Regulator Control Theory

Fundamentals of Gas Pressure Regulators

The primary function of any gas regulator is to match the flow of gas through the regulator to the demand for gas placed upon the system. At the same time, the regulator must maintain the system pressure within certain acceptable limits.

A typical gas pressure system might be similar to that shown in Figure 1, where the regulator is placed upstream of the valve or other device that is varying its demand for gas from the regulator.

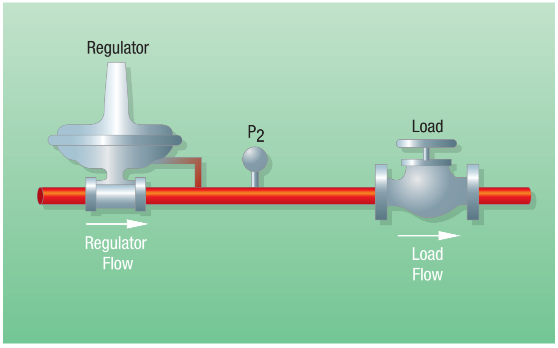

Figure 1

If the load flow decreases, the regulator flow must decrease also. Otherwise, the regulator would put too much gas into the system, and the pressure (P_2) would tend to increase. On the other hand, if the load flow increases, then the regulator flow must increase also in order to keep P_2 from decreasing due to a shortage of gas in the pressure system.

From this simple system it is easy to see that the prime job of the regulator is to put exactly as much gas into the piping system as the load device takes out.

If the regulator were capable of instantaneously matching its flow to the load flow, then we would never have major transient variation in the pressure (P_2) as the load changes rapidly. From practical experience we all know that this is normally not the case, and in most real-life applications, we would expect some fluctuations in P_2 whenever the load changes abruptly.

Because the regulator's job is to modulate the flow of gas into the system, we can see that one of the essential elements of any regulator is a restricting element that will fit into the flow stream and provide a variable restriction that can modulate the flow of gas through the regulator.

Figure 2 shows a schematic of a typical regulator restricting element. This restricting element is usually some type of valve arrangement. It can be a single-port globe valve, a cage style valve, butterfly valve, or any other type of valve that is capable of operating as a variable restriction to the flow.

In order to cause this restricting element to vary, some type of loading force will have to be applied to it. Thus we see that the second essential element of a gas regulator is a Loading Element that can apply the needed force to the restricting element.

The loading element can be one of any number of things such as a weight, a hand jack, a spring, a diaphragm actuator, or a piston actuator, to name a few of the more common ones.

A diaphragm actuator and a spring are frequently combined, as shown in Figure 3, to form the most common type of loading element. A loading pressure is applied to a diaphragm to produce a loading force that will act to close the restricting element. The spring provides a reverse loading force which acts to overcome the weight of the moving parts and to provide a fail-safe operating action that is more positive than a pressure force.

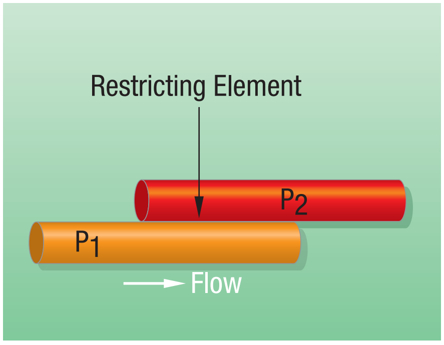

Figure 2

So far, we have a restricting element to modulate the flow through the regulator, and we have a loading element that can apply the necessary force to operate the restricting element. But, how do we know when we are modulating the gas flow correctly? How do we know when we have the regulator flow matched to the load flow? It is rather obvious that we need some type of Measuring Element which will tell us when these two flows have been perfectly matched. If we had some economical method of directly measuring these flows, we could use that approach; however, this is not a very feasible method.

We noted earlier in our discussion of Figure 1 that the system pressure (P_2) was directly related to the matching of the two flows. If the restricting element allows too much gas into the system, P_2 will increase. If the restricting element allows too little gas into the system, P_2 will decrease. We can use this convenient fact to provide a simple means of measuring whether or not the regulator is providing the proper flow.

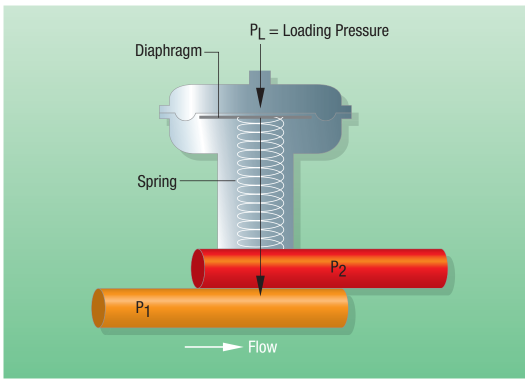

Figure 3

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Manometers, Bourdon tubes, bellows, pressure gauges, and diaphragms are some of the possible measuring elements that we might use. Depending upon what we wish to accomplish, some of these measuring elements would be more advantageous than others. The diaphragm, for instance, will not only act as a measuring element which responds to changes in the measured pressure, but it also acts simultaneously as a loading element. As such, it produces a force to operate the restricting element that varies in response to changes in the measured pressure. If we add this typical measuring element to the loading element and the restricting element that we selected earlier, we will have a complete gas pressure regulator as shown in Figure 4.

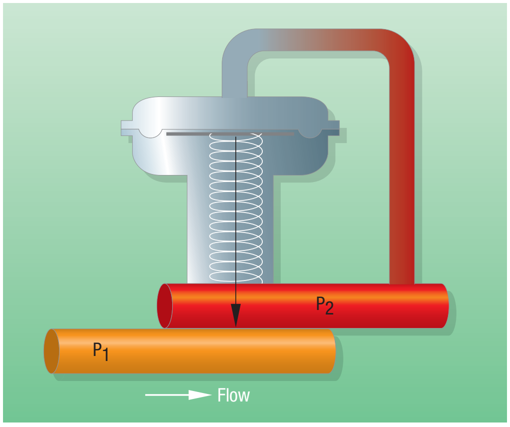

Figure 4

Let's review the action of this regulator. If the restricting element tries to put too much gas into the system, the pressure (P_2) will increase. The diaphragm, as a measuring element, responds to this increase in pressure and, as a loading element, produces a force which compresses the spring and thereby restricts the amount of gas going into the system. On the other hand, if the regulator doesn't put enough gas into the system, the pressure (P_2) falls and the diaphragm responds by producing less force. The spring will then overcome the reduced diaphragm force and open the valve to allow more gas into the system. This type of self-correcting action is known as negative feedback. This example illustrates that there are three essential elements needed to make any operating gas pressure regulator. They are a restricting element, a loading element, and a measuring element. Regardless of how sophisticated the system may become, it still must contain these three essential elements.

Pilot-Operated Regulators

So far we have only discussed direct-operated regulators. This is the name given to that class of regulators where the measured pressure is applied directly to the loading element with no intermediate hardware. There are really only two basic configurations of direct-operated regulators that are practical. These two basic types are illustrated in Figures 4 and 5.

If the proportional band of a given direct-operated regulator is too great for a particular application, there are a number of things we can do. From our previous examples we recall that spring rate, valve travel, and effective diaphragm area were the three parameters that affect the proportional band. In the last section we pointed out the way to change these parameters in order to improve the proportional band. If these changes are either inadequate or impractical, the next logical step is to install a pressure amplifier in the measuring or sensing line. This pressure amplifier is frequently referred to as a pilot.

Conclusion

It should be obvious at this point that there are fundamentals to understand in order to properly select and apply a gas regulator to do a specific job. Although these fundamentals are profuse in number and have a sound theoretical base, they are relatively straightforward and easy to understand.

As you are probably aware by now, we made a number of simplifying assumptions as we progressed. This was done in the interest of gaining a clearer understanding of these fundamentals without getting bogged down in special details and exceptions. By no means has the complete story of gas pressure regulation been told. The subject of gas pressure regulation is much broader in scope than can be presented in a single document such as this, but it is sincerely hoped that this application guide will help to gain a working knowledge of some fundamentals that will enable one to do a better job of designing, selecting, applying, evaluating, or troubleshooting any gas pressure regulation equipment.

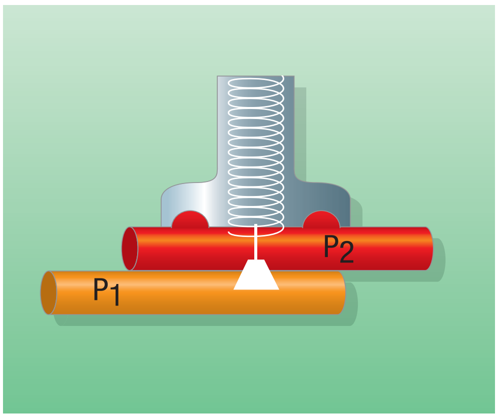

Figure 5