Combating Droop in Self-Contained Pressure Regulators

When selecting valves for pressure reducing applications, there are several factors to consider. First it should be decided whether the application requires a control valve in order to be effective, or if a self-operated or pilot-operated regulator will be sufficient. In order to make this decision, the following considerations are useful:

- What is the inlet pressure and allowable pressure drop?
- What is the set point?
- Speed of Response
- Process Fluid
- Line Size
- Will there be large flow variations or is the flow steady?
- How critical is the regulation/control?
- Is feedback to a Distributed Control System Required (DCS)?

If a regulator meets the design criteria it will prove a more cost-effective means of pressure reduction in almost all cases. In addition to lower overall costs, a regulator offers two major advantages: fast response, and being self-contained (i.e. not requiring control loops, compressed air, or electrical power).

Fast response is a great advantage when applied to non-compressible media or in applications where delayed shut-off might lift a safety relief valve. Additionally, regulators are sensitive to load variations commonly seen when controlling fluid pressures on heating or cooling applications.

When engineering the application, the droop effect of self-operated and pilot-operated regulators is the primary factor to consider. So, what is the droop effect?

Droop is an inherent characteristic of all self-operated and pilot-operated regulators. It is expressed as the deviation of controlled pressure from the set value or set point that occurs when a regulator's trim travels from the minimum flow position toward the full flow position.

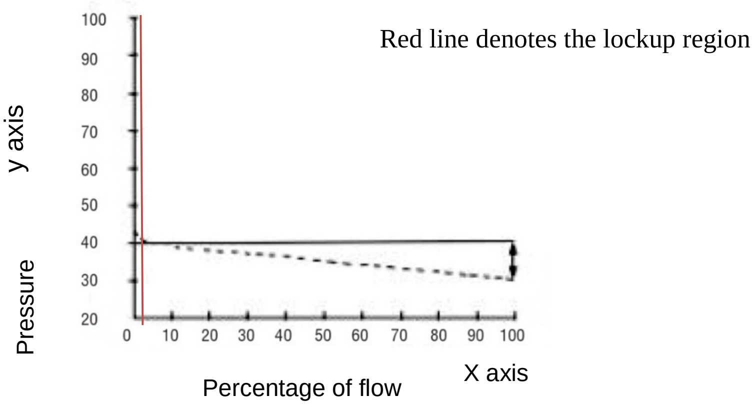

Figure 1

Figure 1 shows the droop effect for a regulator set at 40 psi as the valve travels from minimum flow position to the maximum flow position. The droop is expressed by the difference between the dotted line and solid line. The dotted line represents the actual controlled pressure obtained, and the solid line represents the line of perfect regulation. The red vertical line shows the Lockup Region. When operating to the left of the line, small changes in flow will result in large changes in controlled pressure.

TYPICAL APPLICATION

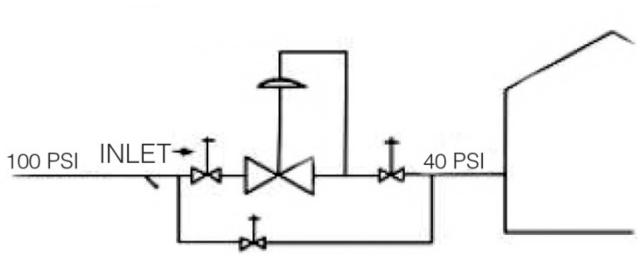

Figure 2

Consider the application in Figure 2. 100 psi water pressure is available to the building. To best operate the equipment and taps, it is necessary to reduce the pressure to 40 psi. A pressure-reducing valve can be installed on the service line to handle this desired reduction.

When there is no water demand, no flow is required and thus the regulator is in lockup. As demand for water increases to the full capacity of the valve, the regulator moves to the fully open position. However, since the regulator will droop with increasing flows, the set pressure of 40 psi to the building will not be maintained without some deviation from the set value. Why?

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Increasing or decreasing the amount of force applied to the spring establishes the set point for a self-contained regulator. In most cases, this is done with an adjusting screw (but can also be accomplished with a lever arm/weight arrangement). Turning the adjusting screw clockwise threads the screw further into the spring housing, which compresses the spring and increases the control pressure set point. Turning the adjusting screw counter-clockwise allows the spring to expand and decreases the control pressure set point.

Downstream pressure is transmitted to the underside of the diaphragm (the side opposite the spring), either by an internal channel within the valve (See Figure 3) or via a downstream control line tapped into the outlet pipeline (See Figure 2). When downstream pressure exceeds 40 psi, the pressure is transmitted to the diaphragm. The elevated downstream counterbalances the spring compression, causing the valve to close. When the pressure beneath the diaphragm decreases, the valve opens once again due to the spring's compression. In other words, once set - the spring will neither expand nor contract until there has been a decrease or an increase in the pressure (force) opposing it from beneath the diaphragm. Therefore, the valve plug will not travel unless there is a change in downstream pressure.

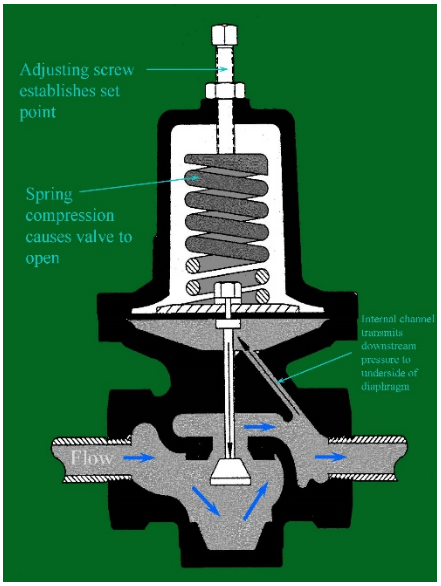

Figure 3

When downstream demand increases, the pressure in the pipeline drops which causes the spring to push the valve toward a more open position. A larger valve opening increases flow to meet the higher demand. The spring having just expanded to further open the valve is now exerting less force on the diaphragm than it was before, so the controlled pressure has to be less to maintain a balance of forces. It should be noted that the set point never changes, it is the controlled pressure that changes and the deviation from set point is either droop (as flow increases from set pressure), or lock-up pressure (as flow decreases from set pressure).

HOW DO YOU REDUCE DROOP?

As stated earlier, droop is an inherent characteristic in any self-operated or pilot-operated regulator. However, it is possible to minimize droop, which is determined by three factors:

1. Diaphragm Area
2. Spring Rate (or stiffness)
3. Length of Stroke

Increasing the diaphragm area, decreasing the spring rate, and/or decreasing the length of the valve stroke can reduce droop. It is important to remember that these factors are interrelated.

1. **Diaphragm Area** - The diaphragm area is restricted by economic and practical reasons. Larger diaphragms tend to increase the overall cost of the regulator since they require larger spring housings, heavier bolting, etc.
2. **Spring Rate** - Manufacturers will typically utilize the lowest pressure spring rating that will allow for an adequate range of pressure adjustment (set points). It is possible to reduce droop with low rate springs, but there is a chance of making the regulator too sensitive, which will create instability.
3. **Length of Stroke -** The distance a spring is required to move the valve plug from closed to the wide open position. The set point for any self-contained regulator is established by increasing or decreasing the initial compression required to balance the controlled pressure force on the diaphragm. In most cases, this is done with the adjusting screw. When flow conditions downstream cause the valve to move toward the full open position, this also "adjusts" the spring from the bottom. Thus, when the valve opens to compensate for additional flow demand, the spring is allowed to expand and the controlled pressure decreases (set point never changes, only the deviation from set point). To minimize the droop, design engineers can utilize regulators offering a shorter overall stroke length.

Pilot-Operated Valves

Pilot-operated valves have less droop than simple self-operated regulators. The additional sensitivity is obtained by a combination of the pilot diaphragm, pilot spring, and pilot valve stroke. The required stroke in most pilot valves is minimal because only a small amount of flow is required to load the diaphragm of the main valve. Small pressure changes are all that is necessary to stroke the pilot valve to load the main diaphragm which will open the main valve. There will be droop, but it will not be as dramatic as a self-operated regulator.

How to Choose the Right Valve

Self-operated regulators can experience droop between 10-30% of the initial set point. For higher set points, heavier springs are often used and droop may be considerably higher. Most pilot-operated regulators have a droop around 1-5% for the rated capacity – but may experience higher droop depending on the specific application.

The majority of applications do not require a valve to throttle from 5% open to 100% open, and so the droop is commonly minimized. In fact, if the lowest flow required is 20-30% of the maximum flow, the droop may be negligible. If the flow demands are relatively constant, or 10-30% deviation from set point is tolerable, a self-operated regulator should be used. If the fluctuations are great, or accuracy is essential, it may be necessary to go to a pilot-operated regulator or a control valve.

General Rules

- A pilot-operated regulator has less droop than a self-operated regulator.
- Air-loaded regulators can be more accurate in certain instances, however, they can be prone to instability in fast changing applications.
- High-flow regulators with longer strokes are less accurate than standard regulators. Typically, the shorter the overall stroke, the lower the droop (but may experience lower sensitivity).
- Larger diaphragms will increase overall accuracy.
- Regulators supplying multiple users/vessels may be more accurate than regulators supplying a single unit/vessel since it is unlikely that multiple user demand will all go on or off at the same time.
- The set point should be toward the high end of the selected spring range to give increased accuracy of regulation (Always use the lowest practical spring range for best accuracy).
- Avoid the temptation to oversize the regulator (i.e. using a higher C_v value) to reduce the amount that the valve has to open to meet a given increase in demand with the thought that droop will be reduced. This can often cause instability resulting in major fluctuations in the controlled pressure.

Oversizing can also result in operation within the “Lockup Region” where small changes in flow can result in large changes in the controlled pressure.

Most of the problems that are experienced with regulators are due to oversizing and selecting the wrong spring range. Applying the suggestions discussed in this paper should greatly reduce the chances of poor regulation.

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