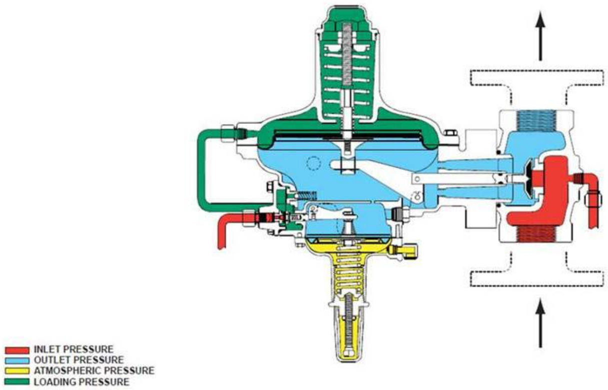

Fig. V Internal Relief Valve- used in distribution systems

The rupture discs are thin diaphragms (generally a solid metal disc) designed to rupture (or burst) at a designated pressure. They are used as a weak element to protect downstream piping against overpressure events. They are not commonly used in gate stations and regulating stations. Device burst pressure cannot be tested. Once rupture discs have ruptured it cannot reclose without replacement of rupture disc.

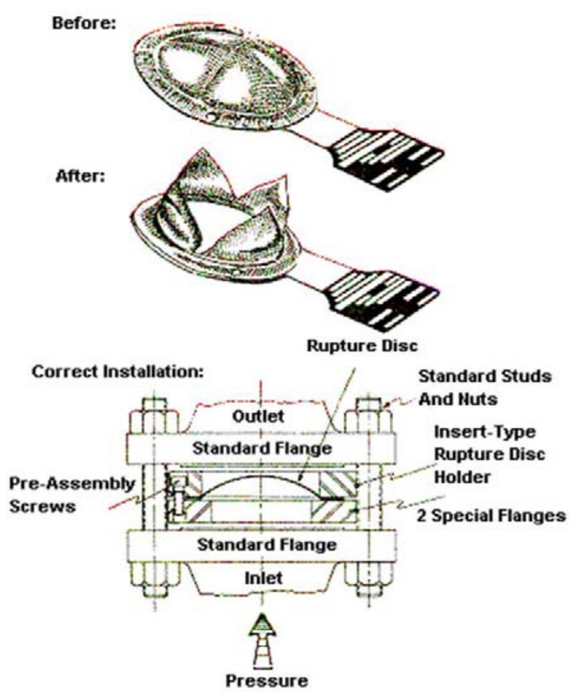

Fig. VI Rupture Disc- example of disc prior to rupture and after rupture

The relief is considered to be the most reliable and cost effect type of overpressure protection. Under normal conditions it is not subject to blockage by foreign objects. It also imposes no decrease in the regulator capacity which it is protecting, and it has the added advantage of being its own alarm when it vents. This can also can be a disadvantage creating a possible hazard area and noise nuisance in populated areas.

Monitoring Regulators

Monitoring Regulators are when you have two regulators installed in series. One regulator is the “worker” and the other the “monitor”. In Figure VII below, the downstream regulator acts as the worker regulator controlling the pressure to a set point during normal operations. The upstream regulator is the monitor in Figure VII. It senses the pressure downstream of the worker regulator and works when the worker regulator fails to control the pressure. This monitor is normally set a slightly higher pressure set point.

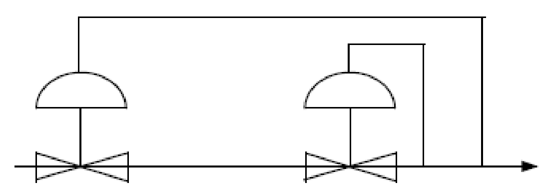

Fig. VII Monitoring Regulators Schematic

There are two types of monitoring upstream and downstream monitoring. If the system is using two identical regulators then the configuration of upstream versus downstream does not matter because the capacity will remain the same. The only difference between the two is the role that regulator is playing. With some companies it is their policy to reverse the roles of the regulators periodically throughout the year so that both are exercised. This is viewed as a way of ensuring the monitor regulator in wide open state will work when needed.

Working Monitor Regulators
Another variation of OPP with regulators is working monitors. In this concept the monitor regulator the “upstream regulator” in Figure VIII below has two pilots installed and senses pressure in two locations; between the regulators and downstream of the worker. It functions as regulator, regulating the intermediate pressure and monitor now. When the worker fails the monitor takes over control at higher set point pressure.

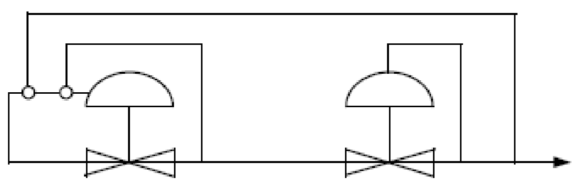

Fig. VIII Working Monitor Regulators Schematic

In this way both units are always operating and can be easily checked for proper operation. This eliminates some of the disadvantages there are with the wide-open monitor in monitor regulator setup.

Shut Off Valves/Automatic Shutoff

Shut off valves/automatic shutoffs are OPP devices that work by containment. The shut off valves will close when the downstream sense line pressure reaches its set point. It isolates the downstream system from the upstream pressure.

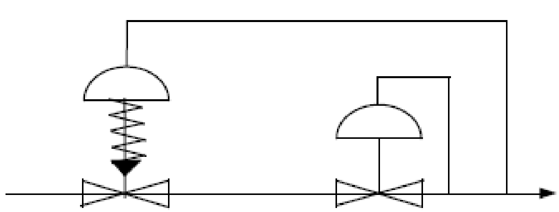

Fig. IX Shut Off Valve Schematic

In this cause the downstream system is completely shut in. This form of OPP is used in distribution companies as an added measure of protection for schools, hospitals, shopping centers, and churches. In these cases it is the secondary device providing OPP.

The passive devices that provide OPP containment monitoring regulators, working monitor, and shut off valves all share the advantage over relief type OPP it is there is no venting to the atmosphere. Monitoring regulators and working monitors share similar advantages in that the customer will still receive gas at a higher pressure if the worker regulator fails. One advantage the worker monitor system has that monitor system does not is that the monitor is not in the wide-open state is continuously being exercised. All three systems are testable.

Some of the disadvantages with monitor systems are they are more expensive to install and can be more expensive to maintain. Due to the regulators being in series there is a capacity reduction. The monitors that operate in the wide-open mode for normal operation have a tendency not to be able to provide bubble tight seal when needed. Some disadvantages to worker monitor systems are they are more complex and might require additional training for workforce to operate and maintain. Shutoff valves main disadvantage is by design it isolates the downstream system until it can be mainly reset. It can require multiple call outs and on a single feed system may require the re-lighting of pilot lights.

Table I. OPP Comparison

TYPES OF OVERPRESSURE PROTECTION	Relief	Monitor	Working Monitor	Shutoff
Keeps customer "on line"?	YES	YES	YES	NO
Public relations problems caused by venting?	YES	NO	NO	NO
Manual resetting required after operation?	NO	NO	NO	YES
Reduces capacity of regulator?	NO	YES	YES	NO
Constantly working during normal operation?	NO	NO	YES	NO
Demands "emergency" action by gas company?	YES	NO	NO	YES
Will surveillance of pressure charts indicate partial loss of performance of overpressure device?	NO	MAYBE	YES	NO
Will surveillance of pressure charts indicate regulator has failed and safety device is in control?	YES	YES	YES	YES

Set Points

Set points for OPP devices are covered under section 192.201 for pipelines except for low pressure distribution. The set points are broken into three categories based off your MAOP.

The first category is if your MAOP is greater than 60 psig, the pressure may not exceed MAOP by 10% or a pressure that produces a hoop stress of 75% of SMYS whichever is less.

The second category is if your pressure is greater than 12 psig but less than 60 psig, the pressure may not exceed MAOP plus 6 psig.

The third category is if your pressure is less than 12 psig, the pressure may not exceed the MAOP plus 50%.

Set points need to take in account the mechanical tolerances of the devices being used. It also needs to take in account the summation of pressure drop from the take off from the main to inlet of the devices. For this example a pop action pilot relief valve is selected and we have determined MAOP plus 10% is limiting factor for set point pressure for a 150 psig MAOP system. The relief valve has mechanical set pressure tolerance is 3% of MAOP and it achieves full lift at set pressure. The next step is to calculate the pressure drop through tees, valves, relief valve, piping, and outlet. The pressure drop through these components was calculated at 2 psig. So the relief valve set point pressure would be MAOP plus 10% (165 psig) minus the set point tolerance of 3% (4 psig) minus the 2 psig of pressure drop equaling a set point of 159 psig.

Conclusion

Gas Engineers have variety of design philosophies and equipment to use while designing effective overpressure protection systems. Each design philosophy has its strengths and weaknesses; these need to be analyzed against the conditions the systems are protecting. Reliefs, monitoring regulators, working monitors, shut off valves/automatic shut offs have all proven to be effective OPP devices when designed, installed and set correctly.

References

The author used the following recourse while compiling information for this paper and recommends using them: 49 CFR Section 192, Anderson Greenwood, Fisher and Mooney manufacturers' technical bulletins. Also another good source of information is the Emerson's *Natural Gas Technologies Application Guide-Edition VI.*