FUNDAMENTALS OF PRESSURE REGULATORS

Paul Murtaugh

Dresser Pressure Regulation Group
40 West Gregson Avenue
Salt Lake City, UT 84115

In the gas industry, there are two basic types of regulators used for both pressure reducing and back pressure (relief) control. The two types are:

1.) Self Operated Type
2.) Pilot Operated Type

The primary purpose of this paper is to discuss the basic principle of Self Operated and Pilot Operated Regulators including components of the system, principles of operation, advantages and disadvantages, and some maintenance and inspection procedures.

SELF OPERATED REGULATORS

A Self Operated Regulator consists of a spring opening valve that is directly opposed by a diaphragm assembly

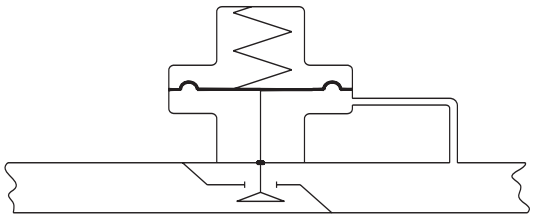
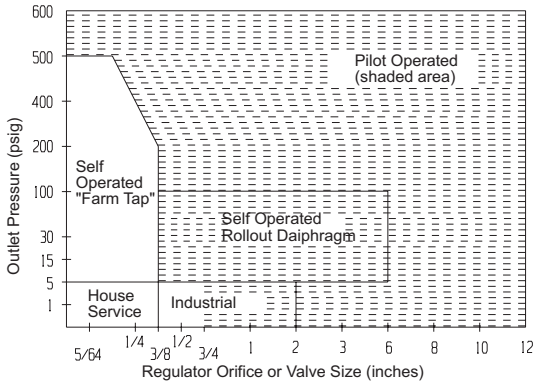


Fig. 1 Self Operated Regulator

(see Figure 1). As downstream pressure increases, the diaphragm will overcome the spring force and close the valve. When downstream pressure decreases, the spring force is greater than the force of the gas acting on the diaphragm and the valve opens.

There are practical, engineering, cost, size, and performance limitations that limit the applications for self operated regulators. For application requiring high pressure drops (over 200 psig) and high outlet pressures (15 to 200 psig), orifice sizing are limited to a maximum of ½", and smaller orifices are required as the pressure drop increases. These regulators fall into a category referred to as "Farm Tap Regulators". Another group referred to as "Industrial Regulators" handle outlet pressure from inches of water column to 5 psig with orifice sizes up to 2 inches. The self operated regulator with the "Rollout Diaphragm" is an exception and is available in fairly high outlet pressures (100 psig) and up to 6 inches in size. However, in these pressure ranges and

Fig. 2 Regulator Selection Chart
Outlet Pressure versus Valve Size



valve sizes, a Pilot Operated Regulator generally offers better accuracy and more capacity at a lower cost. Refer to the Regulator Selection Chart of Outlet Pressure versus Orifice Valve Size (Figure 2) for a graphic indication of where Self Operated Regulators are used in the gas industry.

PILOT SYSTEMS

At the heart of any Pilot Operated Regulator, whether it be a Loading Type or an Unloading Type, is the controlling Pilot. The Pilot is responsible for measuring the pressure signal to the actuator and/or valve mechanism. The Pilot provides an amplified loading pressure signal in response to a small change in the pressure being controlled. This amplification is referred to as the GAIN of the system and can be stated as the change in pilot OUTPUT divided by the change in pilot INPUT or OUTPUT/INPUT.

The accuracy of the system is a function of the "GAIN" or multiplication of the pilot system which is primarily dependent on the ration of the flow area of the Fixed Orifice (FO) to the Variable Orifice (VO) (see Figure 3). The fixed orifice is always smaller that the variable orifice and in many systems the fixed orifice is adjustable so that the regulator may be adjusted in the field for the highest gain (greatest accuracy) possible. Gain values of 50:1 are not uncommon, which means that the pressure can be controlled to within 2% of the set point.

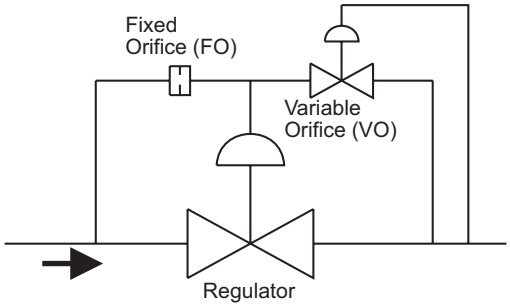


Fig. 3 Typical Pilot System

Another important element in a discussion of Pilot systems is Proportional Band. Proportional Band is the inverse of GAIN and can be defined as the percent drop in set pressure as a regulator goes through its full range of operation, or

% Proportional Band = 1/GAIN x 100.

The corresponding Droop would then be

% Proportional Band x Set Pressure. (See Figure 4)

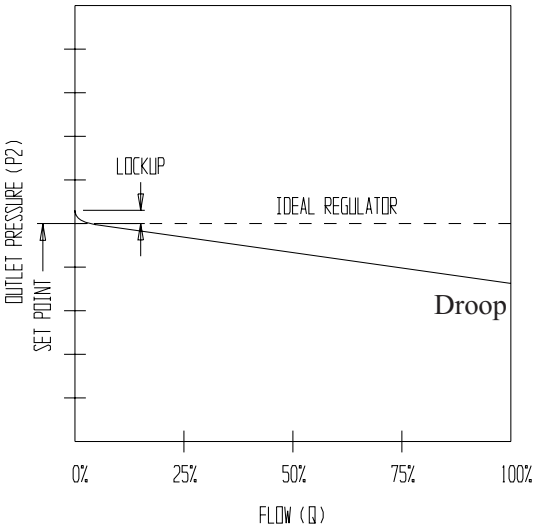


Fig 4 Typical Regulator Droop

LOADING TYPE PILOT OPERATED REGULATORS
(Two Path Control)

A Loading Type System has a Variable Orifice upstream of the Fixed Orifice. The Loading pressure on the regulator increases as the regulator outlet pressure decreases and therefore the system is termed Reverse Acting. (See Figure 5)

Another term associated with Loading type regulators is Two Path Control. In a Two Path Control system, an initial change in downstream pressure is felt immediately by the main operating diaphragm and the valve begins to move in the desired direction. The pilot will supplement the moving action of the main diaphragm at a more precise level to attain a precise final control pressure. In other words, a Two Path Control system consists of 1) rapid adjustment from the main diaphragm in response to changes in outlet pressure and 2) slower but more precise adjustment from the controlling pilot.

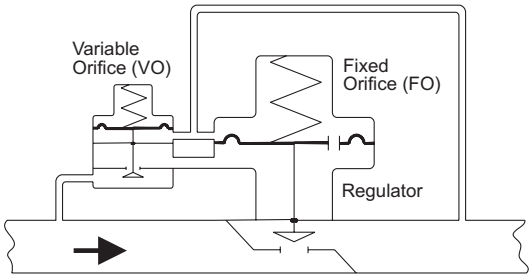


Fig. 5 Loading Type Pilot Operated Regulator

The Advantages of Loading Type Pilot Operated Regulators are:

1. Accuracy and stability due to Two Path Control
2. Low Minimum Differentials (2 psi to 30 psi available depending on the size of the actuator diaphragm and main spring)

Disadvantages of Loading Type Pilot Operated Regulators are:

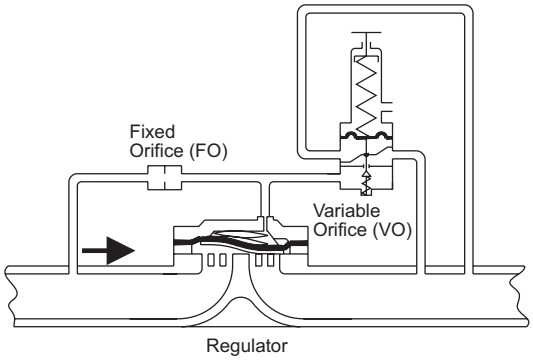
1. More complicated due to increased number of parts
2. Generally more expensive
3. Larger and heavier
4. Globe style valves may require seat adjustments
5. Time consuming and costly maintenance
6. Shutoff depends strictly on force of main spring

UNLOADING TYPE PILOT OPERATED REGULATORS

The Unloading Type Pilot Operated Regulator system has the Variable Orifice downstream of the Fixed Orifice (see Figure 6). The loading pressure on the regulator decreases when the outlet pressure decreases. Therefore, the Pilot system is referred to as Direct Acting.

In a common Unloading Type operating system, an elastomeric diaphragm or boot is held against a grid plate by loading pressure passing through the pilot. This unique combination enables the diaphragm or boot to act as both a valve and an actuator. The throttling of the main valve is accomplished by exhausting or Unloading the gas from the loading chamber downstream faster than the Fixed Orifice can fill the loading chamber. The same GAIN relationship as previously discussed between the Fixed and Variable Orifice also applies to the Unloading Type System.

Fig. 6 Unloading Type Pilot Operated Regulator



The advantages of the Unloading Type Pilot Operated Regulators are:

1. Smaller and more compact
2. Fewer parts and simpler construction
3. Less Expensive
4. Lower maintenance costs
5. Quieter operation
6. Shutoff force increases with pressure drop

The disadvantages of the Unloading Type Pilot Operated Regulator are:

1. Some types must be removed from line for maintenance
2. Certain distillates can affect the diaphragm and resulting operations

MAINTENANCE AND INSPECTION

According to Federal Law, each multi-user Transmission and Distribution System pressure limiting and regulating station, and its equipment, must be subjected to inspections and tests at intervals not exceeding (1) year to determine that the regulator is:

1. in good mechanical condition
2. adequate from the standpoint of capacity and reliability of operation for the service for which it is employed
3. set to function at the correct pressure
4. properly installed and protected from dirt, liquids, or other conditions that might prevent proper operation

Maintenance of other regulators not covered by the above are usually maintained at intervals determined by individual company policy and experience. These regulators generally supply individual customers. The required “Inspection and Tests” can be interpreted in different ways by different companies. Where practical, most companies will disassemble the regulator and pilot and visually inspect it for wear and defects. Worn parts and seals, seats, and diaphragms are generally replaced. Many times, tests can be performed to determine if the regulator or relief valve is in good mechanical condition even if the equipment is more complex or if disassembly is not practical. These tests could include:

1. External leak test
2. Stroke test
3. Shutoff test

CONCLUSION

After reviewing both Self Operated and Pilot Operated Regulators, you can see both have their pros and cons. Pilot operated regulators are the most accurate and versatile pressure regulating devices used in the gas industry

A thorough understanding of both Self and Pilot Operated Regulators operation, application, and maintenance is vital to the engineers and operations personnel of all gas transmission and distribution companies.