Basics of Pilot Loading Regulators

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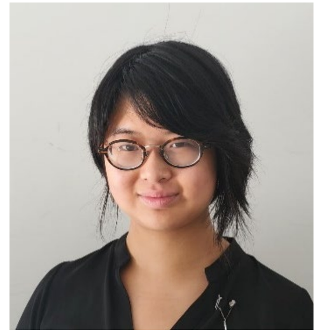

Introduction

Regulators are self-contained devices that are used to maintain constant pressure in a system despite changing flow demand. Regulators can be characterized into two categories: self-operated and pilot-operated.

Self-operated regulators are the simplest style of regulators as they only consist of one device that contains a loading element, measuring element, and restricting element. These elements are usually a spring, diaphragm, and plug/orifice; respectively. These regulators are usually restricted in size, due to limitations of the size of the diaphragm. Since these regulators have less flow paths, they are quick to respond to pressure fluctuations. However, these regulators are more susceptible to the effects of "droop," which is the offset between the desired pressure set point and the actual pressure or accuracy of the regulator.

Due to the limitations of self-operated regulators, pilot-regulators are preferred for applications with higher capacity requirements, where precise pressure control is required, and for larger line sizes. These regulators utilize a pilot regulator, in addition to the main regulator, to amplify the effects of changes in downstream pressure.

A popular type of pilot-operated regulator uses a system called pilot-loading or two-path control. In two-path control, the outlet pressure is sensed through two different paths. One path causes the main valve diaphragm to respond quickly to downstream pressure changes. This causes an immediate correction in the main valve plug position. At the same time, the pilot also senses the changes in outlet pressure through the second path. The pilot diaphragm diverts some of the reduced inlet pressure to the other side of the main valve diaphragm to control the final positioning of the main valve plug. This is called the loading pressure. Two-path control results in fast response and accurate control.

A pilot loading style regulator (Figure 1) is so named because the action of the pilot loads pressure onto the main valve diaphragm (shown in green). The variable restriction or pilot orifice, opens to increase the loading pressure.

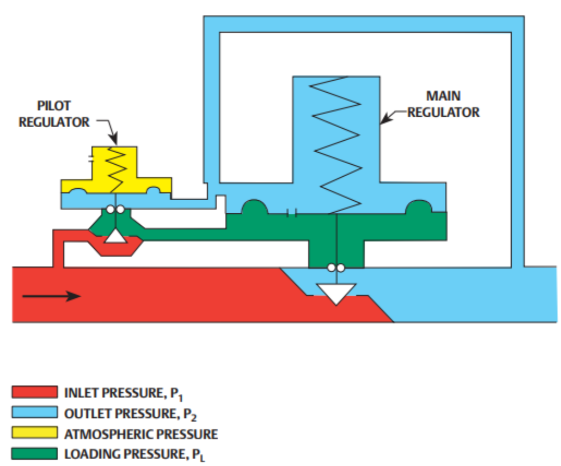

Figure 1

Principles of Operation

In two-path control systems, the pilot is piped so that the outlet pressure is registered on the pilot diaphragm and on the main regulator diaphragm at the same time. When downstream demand is constant, the outlet pressure positions the pilot diaphragm so that flow through the pilot will keep the downstream pressure and the loading pressure on the main regulator diaphragm. When downstream demand changes, the force on top of the main regulator diaphragm and on the bottom of the pilot diaphragm changes. As the outlet pressure acts on the main diaphragm, it begins repositioning the main valve plug.

Simultaneously, the downstream pressure acting on the pilot diaphragm repositions the pilot valve and changes the loading pressure on the main regulator diaphragm. This adjustment to loading pressure accurately positions the main regulator valve plug. The loading pressure on the main regulator diaphragm bleeds through a fixed restriction until the forces on both sides are in equilibrium. At that point, flow through the regulator valve matches the downstream demand again.

Since the outlet pressure acts directly on both the pilot and main regulator diaphragms simultaneously, the main valve plug and diaphragm are able to move without having to wait for a response from the pilot, like in other pilot regulator designs (i.e. pilot-unloading and pressure loaded regulators). This immediate reaction to changes in downstream pressure makes two-path designs faster than the aforementioned pilot-operated regulators. This fast response also minimizes droop making the two-path regulator one of the most accurate regulators.

Another way to control accuracy is by controlling the gain or sensitivity of the pilot. There are two primary components used in this type of piloting system: a fixed restriction and a variable restriction. On the upstream side of the loading chamber (the area behind the diaphragm), the control pilot is installed and acts as the variable restriction. Downstream of the loading chamber, is a fixed restriction which allows the loading pressure to bleed into the outlet of the system. The pilot's wide-open position is always larger than the largest setting on the adjustable orifice (fixed restriction).

Tuning adjustments can be made to the fixed and variable restrictions to adjust the regulator gain, speed of response, accuracy, etc. Consider the example shown in Figure 2 with a small fixed restriction. Decreasing outlet pressure will result in the loading pressure increasing. Increasing outlet pressure will result in a decrease in loading pressure while loading pressure bleeds out through the small fixed restriction.

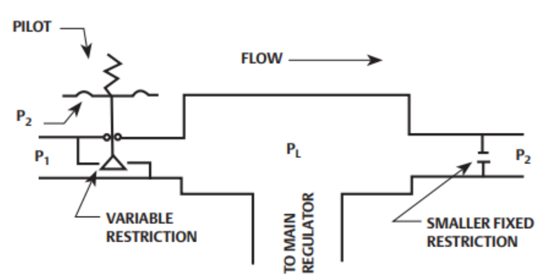

Figure 2

If a larger fixed restriction is used (Figure 3), with a variable restriction, the gain (sensitivity) is reduced. This is because a larger decrease in outlet pressure is required to increase loading pressure to the desired level because of the larger fixed restriction.

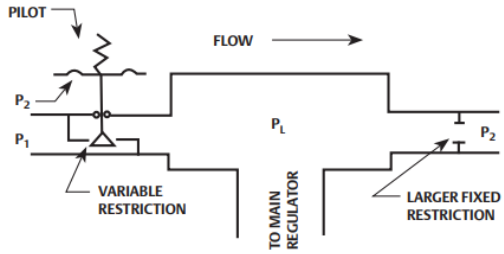

Figure 3

There are many variations of pilots for pilot loading regulators, some having better accuracy, control and tunability than others, and many of them are interchangeable between manufacturers.

Overpressure Protection –Monitoring and Relief Regulators

All designs of regulators can be used for overpressure protection as a monitoring and/or a relief regulator.

Monitoring is the method of overpressure protection by containment (i.e. does not vent gas to atmosphere). Two regulators are installed in series and sense the same downstream pressure. The "worker" is the primary regulator that controls the downstream pressure to the desired set-point. The "monitor" is the safe-guard regulator that senses the same downstream pressure, but is set to a slightly higher pressure than the worker. In the event that the worker regulator fails to control the downstream pressure, the pressure would increase and approach the set-point of the monitor. The monitor would then take over and control to its set-point. During normal operation, the worker controls the final downstream pressure, and the monitor sits idle ready to take over if the worker fails.

There are two types of monitoring configurations that can be used for overpressure protection – wide-open monitor and working-monitor. In a wide-open monitor system, the monitor operates as the name suggests – during normal operation the monitor regulator sits in the wide-open position, until it senses a pressure that reaches its higher set-point (a failure of the worker regulator), then takes over control of the downstream pressure (see Figure 4). In the wide-open monitor configuration, the monitor regulator can be installed either upstream or downstream of

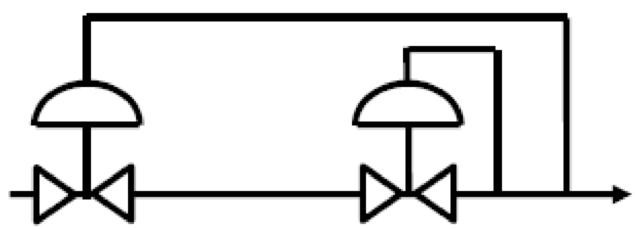

Figure 4

the worker regulator.

In a working-monitor system, both the monitor-regulator and worker-regulator are "working" to reduce the overall pressure in two stages during normal operation. This is done by introducing an intermediate pressure between the two regulators. The monitoring regulator is equipped with two pilots – one to sense the downstream pressure and control to its monitor set-point if required (slightly higher than the worker set-point), and a second pilot to take a first-stage pressure drop and control to an intermediate pressure between the monitor and downstream worker (see Figure 5).

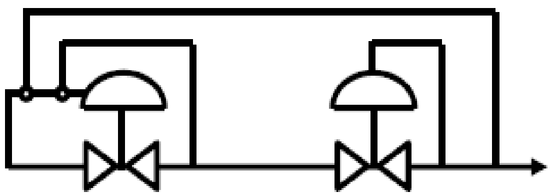

Figure 5

In the event that the worker regulator failed, and the downstream pressure increased to that of the monitor pilot, the monitor pilot would take over the working-monitor regulator and control the downstream pressure to its set-point.

Wide-open monitors are more common with two-path control regulators. This is because the pilot loading style regulator has the measuring element separated from the restricting element. There is no negative impact of the pilot loading regulator being in a wide-open monitor solution as the diaphragm will never "take a set." This means that the monitor will need less maintenance as there is less moving parts in the main flow path compared to a working monitor. Additionally, the working monitor set-up can be more complex as there is a second pilot, more tubing, etc.

Working monitors also need more physical space than wide-open monitors. This is because small intermediate pipe runs can lead to instability in operation. With the working monitor causing a first-stage pressure drop, the flow immediately after the working monitor will be turbulent and will need to stabilize before the pressure can accurately be reduced again. Therefore, longer intermediate pipe spool is needed causing the overall size of the set to be larger.

When using pilot loading regulators in monitoring applications on dead-end installations, it is good practice to use a token relief or "burping" valve (see Figure 6). A token relief valve provides a smaller (less than full capacity) relief capability should any damage to the pilot loading regulating seats occur or debris become stuck in the regulator.

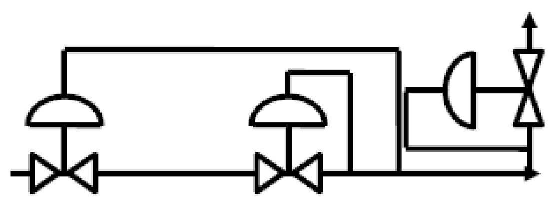

Figure 6

The monitoring method of overpressure protection is growing in popularity as an industry focus on emission reduction increase and regulations on venting natural gas become more strict.

Another form of overpressure protection using pilot loading regulators is as a full capacity relief valve. Relief valves offer an inexpensive solution for applications requiring high relief capacity. Usually, the same body and trim can be used with a simple change of the pilot to switch from pressure reducing to relief operation.

Sizing, Selection and Installation

When sizing and selecting pilot loading regulators it is important to take into account all of the industry standards for sizing regulators (line size, pressure ratings, accuracy, capacity, velocity, etc), as well as the following specific considerations for two-path regulators:

- Size the regulators to ensure there is sufficient capacity for the application and consider sizing it to allow for 20% more capacity than required. Pilot loading regulators have good turndown capabilities to handle this sizing margin; however careful consideration should be taken to ensure any low-flow conditions (like summertime load) are within the regulator's capabilities.
- Confirm the minimum and maximum pressure drops are within the published limitations. The minimum pressure drop is critical to ensure that there is enough differential pressure to fully open both regulators (in a monitor configuration). The maximum pressure drop cannot be exceeded as issues like seat erosion and instability can result. The minimum and maximum differential pressures will dictate the selection of the pilot loading material, pilots, and main valve spring.
- Size the regulator to ensure that the velocity does not exceed the manufacturer's limitations (typically 0.5Mach or 700ft/sec for natural gas). Velocities above this limitation can result in premature failure of the seat. If velocities exceed the manufacturer's limitations, a larger regulator can be used to reduce the velocity.
- Overall material compatibility should be taken into consideration for the specific application. Ambient temperature, media/gas temperatures, media/gas composition, and pressure drop will all affect the selection of the material.
- Speed of response requirements of the application should be considered. Selection of the regulator will depend on the speed of response requirements as some pilots are available with more flexible tuning adjustments to allow for quicker responses.
- Noise should be considered when sizing a regulator system. Pilot loading regulators can handle large flows and large differential pressures, which are the main contributors to noise. The primary method of noise reduction is noise abating trims. Working monitor systems are also an option to attenuate noise. Noise levels above 110dBA can cause physical damage to regulator parts, as well as surrounding equipment.
- Overpressure protection in the form of monitors and/or relief valves should be considered to protect the downstream system. Token relief should also be considered to protect the system from any small seat leakage and thermal expansion of the gas downstream.

- Hydrates and Freezing can cause unpredictable responses from regulators and should be addressed if a concern. Line heaters, pilot gas heaters, or alcohol injection can be used to prevent issues.
- The quick speed of response of the pilot loading regulator makes it the most suitable for the following applications:
    - Large flow, single-use customer
    - Dead end customer service

Once a suitable regulator has been selected for the application, there are installation considerations that should be taken into account to ensure the regulators perform optimally:

- Filtration should be considered either for the entire station and/or for the pilots. Because pilot loading regulators are inherently susceptible to small particulate in the pilot from debris in the gas flow, filtration for the station should be considered if the gas flow is known to be dirty.
- Connecting control lines should be planned in advance to ensure good performance and reliability. A rule of thumb for control lines is to locate these 6-10 pipe diameters downstream from any turbulence generators (regulators, elbows, swages, block valves, etc). When using a monitor, ensure both the monitor and worker regulator each have a control line with an independent tap to the downstream piping - control lines should never share tubing or a tap. This ensures complete redundancy.
- Connecting bleed lines should also be planned in advance. Some manufacturers require bleed lines to be installed directly downstream of the regulator's outlet so the diaphragm will not be damaged in a monitor application. For any pilot that has a separate bleed and sense line, always connect the bleed line upstream of the sense line.

Maintenance and Troubleshooting

Shutoff or lock-up tests are the typical way to do an operation test on a regulator in the field. Although this is the easiest method for testing, it does not provide a complete picture on the overall health of the regulator and its components. Considerations for a full inspection of the regulator and its components can include:

- If the filter is blocked or clogged by debris or aromatics present in the gas, this may cause the regulator to close. This is because the decrease of supply pressure gives a decrease in loading pressure.
- If the pilot cannot be closed, this will cause an increase in loading pressure causing the regulator to go open. This is caused by debris getting caught in the disk/orifice.
- If damage is caused by debris to the pilot diaphragm, then the pilot cannot control, and this will cause the loading pressure to decrease and the regulator to close.

- A frozen pilot due to moisture in the gas or freezing caused by the Joules-Thomson effect due to a high-pressure drop may cause the regulator to close if the ice build-up is significant enough to block the passage. These hydrates block the supply to the pilot which will disable it from supplying loading pressure to the lower casing. Wet residue on internal parts of the pilot during inspection is an indicator that freezing has occurred and is an active concern. Line heaters or pilot gas heaters can prevent these issues from occurring.
- If the inlet pipeline pressure decreases below pilot set pressure, the regulator will hover or drift with the decrease in inlet pressure. This is because the loading pressure is still present and will partially hold the regulator open, however the regulator will not be able to fully stroke and control pressure.
- The bleed and sense lines require adequately large diameter to ensure that they do not cause backpressure with the low flow bleed that runs through them. If they are undersized, then instability of the sense pressure can occur.

Conclusion

Pilot loading regulators are a major part of the natural gas distribution industry. They have many benefits that make them ideal for specific applications: ease of maintenance, large flow capacities, accuracy, noise abatement, and emissions reduction. It is also important to recognize that, like all technologies, pilot loading regulators do have their limitations and care must be given when selecting and choosing installations for the technology. Pilot loading regulators work well in services throughout the distribution system such as continuous duty, large flow volumes, dead-end service, single end-user stations, and applications with larger pressure drops.