

Over-Pressure Protection for Natural Gas Distribution Systems

By John Deveau, Baker Hughes

Natural gas is an abundant fuel that is used for both industrial and residential energy and is one of the few energy sources that is delivered directly into our homes. Because it's also a flammable, potentially explosive fluid, utilities and distribution companies are required to prioritize safety and devote focus to their protection systems to prevent accidents.

As we have seen in recent events, even with that knowledge and safety precautions in place, it is still possible for something to potentially go wrong.

Every natural gas system is designed and approved for a maximum allowable operating pressure (MAOP). Pressure regulation or control devices are used to keep the system pressure under that maximum rating. In residential supply systems, the MAOP can be extremely low; often only a few inches of water column (<1 PSI).

Such low-pressure systems can be vulnerable to even minor pressure excursions and can result in severe effects. That's why over-pressure protection equipment, or systems, are critically employed to ensure a single point of failure cannot result in exceeding the system MAOP.

Natural gas supply systems vary in design and pressures, and it's up to the utility or operator to select the appropriate safety devices for their system, in line with Federal regulations, codes, and company

design standards. The following provides a basic overview of today's common methods to achieve over-pressure protection.

Pressure Relief Valve

In years gone by, pressure relief valves (PRV) were the most common overpressure protection method for gas pipelines. As relief valves sensed downstream pressure exceeded the setpoint, they automatically opened to relieve the excess pressure. While this method is proven, it also comes with some disadvantages.

- More than one relief valve may be required to ensure sufficient capacity for all conditions, with each valve set at a slightly different set pressure such that they activate in sequence depending on the level of overpressure in the system. This pressure build-up with this design must be considered in determining safe operating and relieving pressures.
- When relieving, these valves are not only loud, but they also vent flammable, unfriendly greenhouse gas emissions (90-95% methane) direct into our atmosphere.

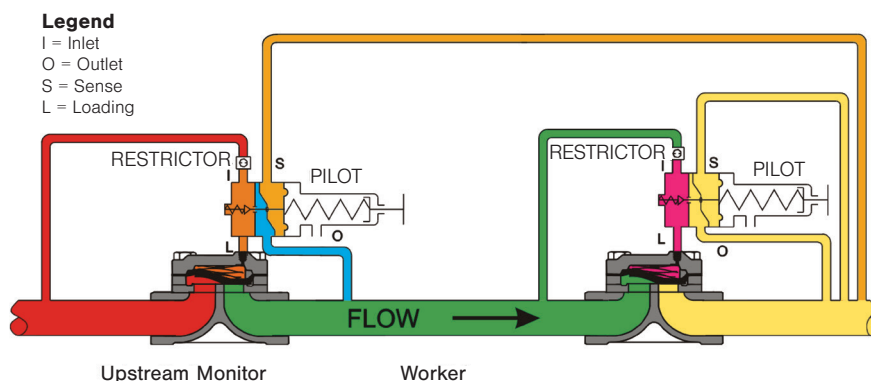
Relief valves used in these systems can be relieving regulators (back-pressure regulators), either spring-loaded or pilot operated, a control valve, generally for larger capacity systems.

The most common system used today for natural gas regulation stations is two pilot operated regulators, or control valves, in series with one operating as the "worker" and the other set with a slightly higher set pressure as the "monitor." This results in the Worker being the primary controlling device that is functioning under normal conditions. The monitor will remain open unless it senses the downstream pressure has increased beyond its higher set pressure at which time it will start to close and control the pressure at its higher setting. This creates a redundant system that statistically reduces the risk of total failure by 400%.

This system can be constructed using control valves or pilot operated regulators. Pilot regulators are usually simpler designs and have no external bleeds (no venting to environment) when operating and are often preferred when capacity requirements allow. Pilot operated designs are preferred over spring loaded versions as they are more sensitive, which higher accuracy – typically within x% as opposed to y% for spring return designs.

Another advantage is a pilot can drive the regulator full open if the pressure is lower than setpoint. This allows for its use in a wide-open monitor setup. as long as the worker is performing its job correctly, the monitor will remain wide open, minimizing restriction on flow. A spring-loaded regulator in a similar setup would remain partially closed. (**Figure 1**)

Figure 1

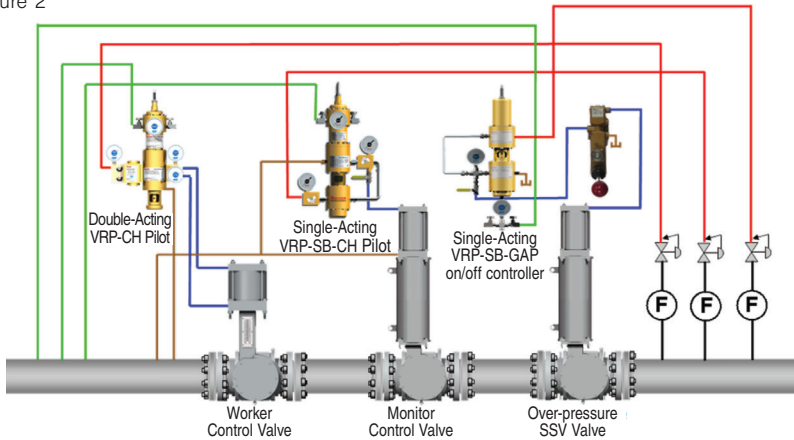


Worker/Monitor System

Control valves are preferred for use as worker/monitors and become necessary in high volume or high pressure drop systems. The control valve used is often a rotary ball type valve due to its high inherent capacity and low restriction when wide open.

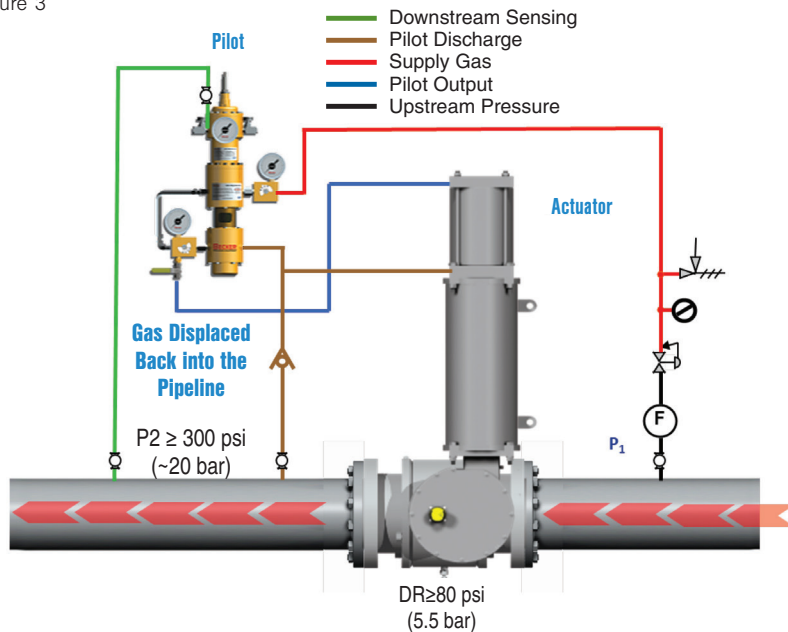
Since control valves are not self-operated, a pressure sensing device is required to provide feedback of regulated pressure, and a controller is necessary to vary the valve position in response to that pressure. Industrial applications, where instrument air or power sources are available, those

Figure 2



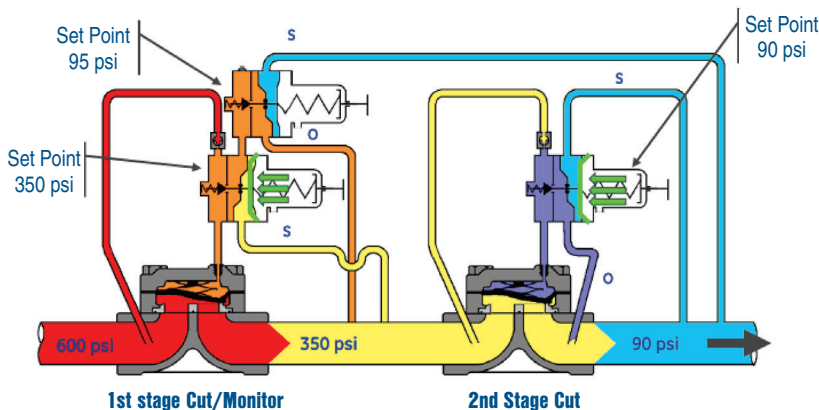
Typical control valve worker/monitor system with optional over-pressure "slam shut" shutoff valve.

Figure 3



Pilot venting back into pipeline (bled to pressure system).

Figure 4



Regulator with working monitor.

devices are typically pneumatic or electrically operated. But those resources are not always available in remote locations where gas regulation may be required, thus another, simpler option should be considered.

Using the higher pressure natural gas from the upstream side of the system, Valve Regulating Pilots can power a control valve directly without any external power supply, essentially combining the pressure sensor/transmitter and controller in one device. There are extremely low-bleed versions as well as designs that vent back into the pipeline, eliminating any atmospheric venting. These devices can transform a control valve into a self-operated regulator while maintaining the high capacity and pressure drop capability of the heavy-duty valve. **(Figure 2 & 3)**

Advantages to a Wide Open (Passive/Standby) Monitor:

- Minimal ΔP across monitor reduces wear in monitor.
- Upstream worker may catch debris before monitor.
- Downstream worker more accurate and responsive.
- Lower flow of gas through monitor pilot system.
- Low cost build.
- Monitor always in position to take over control.

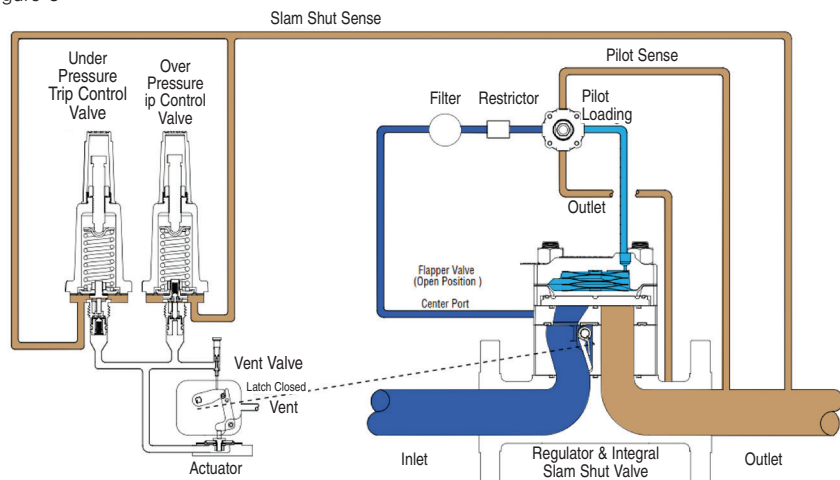
Advantages of a Worker/Monitor System versus a Relief Valve:

- No venting to atmosphere.
- Gas is continuously supplied to system at a safe level.
- Easy maintenance and cost-effective.
- Accurate control.
- Reduced noise with monitor.

Another variation is a Working Monitor approach. This system is very similar to the wide-open monitor system, except in this case both components are actively throttling all the time. In a working monitor setup, each regulator takes part of the pressure cut to stage the pressure reduction in smaller steps. The first regulator is set at a slightly higher pressure compared to the second and becomes the first stage reduction.

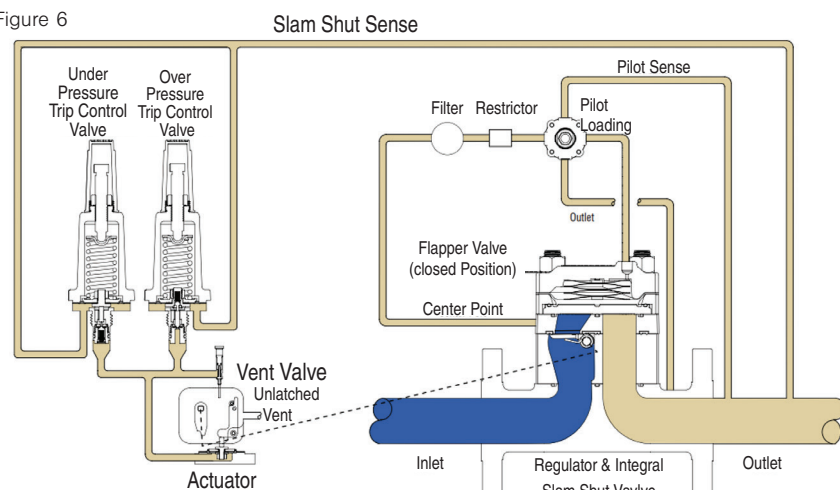
The output pressure of the upstream regulator becoming the inlet pressure to the second, which completes the pressure reduction to the desired downstream pressure. A second pilot/controller is used to sense the downstream system pressure and trigger the first stage monitor to take over in the event of overpressure and maintain that downstream pressure. **(Figure 4)**

Figure 5



Pilot operated regulator with integral slam shut shown in open position.

Figure 6



Pilot operated regulator with integral slam shut shown in closed position.

Working Monitor Advantages

- Two-stage pressure cut reduces stress on regulators by distributing workload.
- Distributed workload reduces system maintenance frequency.
- Reduced system noise for same mass flow.
- Condition of monitor regulator can be determined before emergency condition arises.
- Cost-effective and long term.

The Slam Shut Valve can also be equipped for under-pressure protection and provides an additional layer of over-pressure protection in the event pressure regulation is lost. The difference is with

the other methods above gas continues to flow with the additional devices working to regulate it. But if something goes wrong with those secondary devices, then what? Although not desirable as a first protection method, if the regulating devices, both primary and secondary fail, a slam-shut system will isolate the gas flow.

Slam Shut valves can be standalone devices or as an integral part of a pilot operated regulator, each option designed with their own sensing and control mechanisms.

Its function is simple, upon sensing a pressure exceeding setpoint, for over pressure protection, or below setpoint for

under pressure, the internal mechanism is unlatched and the isolation flapper closes. The flapper remains in that position, stopping all gas flow, until it is manually reset. This provides system protection and keeps the system shut down until the cause of failure is identified and corrected.

(Figure 5)

During normal operation the latch mechanism holds the flapper open. The downstream pressure is monitored by the over-pressure and under-pressure controller diaphragms. The force created by the sense pressure is counter-balanced by the set point adjustment spring located in the spring case. An adjusting screw can be used to vary the spring force and control the over-pressure set point or the optional under-pressure set point.

An added benefit of the slam shut system is the dual security provided in the case of under-pressure protection. Gas appliances are designed to operate with a certain gas supply pressure. What happens if the pressure is less than that? We see pilot lights in older home furnaces, water heaters, stoves, fireplaces, etc.

If the gas pressure drops too low to maintain that pilot light, the gas may not be ignited when delivered. If that occurred, gas could build up in the local atmosphere and in a worst-case scenario, that gas build-up could ignite resulting in an explosion. For this reason, under-pressure protection, that would shut off all gas flow if the pressure drops below a safe point, is also an important consideration in system design.

Conclusion

Overall natural gas system safety is a priority for everyone involved. Gas systems can be very complex, and each system must be assessed to determine the most appropriate regulation and safety system to employ. The purpose of this article is to provide an overview of several methods and equipment that can be used to help ensure safe gas regulation and delivery. **PE&GJ**

Author: John Deveau is senior product manager for Becker and Mooney brand of gas control and regulator product lines at Baker Hughes, a GE Company. He has 35 years of experience in the control valve and regulator industry.