Let's Keep It Simple

PILOT OPERATED REGULATORS

BY TOM POPECK

Before the age of computers and electronics the pilot operated regulator was the preferred device for accurate control. Now, in an era of automated control systems and process technologies, engineers and designers tend to overlook the simpler, cost-effective technologies in favor of expensive, complicated, installation and maintenance intensive products. There are process and HVAC applications where automated control, like the type provided by control valves, are preferred. However, in many situations, the pilot-operated regulator is the low-cost, low-maintenance alternative to these expensive control systems.

The creation of the Pilot Operated Diaphragm Actuated Normally Closed Regulator by Paulsen Spence in 1926 revolutionized the way power generators, process systems, and energy producers provide steam service to their customers today. Although there have been some changes to the materials and configuration of these devices, the overall design and operating principals of the normally closed, pilot-operated regulators has remained the same since its inception seventy-five years ago. This design is still one of the most accurate methods of process and HVAC control available today.

OPERATION OF PILOT OPERATED REGULATORS

A pilot operated regulator consists of two valves: main valve and pilot valve. The main valve is held normally closed by the force of the main spring. The pilot valve, without any compression on the adjusting spring, is held normally closed by the main spring in the pilot valve.

The pilot valve's inlet is connected to the upstream side of the main valve through a nipple and union connection. The outlet of the pilot valve is connected to the main valve through connecting tubing (bends) and fittings. A tee comes off the outlet of the pilot valve. One side goes to the downstream side of the main valve and is connected through a restriction fitting (Bleedport). The other side of the tee is connected to the underside of the diaphragm in the main valve through a restriction elbow. The sensing line is connected from the underside of the pilot valve to the delivery piping with no restrictions.

On placing the regulator in service, the valves are normally closed and the inlet pressure fills the upstream side of the main valve. The inlet pressure flows from the main valve through the nipple and union connection and finally to the inlet of the pilot valve. The set point of the valve is adjusted by compressing the adjusting spring in the pilot valve. This is accomplished by turning the two nuts on top of the pilot valve. When the adjusting spring is compressed, it eventually overcomes the force of the inlet pressure under the plug and the main spring in the pilot valve. This force exerted by the adjusting spring opens the pilot valve. The fluid flows through the pilot valve and is conducted through the connecting tubing from the pilot valve to the main valve diaphragm and bleedport. Initially, the fluid flows through the pilot valve faster than it can escape at the bleedport. This creates an intermediate pressure within all the connecting tubing and underneath the main valve diaphragm. This intermediate force overcomes the force of the main valve spring and causes the main valve to open.

The delivery pipe and the sensing line are now being filled with the fluid flowing through the main valve at a reduced pressure. As this pressure increases, and is conducted back through the sensing line, it overcomes the force exerted by the pilot valve adjusting spring causing the pilot throttle. When the pilot valve throttles, the pressure in the connecting tube also changes. The changes in pressure are due to the bleedport allowing fluid to escape to the downstream side of the main valve. These changes in pressure in the connecting tubes are transmitted under the diaphragm of the main valve causing the main valve to throttle enough just to maintain the set pressure.

If the demand ceases, the pilot valve closes. The pressure in the connecting tubing is completely relieved through the bleedport and the main valve closes—effecting a dead-end shut off. *(See Operating Cycle of a Pressure Regulator, Figure 1)*

BENEFITS OF PILOT OPERATED REGULATORS

There are many benefits of pilot operated regulators that are too often overlooked. Some of the more common benefits are listed and explained below:

- **No external power signal requirement**—A pilot operated regulator is self-contained. A self-contained regulator does not need an external power signal, such as compressed air or electricity, to stroke the valve. Here, the process fluid itself provides the necessary energy to operate the valve. This becomes critical during power outages when a loss of power will mean a shut down in the system. *(See Figure 2)*
- **Packless construction**—A packless construction frees the user from packing leaks and scoring, which are commonly found in control valves. A packless construction reduces maintenance costs and downtime.
- **High-speed response**—Any change in the process variable is immediately transferred back through the sensing line to the main valve. This results in a response that is faster than any other method of control. The response speed is typically in the millisecond range. This quick response speed improves control and stability in the user's system. In contrast, the typical automated control system has a slow response when compared to the pilot operated regulator. There is a time lag in the control loop due to the response speed of the controller, positioner and the time it takes the air signal to flow through the piping and fill the actuator. This can easily lead to instability in applications where there are wide and unpredictable changes in load conditions. Control valve systems continually need tuning to keep them operating effectively. *See Figure 3.*

THE OPERATING CYCLE OF A PRESSURE REGULATOR

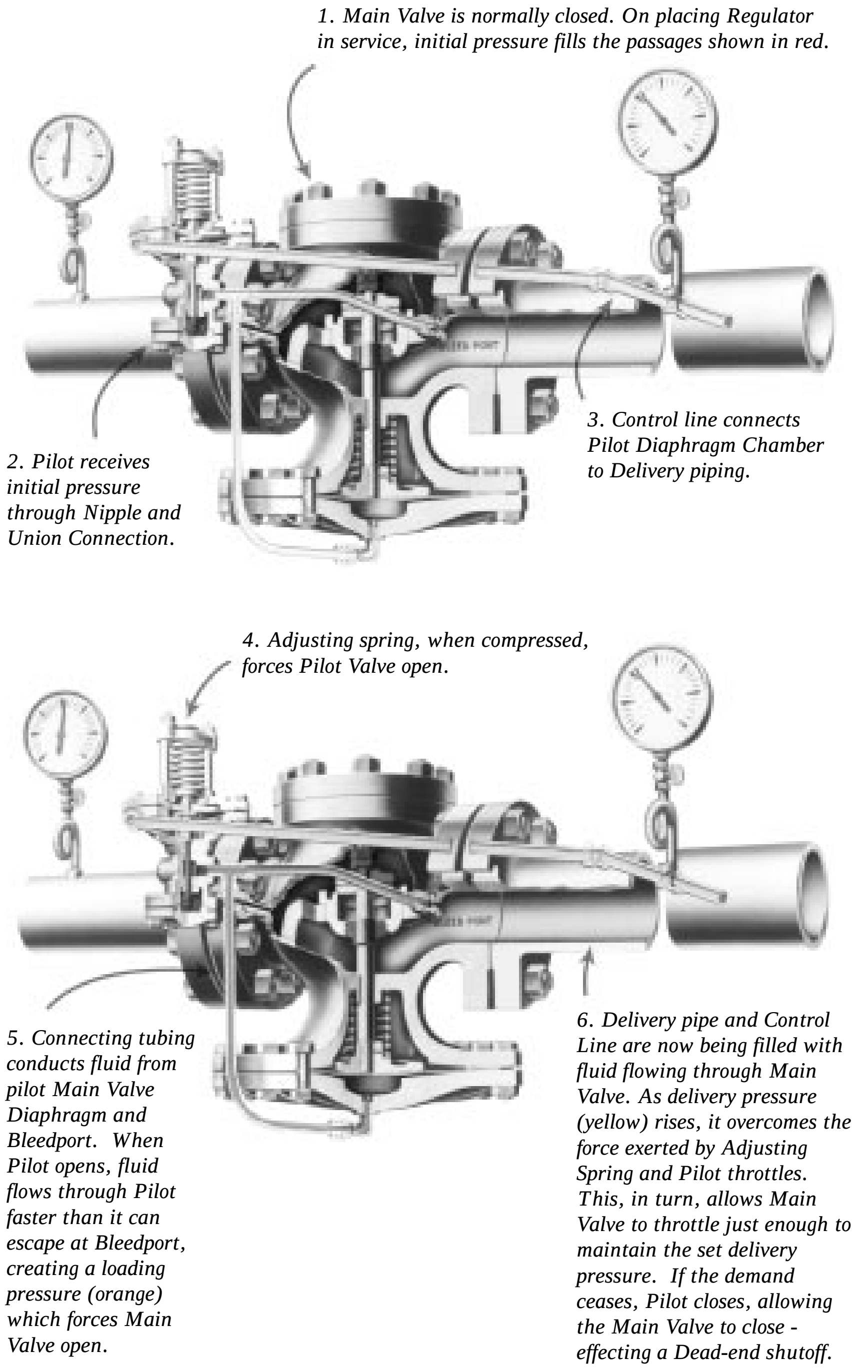

Figure 1: This presentation describes the successive steps in the mechanical cycle of a pilot operated pressure regulator.

- **Simple and easy to understand**—A pilot operated regulator consists of a main valve and a pilot valve. They are connected together through bends and fittings, which are usually supplied with the valves. Whereas, a typical automated control system includes a control valve, positioner, I/P transducer, controller, sensing device, air filter regulators and a supply of instrument quality air. In this type of control, there are many variables that must be tuned precisely in order to attain the desired control and stability. Too often this requires the expertise of a high paid and significantly trained control specialist to perform any type of troubleshooting or maintenance.

• Cost Savings—The typical automated control system consists of many expensive components, which in some cases are double or triple the cost of a pilot operated regulator. There is also a savings in the cost of piping, installation, tuning and maintenance.

• Accurate Regulation—Pilot operated regulators can typically control within +/- 1 PSIG. This is accomplished by a sensitive pilot valve and actuated by a large, frictionless diaphragm in the main valve. Backlash and the highly nonlinear frictional forces always associated with the control valve are not present in a well-designed packless regulator.

• Dependable and rugged construction—Pilot-operated regulators are a long lasting, cost-effective investment. Typically, once in service, a properly sized and installed regulator will work years before it requires any service or maintenance. For example steam pressure pilot operated regulators in buildings in New York City have been in service for over fifty years without requiring any service.

• Versatility—A pilot operated regulator can be used to perform many different control functions. They can be used to control downstream pressure, back-pressure, differential pressure, over-pressure, temperature, or a combination of variables. It can perform functions of load allocation or pump governing. A pilot operated regulator can be pneumatically, electronically or solenoid operated. It can be controlled at the valve, remotely or with a DCS—Digital Control System. Typically, it can handle upstream pressures up to 600 PSIG and 750°F and used on steam, water, or air services.

Too often engineers and designers overlook the versatility of the Pilot Operated Regulator. With the increased use of Building Automation Systems (BAS) and Digital Control Systems (DSC), the pilot operated regulator is usually counted out. Many engineers mistakenly believe that the regulator does not fit in with the rest of the automated control system. The regulator is seen as a device that is only adjusted manually and is not capable of a set point change from a central control room or of cascade control. In fact, 25% of all control valve application could probably be replaced with a properly sized and installed regulator.

PILOT OPERATED PRESSURE REGULATOR

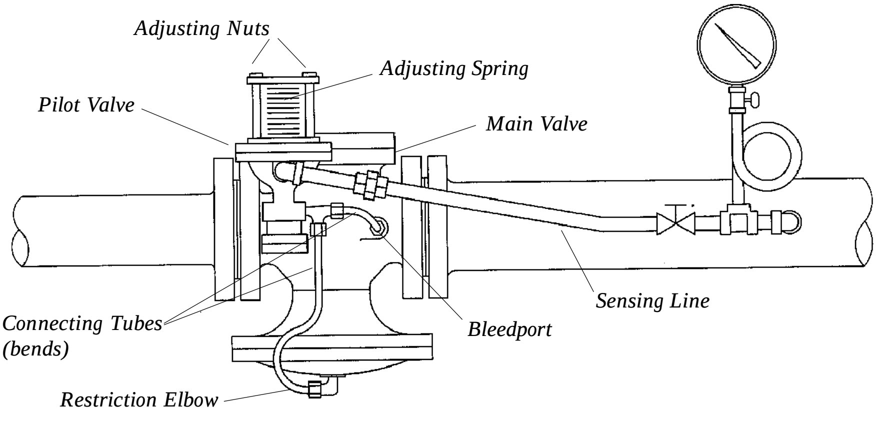

Figure 2

TYPICAL CONTROL VALVE SYSTEM

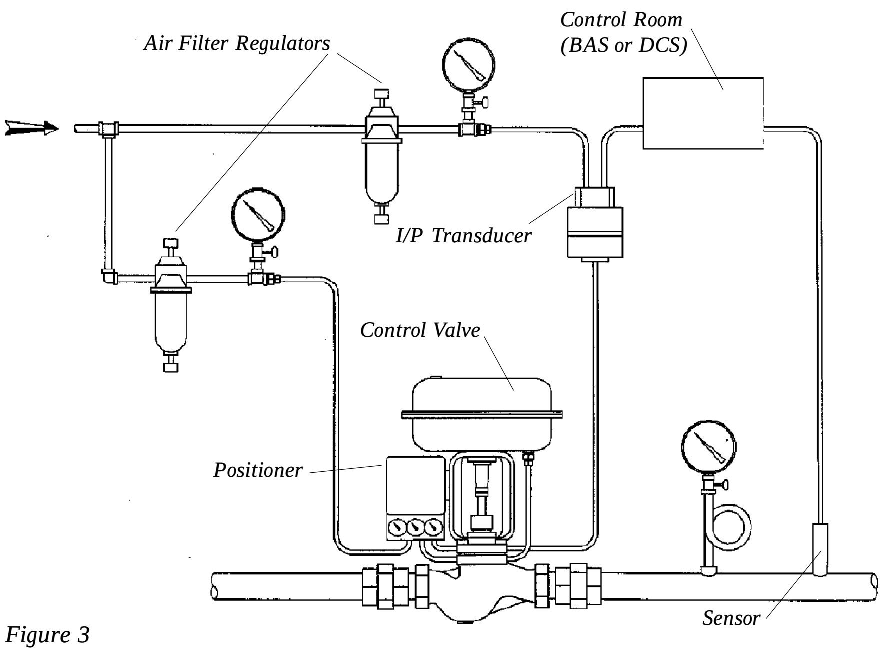

Figure 3

The pilot operated regulator is capable of accurate control, but the big secret is, it can also be integrated with the computer and other modern control devices. Pilot operated regulators can be pneumatically or electronically controlled with very little effort. For example, a user can select a pneumatic controlled pilot valve in place of the manual spring adjustment to provide remote control of the set point. Through the use of a BAS or DCS and I/P transducer, an engineer can retain the benefits of the pilot operated regulator without sacrificing the remote control flexibility. This system can further be set up to provide cascade control. Or, with the use of an electronically controlled pilot, a BAS or DCS can send a signal to the pilot to modulate the valve and control the system variable.

An example of how a user can attain the benefits of cascade controlled pilot operated regulator by tying into the BAS or DSC system is easily shown. In *Figure 4*, a main valve and a pneumatic controlled pilot valve can be used to control the air temperature in building. The pilot operated regulator provides steam to a heat exchanger and the heat exchanger creates hot water. This hot water can be piped to a coil to provide forced air heating, piped directly for traditional baseboard radiation or directed for any hot water use. In this system the temperature of the hot water required for heating is a function of the outside temperature and controlled by the BAS.

The pilot operated regulator controls the steam to the heat exchanger. The sensing line of the pneumatic pilot is directly connected to the shell of the heat exchanger. Therefore, the pilot immediately senses any change in steam pressure in the shell of the heater. The pressure in the shell of the heater is transferred back through the sensing line to the pilot valve. The pilot valve modulates in response to the pressure and then controls the modulation of the main valve. The response speed is fast and typically in the millisecond range.

The BAS measures the outside air temperature through a temperature probe. The temperature probe sends an electric signal to the BAS. The BAS processes the signal and sends an electric signal to the regulator. The electric signal is then converted to a pneumatic signal by an I/P transducer. The signal from the BAS provides a step by step reduction in set pressure of the regulator in response to the outside air temperature. The result is a quick responding system at an affordable price.

The above example is a classic case of cascade control. Cascade control is a step-by-step adjustment in a set point variable. In this example, the pilot operated regulator provides a step-by-step reduction in set pressure as the outside temperature changes. The use of a pilot operated regulator set up for cascade control and tied to BAS system, provides a quick responding, stable, inexpensive and dependable way to control temperature.

In other cases, where it is not necessary to tie into a BAS, the use of an integrally combined pressure & temperature pilot valve can also provide cascade control. This solution even further reduces the cost and simplicity of the system. These pilot operated regulators have been the choice control on many manufacturers hot water heaters for many years.

The steam heater is just one process in which the cascade control provided by a pilot operated regulator is highly effective. In this application, a standard control valve system will work fine with slow or weak load changes. However, as the load changes speed up the control system may become unstable due to the expected slower response speed. A sudden and rapid increase in load will immediately drop the steam pressure in the shell. The temperature of the outlet water falls excessively before the sensor on the outlet is able to respond to the change. The system then becomes unstable and is not very accurate.

Although pilot operated regulators have been around for seventy-five years, without many changes, they are still highly effective ways to control processes. There are many industrial and process applications that could benefit from the use of a pilot operated regulator without the complexity and cost of a control valve system. In a time where everyone believes that automation and computers make things easier, sometimes we must remember that bigger is not better. LET'S KEEP IT SIMPLE.

CASCADE PILOT OPERATED REGULATOR IN BAS

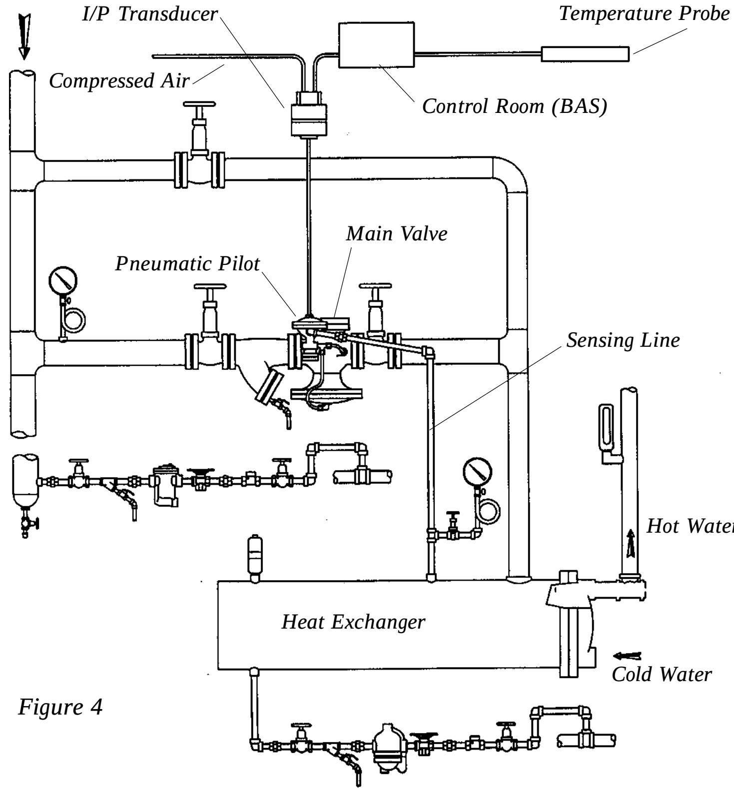

Figure 4

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