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Conroe, Texas 77302
(713) 242-1190

CAUSES AND CURES OF REGULATOR INSTABILITY

Class # 6010

Paul Anderson
Regional Sales Manager
Emerson Process Management
310 E. University Drive
McKinney, Texas USA

Introduction

This paper will address the gas pressure reducing regulator installation and the issue of erratic control of the downstream pressure. A gas pressure reducing regulator's job is to manipulate flow in order to control pressure. When the downstream pressure is not properly controlled, the term "unstable control" is applied. Figure 1 is a list of other terms used for various forms of downstream pressure instability. This paper will not address the mathematical methods of describing the automatic control system of the pressure reducing station, but will deal with more of the components and their effect on the system stability.

Unstable	**Hunt**
Pulsate	**Cycle**
Oscillate	**Pump**
Buzz	**Chugs**
Paint	**Vibrate**
Hammer	**Floats**
Surges	

Figure 1

System Causes

The term "system" is used to describe not only the regulator but all of the piping, both upstream and downstream, of the pressure reducing regulator installation. Without this piping, all the requirements for closed loop control of pressure would not exist. In other words, a regulator by itself cannot be unstable. It must be installed in a piping system such that it is required to manipulate the flow into the downstream system. This flow into the system must be exactly the same as the flow demand on the system, sometimes called the load flow. The piping itself is the component most significant in defining the system. Three styles of piping can contribute to poor pressure control:

<u>Small Volume Piping</u> - This can create a volume downstream of the regulator such that any flow into or out of this volume will cause rapid or large changes in the piping pressure. A regulator that does not have fast enough response to these piping enhanced transient pressures will not be able to follow the load changes; thus the control of pressure will be erratic.

<u>Restricted Piping</u> - This occurs many times when large distribution systems are involved where the piping volume downstream is actually very large; however, the regulator station itself has many restrictions immediately downstream of the pressure reducing regulator. Examples of this would be orifice plate runs, block valves, and headers that create restrictions to the apparent volume which the regulator effectively sees. This creates the effect of a small volume system for the regulator, even though the total downstream volume is very large. This apparent small downstream volume becomes very sensitive to load changes, as did the small volume piping addressed above.

<u>Turbulent Piping</u> - This most often would be the result of extreme piping expansions or contractions from swages or other piping components. Turbulence by itself causes erratic pressure profiles within the piping. The regulator

prefers smooth static pressure readings at its control point since it must measure this pressure to compare it to the regulator set point. If this pressure is erratic due to turbulence, then some regulators may try to respond to such transient pressures and go unstable as a result.

The Load Flow

Fast Changing Flow – A rapid change in flow rate out of the downstream piping system causes a transient decrease in control pressure. The regulator, having a mass, will not instantly travel to a new position to increase the flow into the system. Therefore, the pressure will fall below set point even though for a short period of time. When the regulator does begin to travel and achieves the load flow equivalent, many times the mass of the moving parts in some regulators will not stop at that travel but overshoot. This can be the beginning of a sustained cycle.

High Flows – The nature of extremely high flows in piping systems can cause turbulence, as discussed previously. This turbulence can cause erratic pressure within the piping system, which the regulator will attempt response to, which again can be initial conditions to establish continued cycling.

Low Flows – Extremely low flows will require a regulator to operate very near its shutoff position. Most regulators will control pressure (manipulate flows) down very close to the zero travel position. However, a combination of above system conditions and a very low flow can initiate instability.

Meters - Some positive displacement meters have an operating frequency that nearly matches many self-operated regulators. These are the non-diaphragm or lobe styles. Occasionally, this meter will introduce slight pressure pulsations within the downstream piping system that can drive a regulator to cause resonance or continued cycling

Regulator Causes

Thus far, the discussion has been on components of the system other than the regulator itself. These, in conjunction with the following elements of a regulator, make up the entire loop control system for pressure control.

Valve

Figure 2 illustrates the simplest form of the valve elements of a regulator, this being an orifice and movable element to cause the manipulation or throttling of flow.

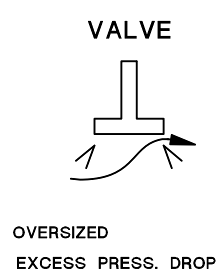

Figure 2

Probably the single largest cause of regulator instability has to do with over sizing of the valve portion of the regulator. The service regulator, for example, has many different orifice sizes for optimum control of pressure up to some maximum regulating flow. Selecting too large an orifice requires this valve and orifice to operate extremely close to the seat. This causes the valve to become very sensitive to inlet pressure changes and flow demands. Pressure drops across the regulator trim that exceed the recommended working range for a particular trim can cause instability due to excess forces within the valve trim, which cannot be overpowered by the actuator portion of the regulator. This can also occur in larger control valves as well as service regulators. This is why many regulators have a pressure drop limitation lower than the maximum inlet.

Actuators

Figure 3 shows the schematic of a simple self-operated regulator and its components. Many different service conditions require a multitude of constructions; however, they all have the basic components as shown in Figure 3. These are a 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. A measure of self-operated regulator accuracy is called the proportional band, droop, or offset in the downstream pressure.

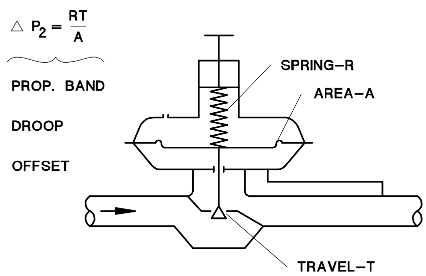

Figure 3

It is expressed in Figure 3 by a formula. The perfect regulator would have a proportional band of zero. This would be a regulator that allowed zero change in the control pressure downstream to cause the entire rated travel of the regulator. This is not possible. This is illustrated by the simplified formula. A regulator with a very large area (A) will cause the offset to be smaller, but an infinitely large area would be needed for zero offset. Also a very small rate (R) or a small travel (T) will reduce the offset. Since zero travel or zero rate would not provide a functional device, a zero offset regulator of this type is not possible. For any given regulator, the affective area is a given value. The travel is established by design. Several springs with different ranges (different rates) are usually provided to cover various control pressure values. The formula illustrates that the higher the rate (range) of a spring the larger the proportional band for that regulator. This also associates with the sensitivity or gain of that regulator to its likelihood of becoming unstable. Thus, a compromise between good steady state control and regulator instability is made in the design and selection process of regulator springs. Manufacturers create a combination of components as best they can for most installations. However, since an infinite number of installations exist, there will be a combination of system components and regulator components that can be unstable. If a minimum proportional band is desired, then the lowest rate or range spring to cover the desired set point should be chosen. However, should instability occur, then a higher range of rate spring to cover the desired set point should be chosen. This will result in a larger proportional band, but will desensitize the regulator and many times stabilize its control of downstream pressure.

Pressure Sensing

There are two methods used for sensing or measuring the downstream pressure that the regulator is controlling. First is INTERNAL registration, where the downstream pressure is actually a measure of some pressure within the regulator body itself. This is required by Federal Law in the definition of a service regulator in that no static control lines are allowed. The second form of pressure sensing is the EXTERNAL field piped control line attached between the regulator and downstream piping in which pressure control is required.

Internal Sensing

This mechanism is used by the regulator designer to measure special pressure profiles within the self-operated service regulator to send special pressures back to the actuator sensing diaphragm. This is used to overcome the spring and diaphragm effect of many regulators to "boost" the pressure regulation curve and improve regulating performance. These "boost" techniques must be optimized around select service conditions, otherwise, an infinite number of regulator geometries would result. In recent years, some manufacturers have provided alternate boost mechanisms that can be interchanged to adjust the amount of boost for various service conditions. Even so, high pressure drops or extremely high flows, in conjunction with piping geometries, can cause instability. Restrictive piping immediately downstream can modify the pressures within the body outlet and contribute to cycling.

External Control Line

This method is used by most nonservice regulator style regulators where an external field pipe control line is installed between the regulator sensing element (diaphragm) and the downstream piping. The tap location for this control line is of course critical because it is the starting point of communication between the system pressure and the regulator. Although not always practiced, this tap into the piping should be made as if it were a static pressure tap for metering purposes. A general rule is to install it approximately 10 pipe diameters downstream of the regulator in a straight run of pipe where turbulence is 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 Size - In general, larger control lines are better. One reason is for structural integrity of that control line from outside forces damage. For stability, a larger control line is less restrictive and will provide a better steady state reading of the piping pressure. Many pilot-operated regulators exhaust gas down this control line into the downstream system when they are in operation. Should a control line be too restrictive, this can cause backpressure due to this flow or erratic pressures within the control line itself, even though downstream pressure initially is under control. The regulator only communicates with its control line, and should the pressure within that control line become erratic, then so will regulator travel, which would result in erratic downstream pressure control.

Restricting valves in control lines have been used to tune out instability in some regulators. In general, these most often help on self-operated regulators where this restriction is used to damp out turbulent pressure readings on their way back to the sensing diaphragm of that self-operated regulator. It should be noted that these needle valves can cause larger amplitude cycles from steady state control by causing time lags. Therefore, extreme throttling of such needle valves should be avoided.

Pilot-Operated Regulators

With this style regulator, an amplifier (controller) is issued to increase the sensitivity of pressure control making possible the control of much higher pressures. A pilot, even though it can be more complicated in the number of components, has the same basic components of the self-operated regulator, these being an effective area, a rated travel and a spring rate of some sort. These components establish a pilot gain or sensitivity. This gain relates the change in pressure sent from the pilot to the main regulator as a function of control pressure changes. A very sensitive pilot would send a large signal to the actuator for a small change in control pressure; therefore, an extremely sensitive or very high gain pilot can contribute to instability. As with self-operated regulators, several springs are offered many times to control a given range. The lightest range or lightest rate spring will be most sensitive. It will also have the greatest tendency toward instability. Therefore, should instability occur with pilot-operated regulators, consideration should be given to desensitize the pilot.

Supply Pressure

Many piloting systems use the inlet gas pressure as the supply or energy source from which to draw their power to stroke the main actuator. This supply in many style regulators does not need to be full inlet pressure. A method of lowering the gain or desensitizing a pilot is to install a small pilot supply regulator in front of this pilot or controller. Many controllers require this since their working components cannot survive in the full inlet pressure environment. This applies to control valve controllers. However, pilot-operated regulators are usually capable of full inlet pressure. A high pressure drop across the pilot can cause extremely high pilot gains or sensitivity. A pressure reducing regulator in this pilot supply line can reduce the instability should it occur.

Summary

The contributing factors to any pressure control instability are all of the components in a given pressure system. For the regulator itself, these include the valve, actuator, and pilot. The sensing line between the piping system and load itself are also involved. Many instability problems are difficult to resolve because none of these particular factors evidenced themselves as primary causes when investigating an instability. This paper hopes to have helped increase the knowledge of the causes for regulator instability so that each can be separated as potential causes and worked on to provide cures when they occur in the field.