

Solving Instability Issues in Commercial and Industrial Natural Gas System Applications



Noise and vibration can be some of the largest drawbacks of using regulators in any gas system. Natural gas transmission and distribution companies often go to great lengths to reduce the noise and vibration made by regulators and to prevent them from causing an inconvenience for their customers and people living in the surrounding area. Typically, a regulator will exhibit some noise as a function of the reduction in pressure. This can be evident in large pressure reductions like in City Gate stations

or Transmission applications. In these applications, several regulator brands offer silencing devices to dampen the noise, like the Fisher™ Whisper Trim™.

However, there are times when regulators in commercial and industrial applications will become noisy even in installations with small pressure reductions. This whitepaper will cover the background behind these types of applications and potential solutions that can address many of these issues.

Types of Instability and Contributing Factors

Regulators exist in a complex natural gas system which includes the upstream and downstream piping and everything in between. A regulator is not inherently unstable but may be the most likely place in a gas system where an instability condition may manifest itself. This is because a regulator is one of the few system components with moving parts which can vibrate at the system's resonance frequency. Resonance occurs when the set of a vibrating system's characteristics cause it to oscillate at much higher amplitudes in a specific frequency range.

The system can become unstable by one or more of the modes listed below:

Harmonic Instability

Harmonic instability is the most common mode of instability that regulators exhibit. This condition is caused by a collection of system characteristics during normal operation which results in a "humming" or "buzzing" sound emitting from the regulator due to the vibration of the diaphragm or other parts. Harmonic instability is typically a system issue but can be exacerbated by either hunting or feedback, which will be explained in more detail in later sections.

Every system and component in a system has a natural frequency. With that in mind, any physical change to the system may also change the frequency required to excite the regulator to a resonance condition. For example, a certain meter set may begin exhibiting a humming noise at a moderate inlet pressure and flow but stop when the flow increases. This is something Emerson engineers have seen in lab testing.

Emerson engineers have been told by field technicians that they have occasionally noticed a regulator begin to hum after removing the closing cap for a set point adjustment and would stop once the cap was replaced. This is because the regulator operating very close to its resonance frequency, something as small as removing the closing cap may be enough to cause the regulator to hum or buzz. In a steady-state condition, the regulator was likely on the brink of instability and by removing the cap, changed the system characteristics just enough that it became unstable.

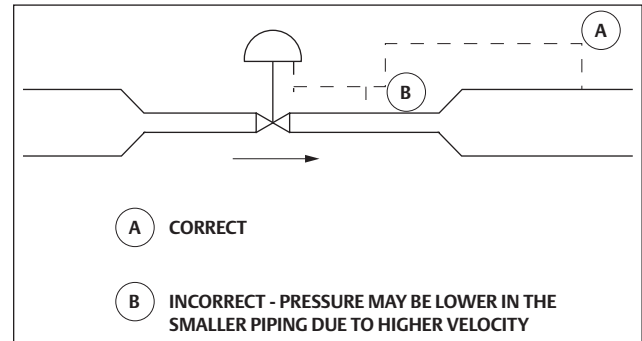


Figure 1. Regulator Control Line Placement in Swages

Many researchers in academia have developed models to study the stability characteristics of regulators⁽¹⁾. One such study analyzed the effect of large vent piping on system instability. The researchers could adjust the size of the regulator's vent piping to induce instability in regulators, another factor to keep in mind during system design.

Hunting

"Hunting" is a condition in which a regulator's outlet pressure slowly fluctuates on either side of the set point. In this condition, the regulator will "hunt" for a desired pressure but certain factors may prevent it from quickly reaching equilibrium.

Hunting can occur as a result of several factors causing turbulent flow in the system:

- Pressure Registration

A poor regulator setup may lead to increased probability of regulator instability. In external registration applications, the placement of the control lines makes a significant impact on the operation of the regulator. If the control lines are incorrectly placed in the system, the regulator will exhibit hunting to try to match downstream pressure to a set point using an erroneous reference pressure. Common sources of turbulent flow in gas systems include elbows, swages, valves and meters. Placing a pressure tap too close to these components may negatively affect the operation of the regulator and may contribute to instability. Figure 1 shows an example of a correct and incorrect placement of these control lines. Control line

1. Earney, W.H. 1995. "Causes and cures of regulator instability". United States.

diameter is also a factor to consider. If the diameter of the control line is too small, it may trigger an instability condition because it would slow regulator response time.

- Piping Characteristics

Small volume piping downstream of the regulator can exacerbate pressure transients. In cases like these, the regulator may not be able to respond quickly enough which can slow down the regulator's speed of response. This may lead to erratic pressure control resulting in excessive vibration or harmonic instability.

- Effective Flow Area

Swages or other changes in piping diameter may cause turbulence resulting in erratic system piping pressures. If the regulator is set up to sense pressure near an area of turbulence, it may erratically attempt to respond to this pressure which may cause it to go unstable.

Restrictions downstream of the regulator could also cause similar problems. In large runs of downstream piping, instability can be caused by piping restrictions such as orifice plates and blocking valves. This could make the downstream volume sensitive to load changes and make pressure much more difficult to control, resulting in hunting.

- Flow Characteristics

Flow characteristics may also be a root cause of system instability. High flows and rapidly changing flows can all be contributing factors to erratic local pressures in a system. The regulator may continually overshoot the set point as it attempts to control pressure under these conditions.

The hunting type of regulator instability can also be caused by regulator sizing and selection decisions:

- Regulator Size

Hunting can also be caused by incorrect regulator sizing. If the orifice is too large for the application, it will operate very close to the seat during normal



Figure 2. Commercial Meter Set

operation requiring low flow. Not only does this contribute to seat wear over time, but the regulator will be more sensitive to changes in demand. This causes the regulator to overcompensate and take much longer to achieve the desired set point.

Feedback

- Meters

Some meters, such as larger turbine or rotary, meters, have operating frequencies close to those of self-operated regulators as seen in Figure 2. These meters create pulsations that can feed back into a regulator in close proximity, sometimes resonating in the diaphragm. This may cause a “chugging” sound in the regulator. The less piping between the meter and the regulator, the more likely this phenomenon is to occur. Large diaphragm meters can also cause this condition but at much lower frequencies, manifested by a chugging sound.

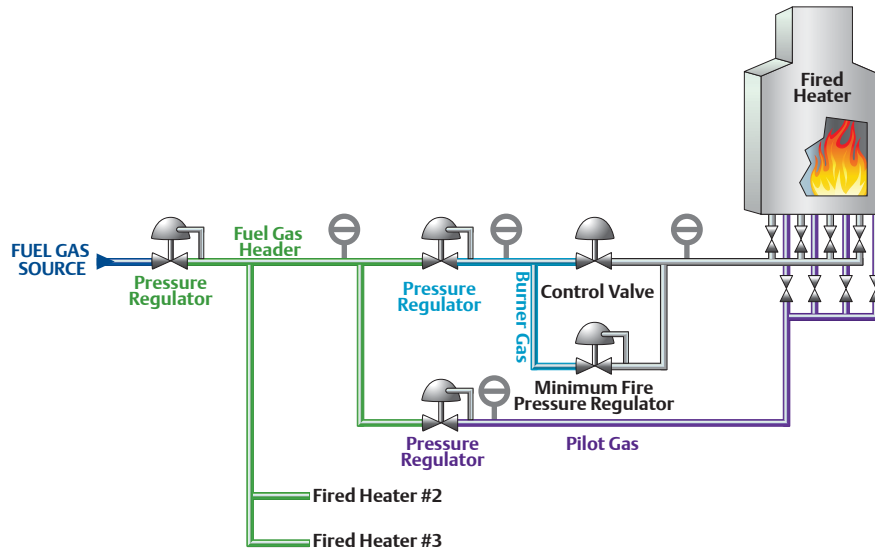


Figure 3. Industrial Boiler Train

- Boilers and Burners

In certain boiler applications, Figure 3, most notably in “pulse-type” combustion models, feedback can occur causing excessive regulator vibration. Combustion in these applications is sustained through a series of pressure swings which draws the flow of the gas and air mixture into the system to sustain the process. These pressure fluctuations are necessary for the boiler to operate correctly but may also cause the regulator vibration.

Instability Drawbacks

Depending on where the regulator is installed, this condition may range from somewhat innocuous (a regulator installed in a basement far away from anyone who may hear it) to a large annoyance (a regulator installed in an apartment building or school). The noise or vibration may be so problematic that the end user may have to redesign or move the system, exposing them to a significant additional cost.

Although the operation of the regulator is typically not affected in an unstable system condition, if the condition is not addressed, the excess vibration may fatigue and eventually damage the regulator in more severe conditions. To correct this instability, it may be necessary to change one or more aspects of the system to prevent resonance and feedback from occurring. Depending on the change required, this

may be a large expense for the end user but is still less than the cost of system downtime if the regulator were to become damaged.

What Can Be Done?

In the paper, *Causes and Cures of Regulator Instability*⁽¹⁾, W. H. Earney points out that, while manufacturers do the best they can to prevent unstable conditions in most installations, since an infinite number of installations exist, there are also an equal number of combination of system and regulator components that will result in instability. However, there are several best practices to correct an unstable condition:

Regulator Sizing and Selection

When designing a regulator, manufacturers attempt to balance pressure control with instability by careful consideration of the spring selection, diaphragm area design and amount of travel by the valve plug.

The manufacturer can change the diaphragm area of the regulator but more realistically, the customer can only change the orifice or spring. For spring selection, Emerson recommends the lightest spring, however if the next heavier spring is advertised as able to control the required set point, then it can be used to reduce the sensitivity of the regulator. Emerson also

1. Earney, W.H. 1995. “Causes and cures of regulator instability”. United States.

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recommends using the smallest orifice possible for any application's demands. Not doing so may result in a hunting condition.

Vent Piping

Vent piping is necessary for many regulator installations but increases the likelihood of harmonic instability in the field. Emerson has the following recommendations for the installation of vent piping, based on CSA B149 Natural Gas and Propane Installation Code:

- Use at least the same diameter pipe as vent
- Treat one pipe elbow as 3 ft of straight pipe while planning the installation
- Increase one pipe size for every 10 ft of piping (for regulators with an internal relief valve) and one pipe size for every 50 ft (for regulators without an internal relief valve)

Pressure Registration

Regulators with internal or dual registration have historically been less likely to exhibit hunting than those with external registration.

Placement of Control Lines

If control lines are to be used for a regulator installation, Emerson recommends the following guidelines to prevent a hunting condition, Figure 4:

- Make the control line as short and as straight as practical.
- Connect the control line at least 6 to 10 pipe diameters downstream of a source of turbulence (valve, tee, elbow, swage, etc.).
- Connect the control line to the point where pressure is to be controlled.
- The control line diameter should be selected to match the connection provided on the regulator. If the control line is over 10 feet long, the size should be increased.

However, changing these system characteristics may not be approved in engineering drawings or even be realistic due to space constraints. And in the end, trial and error may still not even correct the issue.

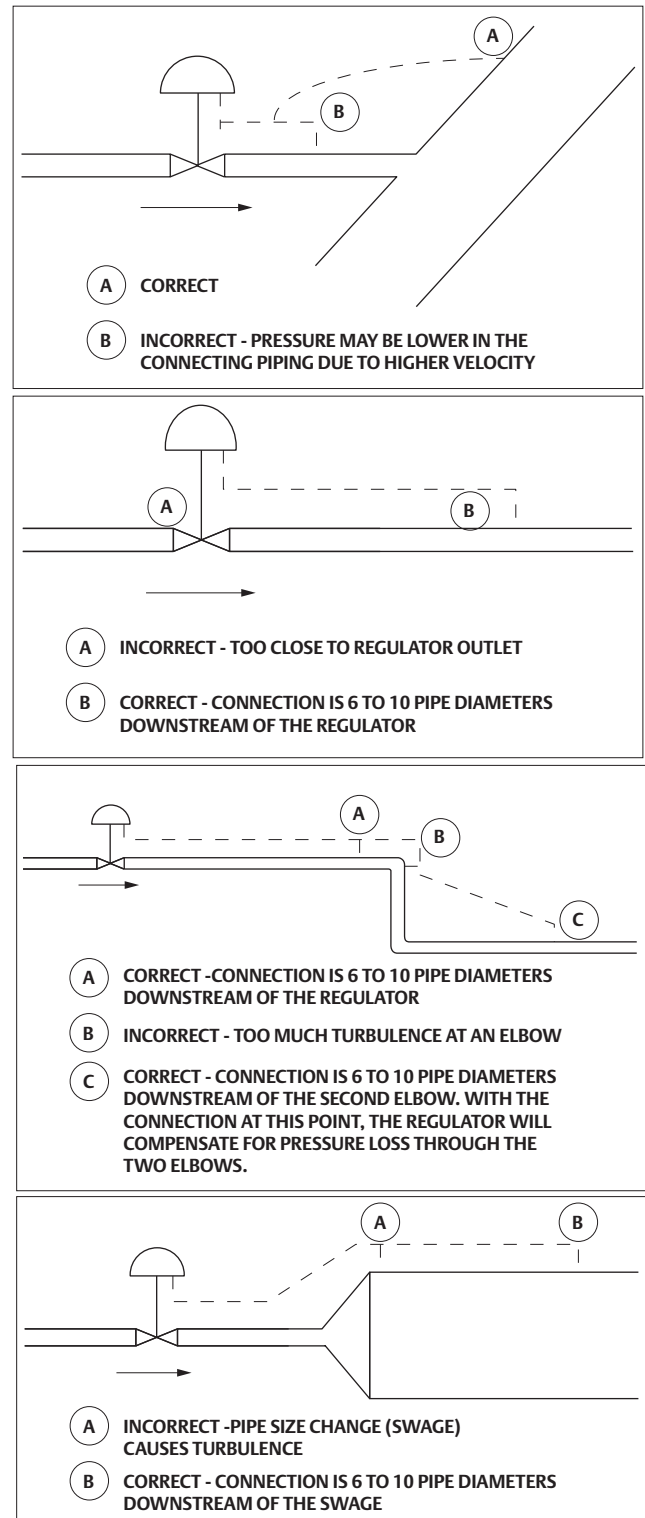


Figure 4. Control Line Placement Issues

Stabilizer Cartridge Solution

If the above options do not solve the instability condition or are unfeasible, what other solutions are available? Emerson has developed a stabilizer cartridge to be installed in the Fisher™ CS800 Series regulator. The stabilizer cartridge is a compact assembly that is installed in the throat of the CS800 Series regulator. It increases system stability with no piping and/or minimal specification changes and can be installed quickly in the existing installation and without using any special tools. Ultimately, it eliminates most instances of regulator noise from system instability and minimizes end user complaints.

A large American utility company was facing system instability issues with their regulator installed near an apartment complex. The residents close to the meter set complained to management about the noise so

frequently that the utility company was considering relocating the entire meter set at a considerable cost. To solve the instability challenges, a Fisher CS800 Series unit with a stabilizer cartridge was installed in the same location. Immediately the noise was eliminated with no other changes to the system or regulator. The regulator was so quiet that the building manager did not even think that gas was flowing through the regulator.

Noise can be an undesirable condition effecting regulators in important commercial and industrial applications, but it doesn't have to be. The Fisher CS800 Series with an installed stabilizer cartridge can correct harmonic instability issues facing large commercial and industrial gas regulators without sacrificing system or regulator performance.

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