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INTRODUCTION TO OVER PRESSURE PROTECTION

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Introduction

The following paper will provide an introduction to gas over pressure protection systems used in the natural gas industry today.

Code Requirements

Each natural gas distribution system operates at a designated maximum allowable operating pressure (MAOP). The CFR 49, Part 192 – Transportation of Natural and Other Gas by Pipeline Minimum Federal Safety Standards, Subpart D - Design of Pipeline Components lays out specific requirements for overpressure protection for these systems. I have listed below the most pertinent sections of this subpart and what those sections address.

192.195 – Protection against accidental overpressuring.
This section spells out the need for pressure relieving or pressure limiting devices in the event of a pressure control failure.

192.197 – Control of the pressure of gas delivered from high-pressure distribution systems.
This section gives exceptions for overpressure protection and if necessary, four methods for obtaining adequate overpressure protection.

192.199 – Requirements for design of pressure relief and limiting devices.
This section specifies essential design considerations for overpressure protection systems.

192.201 – Required capacity of pressure relieving and limiting stations.
This section details the design limits for pressure relieving or pressure limiting devices in the event of a pressure control failure.

Subpart M – Maintenance addresses the inspection and maintenance to be done on those same systems. I have listed below the most pertinent sections of this subpart and what those sections address.

192.739 – Pressure limiting and regulation stations: Inspection and testing.
This section states how often each station must be inspected and what needs to be inspected.

192.741 – Pressure limiting and regulating stations: Telemetering or recording gauges. *This section states the requirements for pressure monitoring of the system.*

192.743 – Pressure limiting and regulating stations: Capacity of relief devices.
This section states the capacity requirements of the over pressure protection (OPP) system and requirements for design review.

Over Pressure Protection Systems

Section 192.195 states that we must design into our over pressure protection (OPP) system, measures to prevent accidental over pressuring of a system in the event of a failure of the pressure control system. In order to do that, three common systems are called out in 192.197(c) of the code. They are as follows:

1. Operator – Monitor
2. Relief Valve (RV)
3. Automatic Shut Off

I will describe each system in detail. Let's start with the operator monitor system.

Operator Monitor OPP Systems

The operator monitor system uses two regulators in series. There is an operating regulator (or operator) that is controlling the downstream pressure and a monitoring regulator (or monitor) that is sensing the downstream pressure and "monitoring" the outlet pressure of the operator.

Operator monitor systems can be further classified into either wide open monitor systems or working monitor systems.

The wide open monitor system is the most common and is illustrated in Figure 1.

(Note: In my Figure schematics, I will use colors to depict the various pressures. I will show the inlet MAOP as "red", the outlet MAOP as "green" and any intermediate pressure as "blue", for the sake of clarity.)

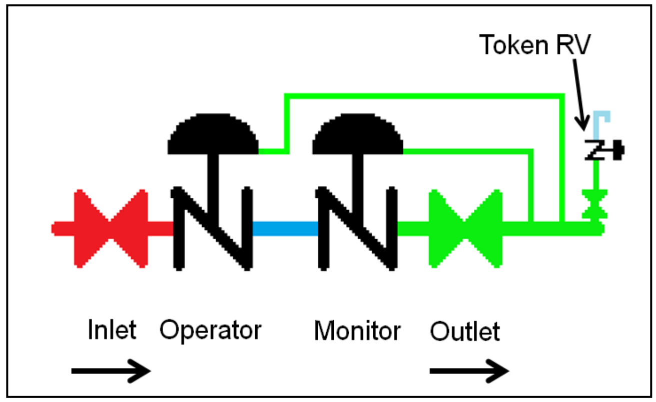

Figure 1
Wide Open Monitor System

The operator is set lower than the monitor, so the operator has control of the outlet pressure during normal operation. If the operator fails, the downstream pressure rises to the set point of the monitor which then begins to regulate the downstream pressure at its new higher set point.

In these systems, the monitor actuator sits in a "wide open" position, because the sensing pressure is below the set point of the operating regulator or its pilot, if pilot operated. The monitor actuator moves to full stroke in a vain attempt to raise the downstream pressure which is being choked and regulated by the operating regulator.

A token relief valve monitors downstream pressure and is set somewhere between the operator and monitor's set points to blow and signal if the operator has failed. The monitor can be either upstream or downstream in this configuration. It is a matter of preference. The capacity of the system is the same.

A possible flaw of this system is that the monitor actuator does not change position, as it sits in the full travel position while monitoring the operator. This can lead to issues when the monitor is finally called into action as a result of a problem with the operator.

Therefore, sometimes a “working” monitor system is used. In this system, two pilot regulators allow the monitor to sense outlet pressure and an intermediate pressure between the monitor and operator. This working monitor is controlling an intermediate pressure which causes the regulator actuator to change positions with different flow rates. This is the intent of the design. Since the monitor is sensing two different pressures downstream, the monitor needs to be placed in the upstream position (see Figure 2).

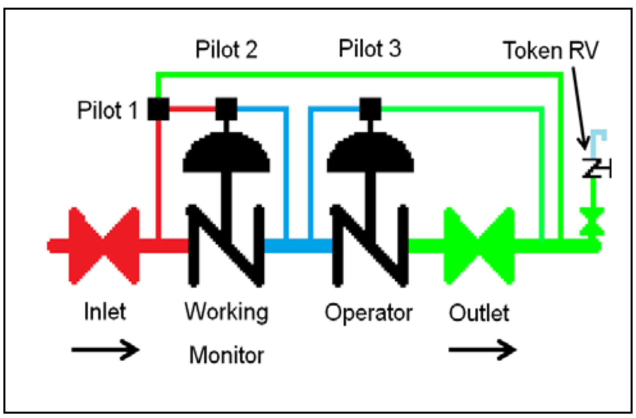

Figure 2
Working Monitor System

Pilot 1 is the first of two pilots controlling the working monitor. It senses outlet pressure downstream of the operator which is below its set point. As a result, it sits wide open most of the time supplying full inlet pressure to Pilot 2 of the working monitor. Pilot 2 senses the blue intermediate pressure and changes position to adjust the loading on the monitor actuator. Pilot 3 takes the intermediate pressure and uses it to load the operator actuator based on the pressure signal received from the outlet pressure.

If the operator were to fail, outlet pressure would rise and intermediate pressure would fall. This will cause Pilot 1 to take control as set point is reached and Pilot 2 goes to wide open position, as the intermediate pressure approaches the set point of Pilot 1.

As in the wide open monitor scheme, a token relief valve is used with a set point somewhere between the operator and monitor set points to blow and signal when the operator has failed. In gate station designs, SCADA is often used to monitor the intermediate pressure which negates the need for a token RV.

Operator monitor systems have advantages over other OPP systems in that there is neither interruption to service nor release of gas to the atmosphere. A disadvantage of the design is that using two regulators in series reduces the capacity of the regulators to approx 70% of a single regulator. This can cause an increase in the size of regulator needed and raise the overall cost of the system.

Relief Valve Systems

A second way to provide OPP is to use a relief valve, either internal or external to the regulator. Unlike the token RV in the previous system, this system uses the RV to vent gas from the piping system to avoid hazardous downstream pressure build up. This is by far the most common method of OPP used in gas distribution systems.

In Figure 3, I have shown a typical external relief system. The relief valve set point is set higher than the regulator set point, but is set less than the allowable pressure for the given MAOP, less the calculated “build up” in the relief valve itself. This build up pressure in a relief valve is the differential between relief set point and final flowing pressure, for a given flow condition, when the device operating.

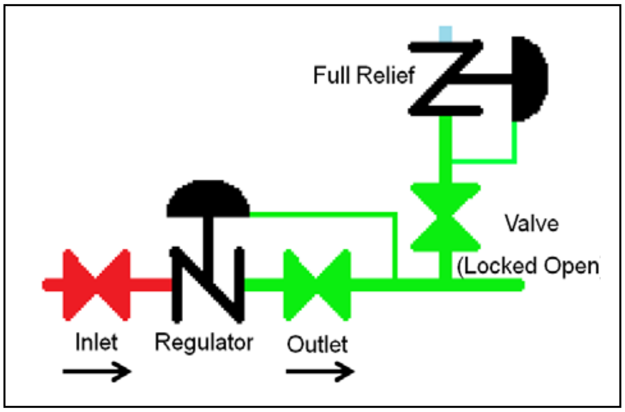

Figure 3
Full Relief System

Since the relief valve's set point is higher than the regulator set point, the relief valve is normally closed and hopefully locked up bubble tight. If there is a problem with the regulator and outlet pressure begins to rise, the relief valve will begin to open once its own set point is realized. It is common for the relief to open slightly or "weep" if the pressure rise is gradual. If the regulator failure is wide open, the relief may need to open to full travel to keep the outlet pressure within design limits.

The relief valve port must be considerably larger than the port of the regulator it is monitoring. This is due to the fact that the relief valve capacity is based on the outlet MAOP, while the capacity of the regulator is based on the inlet MAOP. The difference in those two MAOPs is quite considerable in most designs.

One downside of a relief valve system is the intentional release of sometimes large amounts of natural gas in the event of an abnormal operating condition (AOC) of the regulator. Care must be taken with the location of the relief vent/stack to ensure a hazard is not created with the release of the gas to the open atmosphere. It is common practice to install a stack on larger external relief valves to project the natural gas to atmosphere at a location that is away from the public and ignition sources. However, the design calculation must take into account the length and size of the stack, as this will add to the build up in the relief valve system.

Figure 4 shows a curve table for a spring operated 2" Type 289H relief valve.

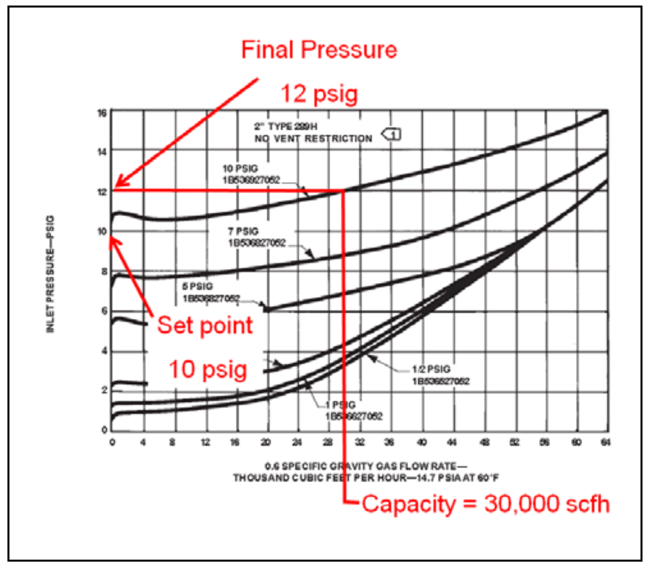

Figure 4
Relief Capacity for Fisher 289H RV

The relief curves are plotted on a chart that has inlet pressure (in psig) on the "Y" axis and flowrate (in mcfh) on the "X" axis. I have illustrated how to use the table to calculate relief capacity.

In this Figure, you will see that for a relief set point of 10 psig, the device will flow approx 30,000 scfh at a final pressure of 12 psig. This 2 psi difference in pressure from set point to final pressure is the build up pressure mentioned earlier. This build up value must be accounted for when determining set pressure for the relief valve.

Automatic Shut-off Systems

A third way to provide OPP is the full shut off system. Like the relief system, this can be internal to the regulator or external. When external, the full shut off device or "security valve" is located ahead of the regulator (See Figure 5).

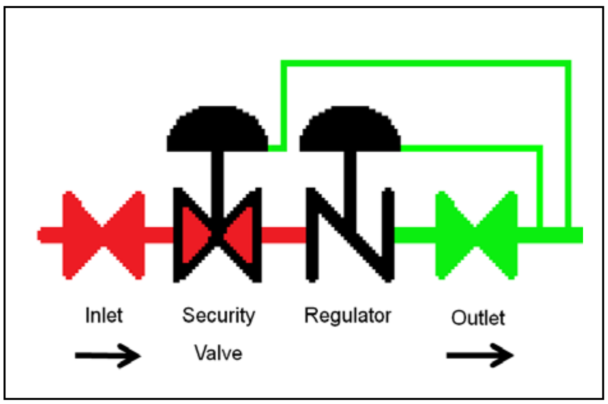

Figure 5
Automatic Shut-off System

The security valve senses downstream pressure and is normally open. If the regulator experiences a problem that raises the outlet pressure to the set point of the security valve, the security valve trips shut, interrupting the flow of gas. It is important that the security valve is located upstream of the regulator as many times the outlet rating of the regulator is far below the inlet MAOP serving the regulator. The security valve does not reset and needs a technician to manually reset it after the problem has been remedied.

An obvious downside to the security valve is the loss in service to the customer. This may be undesirable to most customers and unacceptable to customers with critical service needs.

A pro is that there is no release of gas to the atmosphere.

Design Requirements of OPP Systems

The code is very specific on what build up pressure is allowable in the event of an abnormal operating condition. Section 192.201(2) states that:

- When the MAOP is 60 psig or more, you may not exceed MAOP plus 10%.
- When the MAOP is 60 psig to 12 psig, you may not exceed MAOP plus 6 psi.
- When the MAOP is 12 psig or less, you may not exceed MAOP plus 50%.

I have illustrated these limits below in Table 1 for the sake of clarity.

OPP Limits per 192.201(a)(2)				
<	MAOP 12 psig	Between	MAOP 60 psig	<
50% of MAOP	50% of 12 = 6 psi	6 psi	10% of 60 = 6 psi	10% of MAOP

Table 1

These design values are the limits after the OPP device has operated. They are not set points. In the case of operator-monitor systems, lock up of the monitor must be considered. In relief systems, the build-up of the relief valve must be factored into the set point.

Conclusion

This paper has given the reader a quick overview of OPP systems in the industry. Each design represents a series of compromises. It is the job of the design engineer to weigh these factors when selecting the best OPP system for the job.