Tech Sheet #CVR 404

SIMPLE REFERENCE GUIDE: DIFFERENCES BETWEEN DIRECT AND PILOT-OPERATED REGULATING VALVES

Regulators, both pressure and temperature, can be classified as either "direct" or "pilot" operated depending on their design characteristics. The purpose of this primer is simply to explain the differences between these two types and highlight the benefits of each for proper selection per application.

Below is a simple comparison highlighting the basic variations and characteristics of direct and pilot-operated regulators. Additional detail can be found in the subsequent pages, as well as in the following FCI publications:

- Tech Sheet CVR #402
  Fundamental Principles of Self-Operated Pressure Reducing Regulators

- FCI 86-2
  Regulating Valve Terminology

- ANSI/FCI 99-2
  Pressure Reducing Regulator Capacity

Tech Sheet #CVR 404

COMPARISON OF GENERAL CHARACTERISTICS OF DIRECT AND PILOT-OPERATED REGULATORS

Direct-Operated	**Pilot-Operated**
• Simpler Design	• Reduces valve "droop" (i.e. variation from set point – see FCI 86-2 for terminology) for increased accuracy
• Generally no external sensing line required	• External sensing improves regulator sensitivity
• Faster response	• Fast response
• Can control a single mode of regulation (i.e. pressure, temperature)	• Multiple modes of regulation (i.e. pressure, temperature) with a single valve
• Cost-efficient	• Increased initial and installation costs
• Generally accurate with stable flow conditions	• Responsive to changes in flow conditions while maintaining accuracy
• More compact as all regulator components are within main valve structure, simplifying installation in less sensitive control applications	• Uses pilot regulator in conjunction with main valve to maintain closer control of set point

Review of Regulator Basics

A regulator is a device used to control system pressure or temperature without requiring an external power source such as pneumatic, hydraulic, or electrical supply. This can also be referred to as "self-powered". All regulators operate based on a balance of forces, between those generated by system pressure and the controlling method of the regulator. Depending on whether the application is for pressure or temperature, a variety of components may be used to provide this force balance, including spring or pressure loaded diaphragms, bellows, pistons, etc.

To provide the fundamentals and a basic understanding of the force balance, this article will focus on pressure regulators utilizing a spring to counteract downstream pressure forces, separated by a diaphragm. Spring compression can then be increased or decreased to counteract pressure forces and, ultimately, control the downstream pressure to the desired level.

Tech Sheet #CVR 404

Regulator Components

Regulators consist of basic components in order to control pressure and/or temperature. Below are the **components** and *typical configurations*, as well as their function:

1) **Restricting Element** (*Plug and Seat*) – This element combination modulates fluid flow through the regulator.

2) **Sensing Element** (*Diaphragm*) – The diaphragm area provides a force to control the travel of the plug and seat.

3) **Loading Element** (*Spring*) – The spring provides the balance force against the pressure force created on the opposite side of the diaphragm. The spring can be adjusted to maintain the desired downstream set point.

4) **Pressure Amplifier** (*Pilot*) *Pilot-Operated Only* – Improves regulator sensitivity by separating regulator outlet pressure and the diaphragm loading pressure, allowing a larger change in the loading pressure over the outlet pressure. This increase in loading pressure over the change in outlet pressure is referred to as pilot gain.

Note: It is understood that there are several variations available for the above components. However, for simplicity, only the basic ones listed will be referenced.

Operation - Direct-Operated

It is easiest to begin with our understanding of the differences between direct and pilot operated regulators by focusing on direct-operated. This is because they are the simpler of the two in terms of both design and operation (Figure 1).

Direct-Operated Regulators respond directly to variations in downstream pressure (P2) to provide the necessary flow and pressure to satisfy the system set point. P2 opposes the balance force provided by the spring to determine the plug position. Therefore, for direct-operated regulators, P2 is also considered the loading force.

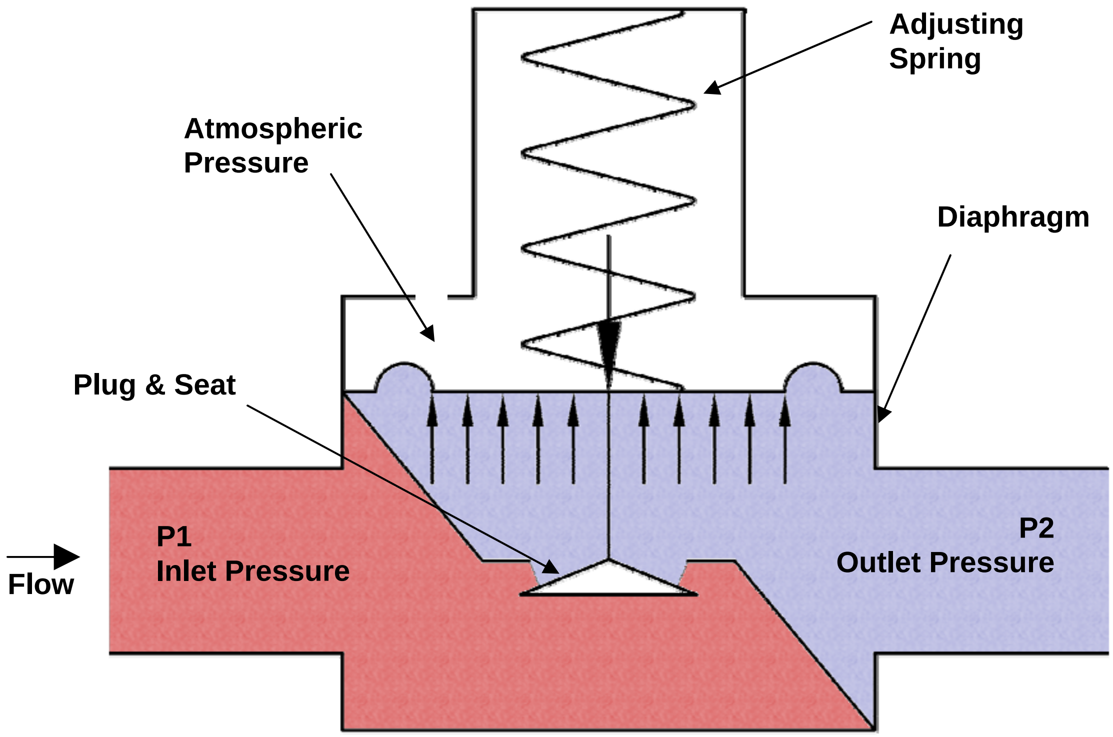

FIGURE 1
Schematic of a Direct-Operated Pressure Reducing Regulator

If P2 increases, the spring is compressed and the plug moves upward towards the closed position, further restricting fluid flow. Conversely, any decrease in P2 allows the spring to move the plug downward, opening the valve further and allowing more fluid to pass. The plug position in a direct-operated regulator responds immediately to any change in P2.

Operation - Pilot Operated

Pilot-Operated Regulators consist of the same essential components of direct-operated units (plug and seat, diaphragm, spring) with the addition of a pilot which separates P2 and the diaphragm loading force (PL). By doing this, PL can be controlled in relation to changes in P2, meaning that PL can be increased from P2 (Figure 2). This allows the regulator to be more responsive to condition changes.

Furthermore, the pilot requires an external sense line connected to the downstream piping. Measuring pressure farther downstream of the valves allows for more accurate sensing of the true outlet pressure conditions as it moves the sense point away from the flow turbulence generated by the plug and seat. For all intent and purpose, the pilot can simply and effectively be

Tech Sheet #CVR 404

considered a second regulator, providing additional control to the main regulator, improving overall sensitivity and, ultimately, accuracy.

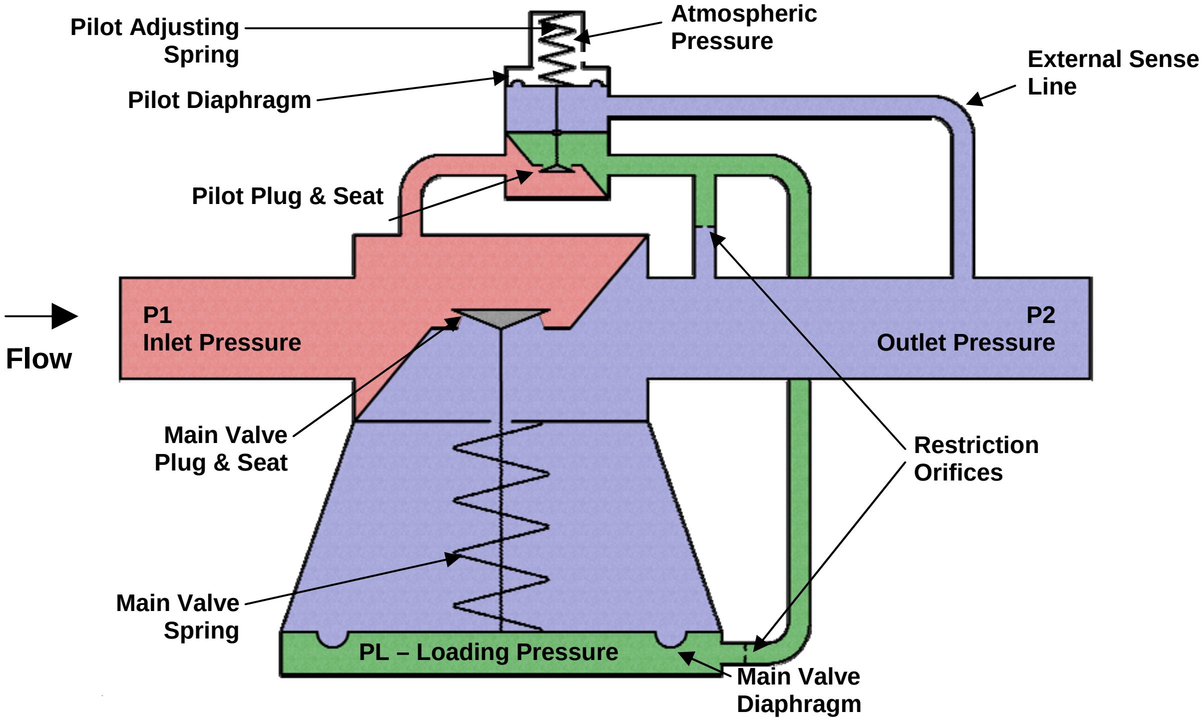

FIGURE 2
Schematic of a Loading-style Pilot-Operated Pressure Reducing Regulator

When flow demand increases, P2 will decrease and the pilot valve will open and increase PL to the main valve diaphragm allowing the main valve to open and supply flow and pressure to the application. When there is a reduction in demand, P2 will increase and the pilot spring will compress moving the pilot plug towards its seat, closing the pilot and reducing PL. This resultant reduction in PL under the main valve diaphragm will allow the main valve plug to modulate towards the seat, closing the valve.