REGULATOR TROUBLESHOOTING: A PRACTICAL GUIDE

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This paper is intended to establish some solutions for common field problems associated with gas pressure regulators. It addresses existing field installations as well as the design of new installations. Due to the complex nature of regulator instability, some emphasis is placed in this area; however consideration is given to all problem types. In order to maintain focus on day-to-day regulator problem solving, the theoretic and mathematical constructs associated with pressure regulators are avoided here.

SECTION 1: NOMENCLATURE AND DEFINITIONS

Pressure regulators are feedback control devices that use mechanical components to actuate a valve and manipulate flow to the downstream. Commonly used service regulators are known as Proportional (P) control devices because they have no automatic method for maintaining the output variable (outlet pressure) such as Integral (reset) or Derivative (rate) control once other variables change. As such, pressure regulators are subject to instability given certain conditions.

Pressure regulators are designed to be inherently stable, however, certain field installation conditions may induce instability in the regulator. Over the years many terms have been used to describe the characteristics exhibited by an unstable pressure regulator. **Table 1** lists some of the common terms for regulator instability:

Table 1 – Terms and Definitions

Term	Meaning
Pulsation	A general term referring to a cyclical variation in outlet pressure of the regulator
Hunting	The regulator outlet pressure increases and decreases with no regular frequency
Buzzing, Chattering, Vibrating	A high frequency pulsation of the outlet pressure of the regulator, usually not detectable by a bourdon tube pressure gage or manometer
Pumping, Panting, Chugging, Surging	A low frequency pulsation of the outlet pressure of the regulator that can easily be seen on a bourdon tube pressure gage or manometer

SECTION 2: INSTALLATION VARIABLES AFFECTING REGULATOR SELECTION

It is important to note again that pressure regulators are stable by design. However, in cases where a regulator appears unstable, it is actually the entire ***system*** that is unstable. The ***system*** refers to the entire installation including:

1) upstream and downstream piping and valving
2) upstream or downstream mechanical devices such as meters or compressors
3) the on/off cycle time(s) of downstream gas equipment
4) other pressure regulators affecting the inlet or outlet pressure of the subject pressure regulator
5) size and length of vent piping extending from the regulator vent

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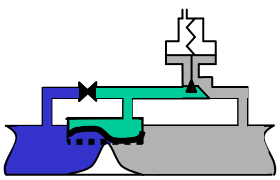
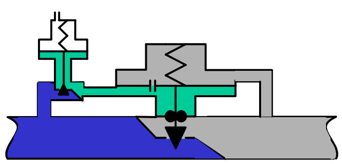
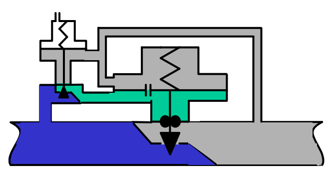
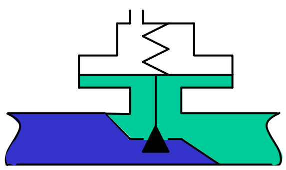
Bear in mind that the regulator, while it appears to be the problem, is merely responding to the ***system*** in which it is installed. Through proper regulator selection and installation design, many instability situations may be avoided.

1. THE RATE OF CHANGE OF THE LOAD

The choice of a regulator is largely dictated by the type of load that it is intended to serve. Specifically, the speed of response of the regulator relative to changing loads is very important and the correct regulator choice may often help to avoid future customer complaints due to equipment pressure problems.

Each regulator type will respond differently to the same change in load. The **Figure 1** depicts various regulator response characteristics:

Figure 1 – Rule of Thumb: Regulator Response Characteristics

Slowest Response			**Fastest Response**
Regulator Type			
Pressure Unloading (flexible element or boot)	Pressure-Loaded	Pilot-Operated (two-path regulator)	Spring-Loaded (self-operated)
			

Spring-Loaded regulators react more quickly than other regulator types because their sensing element (the diaphragm) is directly coupled to the main valve. Unfortunately, over a full range of flow conditions spring-loaded regulators do not maintain a constant outlet pressure as well as the other designs.

Pilot-Operated regulators are somewhat fast-acting regulators since the pilot diaphragm and the main diaphragm (thus the two-path term) are both subject to the downstream pressure. However, there is more mechanical “lag” associated with this design due to the necessary response of the pilot.

Pressure-Loaded regulators are slightly slower in response compared to a Pilot-Operated design. This is due to the fact that while the main diaphragm is sensing the downstream pressure, the pilot is sensing the loading pressure in the upper diaphragm case of the main valve. The result is that the loading pressure must change in order to make the pilot react.

Pressure-Unloading regulators are characteristically slow reacting because they require a series of steps in order to change the position of the main valve. When the load changes, the pilot must react in order to change the loading pressure. The mass of gas in the loading chamber must then change by bleeding out through the pilot or in through the upstream fixed restriction. The relative sizes of the pilot orifice and the fixed restriction will dictate the speed of response of the regulator.

If a regulator is routinely subjected to large sudden load changes, it must be capable of reacting quickly enough to avoid downstream pressure problems. For example, let’s assume that a regulator is to serve a total load of 10,000 scfh. If the load is comprised of five (5) forced-air furnaces (see **Figure 2**), the probability that they will all come “on” or “off” at the exact same time is low. In this case the regulator need not be so fast acting. Conversely, if the load is comprised of a single 10,000 scfh boiler (see **Figure 3**), then the load change will be sudden and the regulator must respond accordingly. If an appropriate regulator is not selected, the result will be a sudden outlet pressure decay when the load comes on, or a sudden outlet pressure rise when the load shuts off.

2. VOLUME BETWEEN THE REGULATOR OUTLET AND THE GAS APPLIANCE

The volume between the regulator and the load acts as a mechanical "capacitor" which stores gas and, therefore, can minimize or maximize the changes in delivery pressure that the gas appliance receives.

Rule of thumb:

- A small volume of pipe between the regulator and the appliance (see **Figure 2**) will dictate a fast acting regulator such as a "spring loaded" regulator
- A large volume of pipe between the regulator and the appliance (see **Figure 3**) will allow the use of a slower acting regulator such as a "Pressure Unloading" regulator

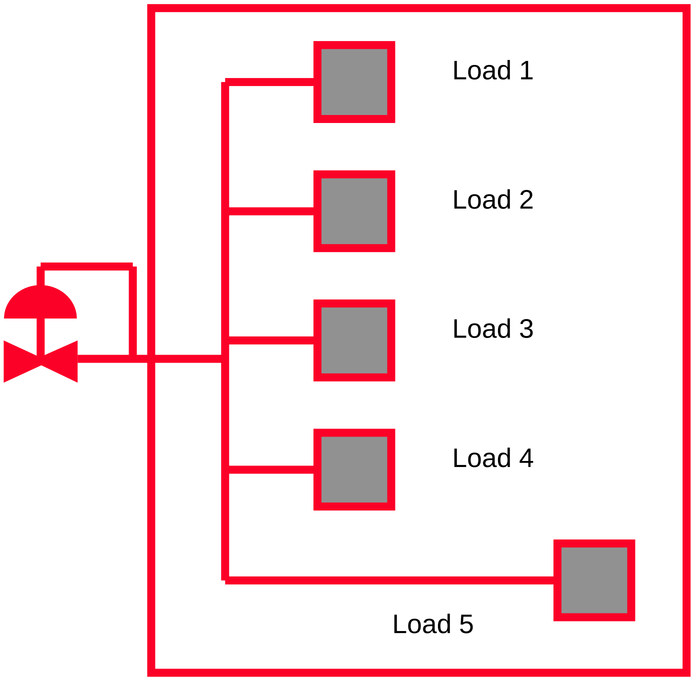


Figure 1 – Diverse Load

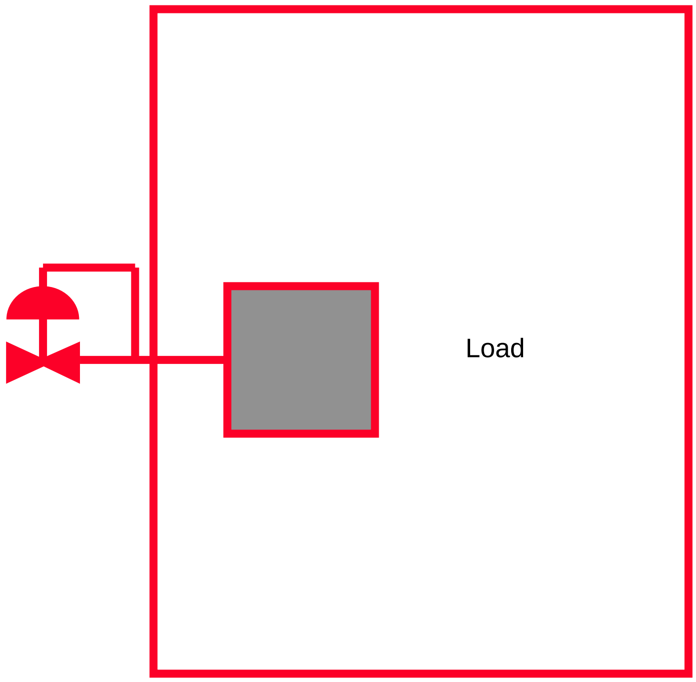


Figure 2 - Non-diverse Load

3. LOAD DIVERSITY AND TURN-DOWN RATIO

Load diversity refers to the probability that all "connected" gas-fired equipment being served by a given regulator will be operating at the same time. If there are a large number of space-heating gas appliances being served by a regulator such as in Figure 1, the probability they will all be operating at the same time is low and the load is said to be diverse. Therefore, a regulator with capacity to meet approximately 80% of the connected load may be chosen. On the other hand, if the load is a single gas appliance as in Figure 2, it is said to be non-diverse and the regulator must be sized to meet 100% of the connected load.

Turn-Down Ratio is defined as:

$$TurnDown = \frac{MaximumLoad}{MinimumLoad}$$

In general, the higher the Turn-Down Ratio, the more likely instability will occur at the minimum load.

Rule of thumb: A regulator should be sized to meet the maximum load requirements with minimal excess capacity.

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SECTION 3: SYMPTOMS AND SOLUTIONS

Symptom	Possible Cause	Possible Solution
Outlet pressure decays when load increases	1) Orifice is undersized 2) Restriction between regulator and load 3) Loading ring is missing or not positioned properly	1) Check maximum and minimum load to insure orifice is sized appropriately. 2) Install gage at downstream of regulator and at gas appliance. If pressure difference is significant at high loads, then a restriction (such as a partially closed valve) exists or piping is too small 3) Remove diaphragm case. Insure that loading ring is installed properly (consult manufacturer's documentation)
Symptom	**Possible Cause**	**Possible Solution**
Outlet Pressure Pulsation	1) Orifice is oversized 2) Control line is too small 3) Vent line pipe may be causing instability 4) Rotary meter up-stream may be causing fluctuation in inlet pressure 5) Spring is too light 6) Control line tap is too close to an upstream flow disturbance (valve, elbow, etc)	1) Check maximum and minimum load to insure orifice is sized appropriately 2) Control line should be no smaller than the connection (boss) size on the regulator 3) Vent line should increase one nominal pipe diameter every ten feet 4) Increase distance or pipe size between rotary meter outlet and regulator inlet 5) Replace adjustment spring with heavier spring that will deliver the same outlet pressure (consult factory) 6) Control line tap should be no less than 7-10 pipe diameters from nearest flow disturbance
Symptom	**Possible Cause**	**Possible Solution**
Regulator won't lock-up	1) Debris between valve seat and orifice 2) Valve seat or orifice are damaged	1) Remove diaphragm case from valve body; inspect valve seat and orifice for debris; remove debris 2) Inspect orifice and valve seat for damage; replace orifice or valve seat as necessary
High lock-up	1) Film such as grease or oil on valve seat	1) Remove diaphragm case from valve body; inspect valve seat and orifice for film; clean valve seat and replace
Regulator is relieving gas out vent	1) Debris between valve seat and orifice	1) Remove diaphragm case from valve body; inspect valve seat

	2) Orifice is not torqued to manufacturer's specification 3) Pipe dope on orifice has dried and is allowing leaks across threads	and orifice for debris or damage; replace orifice or valve seat as necessary 2) Obtain torque specifications from manufacturer's literature and use torque wrench to correct torque 3) Inspect dope on threads; add dope to threads and retest
Symptom	**Possible Cause**	**Possible Solution**
Regulator is relieving gas when load shuts off (if rotary meter is downstream of regulator)	1) Inertia of rotary meter impellers allows gas to continue to flow after the load has shut off (i.e. meter becomes a compressor). Pressure rises to point of relief of regulator.	1) Increase volume (distance) between regulator and meter 2) Use a "static" control line regulator with the control line tapped downstream of the rotary meter

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