Flexible Element Regulators

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Introduction

Flexible element regulators are essential components in natural gas systems. They are widely used across the industry because of their ability to control sizable flowrates reliably and affordably. These regulators combine the function of an actuator and throttling element into a single component, the flexible element.

Flexible elements are constructed from an elastomer such as Nitrile, Viton, or Vulcanized Rubber. Some are reinforced with nylon fabric to flex but not stretch. These elements are durable and offer formidable resistance to chemicals and temperatures. Understanding the operation, advantages, and limitations of flexible element regulators is important when considering the variety of system demand and load profiles.

This whitepaper provides a technical overview of flexible element regulators, covering their **operational principles**, **advantages and disadvantages** (specific focus on monitor and single cut relief applications), **sizing considerations**, **installation and maintenance practices**, and industry **best practices** for optimal performance.

Principle of Operation

Flexible element regulators are pilot unloading type regulators. Figures 1 - 3 are examples of pressure unloading regulators that operate on the same basic principle.

The pilot valve itself is a small spring-operated regulator that unloads the element to open the valve and loads the element to close the valve. The balancing of forces between the pilot spring and sense pressure actuates the flexible element to regulate gas and maintain a setpoint established by the adjustable pilot spring.

Restrictors on the pilot supply line ensure that gas unloads off the flexible element through the pilot to the downstream faster than upstream supply can load the element. Thus, allowing the regulator to open. The adjustability of the restrictor allows for tuning. A larger orifice provides faster shut-off and better stability. A smaller orifice provides more responsiveness and sensitivity which can decrease stability.

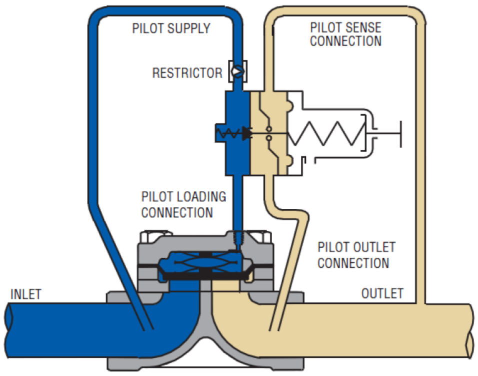

Figure 1

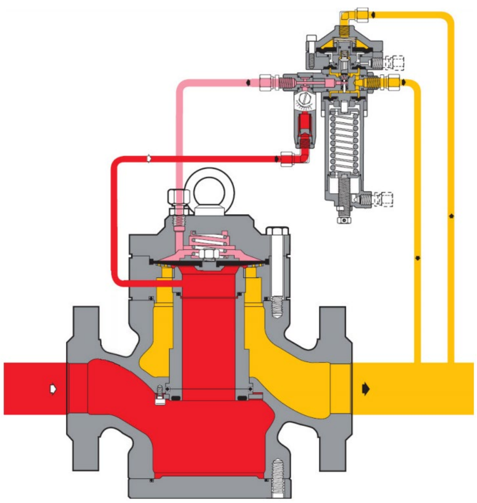

Figure 2

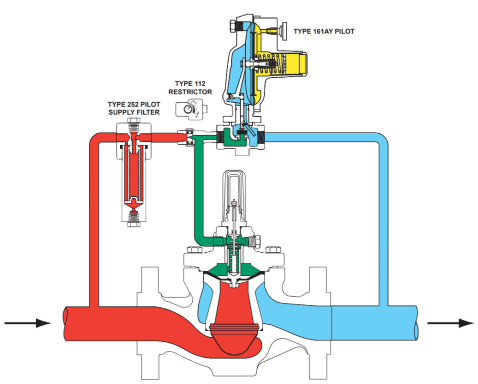

Figure 3

Advantages and Disadvantages

Advantages

- High flow rate capability
- Good set point accuracy when downstream flow rate is wide-ranging
- Extensive inlet and outlet pressure options
- Typically, does not require unbolting and removing the regulator from the line due to many top entry designs
- Trouble shooting is relatively straightforward because of the common principle of operation

Disadvantages

- Flexible element regulator response is not as fast as other regulator types because of the interaction between the pilot, sense lines, and regulator
- Pilot unloading regulators require specific differential pressure to maintain proper control
- More complicated principals of operation
- Vulnerable to debris, sulfur, and liquids which can damage the flexible element or affect the seal
- Fails open typically

Monitor and Single Cut Relief Applications

Flexible element regulators are commonly used in both monitor and single cut relief applications for overpressure protection. If the working regulator fails, a relief will protect the downstream system by releasing gas to atmosphere. Alternatively, a monitor acts as a backup regulator without the release of gas.

- **Standby Monitor**: In this configuration, a normally open monitor regulator is installed in addition to a working regulator. The monitor regulator can be installed upstream or downstream of the working regulator and senses at a point downstream of the worker. The monitor is normally open because the monitor pilot is set to regulate at a higher downstream pressure than the working pilot. The monitor pilot spring keeps the pilot unloading gas off the flexible element and monitor regulator wide open. The monitor only comes into control if downstream pressure rises to the monitor pilot setpoint. At this point the monitor pilot spring is now engaged with downstream pressure and seeking equilibrium. The flexible element is then actively loading and unloading to operate the monitor valve.

  Standby monitors installed downstream of the working regulator do not have the inlet pressure constantly applied to the open flexible element. This can reduce concern of deformation over time or the monitor "taking a set" and not controlling properly when needed. Also, downstream monitors can generally come into control faster in the event the working regulator fails.

  Standby monitors installed upstream of the working regulator have less risk of freezing because they are upstream of the pressure drop and cooler gas downstream of the working regulator (i.e. Joule-Thomson effect).

- **Working Monitor**: In this configuration, the monitor regulator is installed upstream of the working regulator and is configured with two pilots (Figure 4). The first stage pilot is actively controlling the monitor regulator and taking a pressure cut upstream of the working regulator. The second monitor pilot remains open and inactive. If the working regulator fails and downstream pressure increases, the second monitor pilot comes into active control and the first stage pilot remains open and inactive. This configuration makes use of both regulators during normal operations and helps distribute the pressure cut across both regulators.

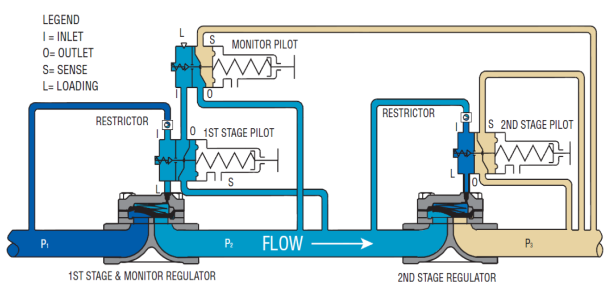

Figure 4

- **Single Cut Relief**: The regulator acts as a relief device, opening to vent excess pressure directly when a pilot set point is reached. In this configuration the pilot supply and pilot sense both come from the upstream (Figure 5). When the inlet pressure is high enough to overcome the spring force the pilot unloads the regulator to flow and relieve gas. Back pressure/relief applications require different pilot internal designs or sometimes alterations to pressure reducing pilots to function in back pressure/relief application. Flexible elements ensure sensitive and accurate relief action but must be checked regularly for set point accuracy.

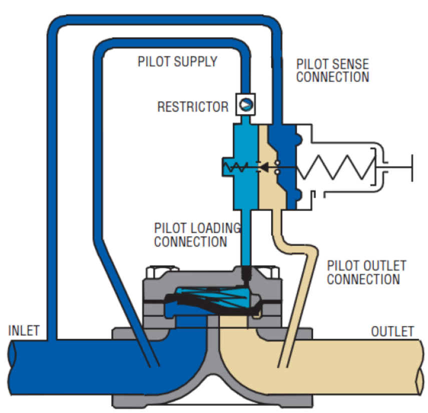

Figure 5

While both applications benefit from the sensitivity and simplicity of flexible element regulators, monitor applications offer redundancy and no release of gas. Single cut relief configurations require diligent maintenance to ensure reliability.

Sizing

Proper sizing is critical to ensure regulator stability, response time, and longevity. Oversized regulators may hunt or oscillate, while undersized units may not meet demand. The following factors must be considered:

- The percent utilization of a regulator is ideally within 20-80% of calculated capacity for all pressure and flow scenarios. This is a rule of thumb and not always possible.
- Consider the published turndown value for a given regulator to determine how well it will operate at low flow rates. Turndown Ratio = Maximum Flow Capacity/Minimum Controllable Flow.
- Consider multiple operational scenarios. Examples:
  - max. flow required @ min. inlet pressure.
  - min. flow @ max. inlet pressure.
  - Percent utilization should be considered for any scenarios considered.
- The capacity of a single regulator can generally be reduced by ~30% when installed in series with a monitor regulator.
- Minimum pressure differential across a regulator needs to be considered to make sure there is enough pressure to load and fully unload the regulator per manufacturer specifications.

- Maximum pressure reduction and velocity through the regulator body should be limited to manufacturer's published values to minimize wear on the flexible element, avoid hydrate formation and reduce noise and mechanical vibration resulting from large pressure reductions.

Sizing typically involves using manufacturer-provided charts, tables or software, inputting process parameters to select an appropriately sized regulator. Consultation with the manufacturer is recommended for complex or critical applications.

Installation and Maintenance

Installation Guidelines

- Flexible element material types are available for a variety of applications and variables such as temperature, pressure drops, and gas quality.
- Pilot filters should be installed and specialized filter options are available to mitigate sulfur or liquids.
- For stations with large pressure drops and high flow rates, catalytic heaters can be used on pilot supply lines to reduce the risk of internal liquids freezing and sulfur formation.
- Pressure-sensing taps should be installed a minimum distance away from sources of turbulence per manufacturer's guidance (e.g. valve, tee, reducer, or similar fitting).
- If calculations show significant pressure drop in the outlet piping where sense lines are to be located, consider increasing the outlet pipe size for better control.
- Isolation Valves: Install upstream and downstream block valves for maintenance.
- Cleanliness: Care should be taken during installation to prevent debris from damaging the flexible element. Borescoping during installation or after upstream construction activities can help find debris before it presents an issue.

Maintenance Practices

- There are two primary methods for maintaining flexible element regulators:
    - The first method is a lock-up test which is an external diagnostic test. This non-invasive inspection is usually completed by shutting an outlet valve to gauge the pilot and regulators lock-up response. If unsatisfactory it could warrant more extensive inspection
    - The second method is an internal inspection and maintenance of the regulator. These inspections allow for parts like the flexible element to be replaced to mitigate wear. Internal inspections can provide valuable insight into conditions such as the presence of sulfur, liquids, or debris. Although lockup tests are a very useful inspection

method, they do not provide the most value in preventative maintenance.

- Regular industry training and exposure to manufacturers and their experiences and recommendations.

Best Practices

- Size for actual demand and pressure parameters: Avoid oversizing and select regulators based on actual system conditions first. Consideration can then be given to future growth in demand or abnormal system operating conditions if it does not create oversized regulation.
- 20-80% utilization is a good target to consider when looking at the calculated capacity of a regulator relative to the various pressure and flow parameters. This is not always achievable, but it can facilitate further research into things like the system parameters or manufacturer turndown ratios to determine how well a regulator will control under low flow conditions.
- Consider a pilot loading style regulator when inlet pressure might drop below the regulator set point. Pilot loading style regulators can regain control better than pilot unloading regulators when inlet pressure is lost and then restored.
- Token reliefs should be considered for small systems with periods of minimal demand. These can protect against overpressure events when demand abruptly stops or if there is thermal expansion in downstream above ground piping.

Conclusion

Flexible element regulators offer precise, reliable pressure and flow control for a wide range of industrial applications. By understanding their operational principles, strengths and weaknesses, and adhering to proper sizing, installation, and maintenance practices, engineers and technical managers can ensure safe, efficient, and long-lasting regulator performance. Incorporating best practices and regular review of application requirements will further enhance system reliability and safety.

References

Mooney (Baker Hughes), Pietro Fiorentini, and Fisher (Emerson) literature

Biography

Ken Morshead PE, PMP is a Senior Consulting Gas Distribution Engineer at Pacific Gas & Electric. His work in the natural gas industry has involved station/plant engineering design and retrofits, system and operational support, gas system modeling and investment planning. Ken holds a BS/MS in Civil Engineering from California State University, Fresno and an MBA from University of Massachusetts Amherst.