Regulator and System Troubleshooting

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Introduction

This paper will address troubleshooting of gas pressure reducing regulators and their applications. The purpose of a gas pressure reducing regulator is to control the flow of gas such that the downstream pressure of the regulator is controlled at a desired level. When not properly controlled downstream pressure can demonstrate various forms of instability and deviation away from the desired setpoint. This paper will cover the mechanical components of the regulator and how changing them can alter the stability of the system.

System Description and Effects

The "System" is describing not just the regulator but all of the piping and other equipment both upstream and downstream of the pressure reducing regulator. The piping is considered part of the system as it is required to close the loop and to contain the pressure. A regulator on its own cannot control or reduce pressure as it will not have any pressure on the outlet to provide feedback. This leads to any evaluation of the stability and function of a pressure reducing regulator to require a full evaluation of the system as a whole to best understand what contributes to the behavior of the regulator. Several piping configurations can contribute to instability and poor pressure control.

<u>Small Downstream Volume</u> – A small volume downstream of the regulator results in rapid changes in the pressure that the regulator may not be able to respond to quickly enough. This can result in inconsistent pressure control with the pressure swinging low on increased demand and high on reduced demand.

<u>Restricted Piping</u> – Restriction downstream of the regulator such as small diameter piping feeding a larger volume system can cause the same effect as a small downstream volume on increase in demand. This will result in the regulator not being able to sense the drop in pressure in the downstream system resulting in a loss of pressure downstream. This can be addressed by using an external sense line bypassing the restriction or by ensuring adequate pipe size for the required flow.

<u>Turbulent piping</u> – This issue often appears as a result of extreme piping expansion or contractions from swages, tees, or other piping components such as valves. Turbulence can cause erratic pressure readings near the turbulence generating components. If the regulator or other sensing or control devices are sensing in one of the turbulent areas this may result in erratic control of the downstream pressure. Relocation of sense lines or pressure sensors into an area of laminar flow, when possible, can reduce the impact of turbulence in piping.

<u>Small Upstream Piping</u> – A reduction in the size of the piping providing the higher inlet pressure to the pressure reducing regulator can cause reduction in the ability of the regulator to meet the required downstream demand. If the piping or other components feeding the pressure reducing regulator restrict flow such that the regulator is flowing more gas to meet the downstream demand that can be supplied to the inlet of the regulator the inlet pressure will drop. If the inlet pressure of the regulator is allowed to drop significantly it is likely that a regulator may

not be able to continue to meet the downstream demand. This can appear as a regulator which performs well outside of high demand scenarios, however under high demand it will not maintain the outlet pressure.

Downstream Demand

Several types of downstream demand can have effects on the performance of the system as a whole and are discussed below.

Fast Changing Flow – With the increased demand for generators from multiple industries rapid changes in downstream demand have become a regular application in the natural gas industry. A rapid change in the downstream flow will result in a commiserate change in the downstream pressure as the regulator adjusts to match the downstream demand. As regulators are mechanical devices that respond to the pressure of the downstream system lower pressure at the initial increase in load is observed and potentially higher outlet pressure is observed as the regulator may overshoot as the downstream demand is met. The exact opposite can be observed during a sudden reduction in flow with sudden increase in the pressure as the regulator combats its internal momentum to close rapidly. Selection of a regulator that can respond at an appropriate speed for the particular application is critical with the fastest speed of response being offered by self-operated regulators while pilot operated regulators are typically slower.

High Flows – Higher steady state flows can contribute more to the above mentioned turbulence. This can cause erratic pressures and as such on high flow systems sense line locations will be critical to ensure best performance.

Low Flows – Very low flows or regulators sized for future much higher demands tend to cause the regulator to operate near its shutoff position. This operation near the shutoff point can tend towards instability as the regulator may open slightly and meet the full downstream demand and result in the regulator quickly returning to fully shut. While most regulators can readily control pressure down to zero flow the flow slightly above zero is most challenging for pilot operated regulators.

Meters – Some meters have an operational frequency that aligns with self-operated regulators causing feedback via the slight pressure pulses in the downstream of the regulator. This can cause humming or cycling of the regulator while it maintains the downstream pressure.

Regulator Causes

For the previous duration of this paper the non regulator components of the system have been discussed. These, in conjunction with the elements of a regulator make up the entire control system for pressure in a typical gas distribution system. Below we will discuss the components of the regulator and how they contribute to the stability of the pressure reduction system.

Valve – Figure 1. Below illustrates the first of the three key components of the regulator, the valve assembly of a plug and orifice.

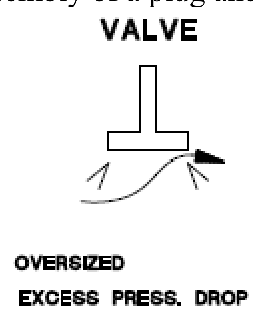

Figure 1.

The plug and orifice are used to throttle the flow of the system. One of the largest contributing factors to instability is due to the oversizing of the regulator. In a service regulator multiple orifice sizes are offered for the same line size allowing for selection of an orifice that is optimal for the maximum flow of your system. The selection of an orifice that is significantly larger than is needed will result in the plug operating close to the orifice. This proximity of the valve plug and orifice increases the sensitivity of the regulator to downstream changes in demand and results in very limited travel of the plug to meet the full demand of the system. This limited travel to meet the full demand of the system reduces ability of the regulator to throttle and steadily control the downstream pressure.

Actuator – Figure 2. Below shows the whole regulator a self-contained valve and actuator combination.

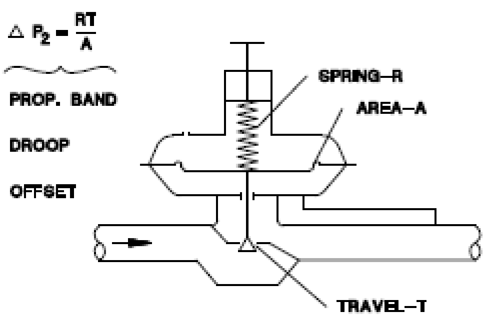

Figure 2.

The actuator contains the two remaining essential elements of the regulator, these being the diaphragm (measuring element) and the spring (loading element). The regulators actuator uses the diaphragm effective area (A) used to measure downstream pressure, a travel (T) for which the valve must be stroked to provide the appropriate flow manipulation, and a spring that has a rate (R) expressed in pounds force per inch of movement or travel. The accuracy of a regulator is measured in proportional band for pilot operated regulators generally 1-2% of the setpoint, and droop in self-operated regulators generally 10-20% of the setpoint. An ideal regulator would be able to meet all downstream demand without deviation from the downstream pressure setpoint. Unfortunately, this is not possible. A regulator with a very large diaphragm area will allow the deviation from the setpoint to be smaller for travel to meet the needed amount for a particular orifice size. The change of the spring rate will have a similar effect a lighter spring rate will allow more travel for the same change in downstream pressure. However, to light of a spring rate will result in a device that moves significantly at any minor change in downstream pressure. Generally, the spring rate of the regulator is designed and tested to control a range of pressures, and higher or lower rate springs are used if the pressure range needs to be changed. All manufacturers must balance these key factors that make up the pressure reducing regulator to offer a product that can meet the customer's particular needs for their applications. Generally, the lightest spring range that is designed for the required downstream pressure is recommended as this allows for the best travel of the regulator for the highest accuracy, however, if instability is experienced a higher rate spring will increase the damping of the system eliminating he instability at the cost of the reduction in accuracy of the regulator.

Pressor Sensing Methodology

There are two methods of sensing or measuring the downstream pressure that the regulator is to control. The most common is internal registration where the regulator has provisions to measure the downstream pressure within the body of the regulator. The second form of pressure sensing is external control via a sense line connected to the downstream piping. These will be discussed in more detail below.

Internal Sensing – This mechanism is generally used in self-operated service regulators. Most internal sensing arrangements utilize boost techniques to register a slightly lower pressure that is observed further downstream. This allows for the regulator to more easily overcome the force of the diaphragm and spring compared to a pure measurement of the downstream pressure. This boost effect must be optimized around the desired service conditions else significant numbers of configurations will be needed making manufacturing and warehousing difficult. Several manufacturers have offered multiple configurable mechanisms that can be interchanged to adjust the boost levels as needed for service conditions. Even with these adjustments high pressure drops, or high flows can cause issues with instability in internally sensed systems. Internally sensed regulators are also particularly sensitive to restricted piping downstream as this can build up pressure into the body making cycling and instability likely.

External Control Line – Control lines are used by most nonservice regulators and pilot operated regulators. This control line connects the reference pressure area under the diaphragm of the actuator to the downstream piping. The location of the pressure tap that connects this sense line to the downstream piping is critical. A general rule is to install it approximately 10 pipe diameters downstream of the regulator or any other turbulence generators in a straight run of pipe where turbulence is at a minimum. A good rule in installing control line taps is to install them as if you were installing a meter. The rules applying to meter installations also apply to control line tap locations. AGA Report #7 deals with measurement of fuel gas by turbine meters and has many good piping practice suggestions on installation. This 10 pipe diameter rule would apply to the last pipe enlargement downstream of the regulator. For example, should the pipe be expanded immediately out of the regulator, the 10 pipe diameter applies to the enlarged pipe size, not the original regulator size.

Control Line Sizing – The control line should be no smaller than the tap where is connects to the regulator and the isolation valve where the sense line connects to the downstream volume should be a full port valve and not a needle valve or other restricting design. If the control line downstream tap is to be located more than 10 feet downstream it should be increased one nominal pipe size for the full length of the control line run. This will minimize the pipe friction in the sense line reducing back pressure if the sense line is also the bleed line for a pilot operated regulator. If the pilot for a pilot operated regulator has separated sense and bleed line connections it is recommended to attach these to separate pipe taps downstream with the location of the sense line port being more critical that it be stable than the bleed line. If the separate sense and bleed lines are attached to the same downstream tap a “sway” in the control pressure may be observed as the bleed pressure feed back into the sense line. In the event of instability on a self-operated regulator with an external control valve a restricting valve can be used to help damp out turbulence in pressure readings in some cases. However, if this valve is closed too far it can cause further increase in the amplitude of instability.

Contaminants in Gas

While natural gas is often referred to as a “clean” gas it is frequently the case that the piping used to transport the gas can have contaminants within. These contaminants can include but are not limited to the following list, water, hydrocarbon oils, rust, welding slag, pipe tickets from taps, nuts, bolts, soda cans, small animals, dirt, tools, and many more unique finds that induce a host of issues for the pressure control system. Typically, water in the line can lead to freezing of the main valve or pilot or if the temperature is not low enough any liquids can lead to instability if they manage to get under the diaphragm of the regulator. For solid debris this can lead to a regulator not shutting off fully due to damage to the disk or orifice when low or now flow conditions occur. In more extreme cases larger debris may jam or fail the regulator in the open position and result in overpressure downstream. Best practice would be to locate any filter or strainer that is to be installed at a station before the regulators as this will remove any debris before it can cause damage to the regulators.

Summary

When working to understand and correct any issues with instability with a pressure control system remember that all components of the system contribute to its behavior. For the regulator the contributing factors include the actuator, pilot, and valve. The sensing line location and size contributes significantly. As there are many factors both internal and external to the pressure reducing regulator it can be difficult to troubleshoot instability as any one of these factors may not be an obvious primary cause. This paper has hopefully increased your understanding of the factors to consider such that each of these factors can be evaluated and addressed to better address issues when located in the field.