FUNDAMENTALS OF PRESSURE REGULATION

John M. Kruse
Invensys Metering Systems
P.O. Box 528, DuBois, PA 15801

INTRODUCTION

A gas pressure regulator is an automatic device which controls the media flow and maintains a desired media pressure while reducing the media supply pressure.

The basic regulator could be an operator at a control valve watching a pressure gauge. The valve is manually opened to allow the line pressure to achieve the desired gauge setting. The operator then visually monitors the gauge and either opens the valve or closes it to maintain the desired pressure. The problem with this system is it would require full time operators for daily operation and continuous monitoring of the gauge. The regulator products on the market do not monitor the gauge. However, via monitoring the outlet pressure, they do automatically open and/or close the valve to control the outlet pressure at an established value.

The manually operated regulator is still employed by gas companies to provide uninterrupted service during repairs or replacement of a regulator on a single feed system.

SPRING REGULATOR

The spring type regulator is by far the most widely used regulator. The design is simple, but effective. The spring style regulator employs a restrictive element, a responsive element, and a standard. The restrictive element can be a single valve, double valve, sleeve multivane, or a balanced valve design. The responsive element can be a diaphragm or piston. The standard can be a spring, weight, or pressure. We shall discuss the spring style self-operated regulators.

The service style regulators employ a lever ratio to control an unbalanced single valve. The lever is operated by a diaphragm, and the standard is a spring. The spring load is adjustable and can be increased or decreased to satisfy the load requirements. Once the pressure requirements have been established, the service regulator will automatically respond to load changes and control the pressure. If the load increases, the outlet pressure will begin to drop which reduces the pressure under the diaphragm. The loss of pressure allows the spring to move the diaphragm and in turn, through the lever ratio, moves the restrictive element to a greater opening. The opening of the orifice then feeds more media flow into the downstream. The regulator will automatically effect a balance position and satisfy the gas requirement. Should the demand decrease, the opposite effect occurs and the regulator will again automatically adjust the valve position until the new load requirement is satisfied. If the demand reduces to zero, the outlet pressure will increase until the valve seals off the orifice opening.

INLET EFFECT

A change in inlet pressure will reposition the valve. If the inlet begins to drop, the flow begins to decrease, pressure under the diaphragm begins to decrease, and the valve begins to open. Keep in mind that the demand is not changing. Only the inlet pressure is changing and it is dropping. A drop in inlet means a decrease in flow, and the valve action works to maintain the constant flow. Thus, when the inlet pressure settles out at a lower value, equilibrium is restored at a new valve position. The opposite occurs for an increased inlet pressure, therefore, the loss of inlet pressure will decrease the outlet pressure and a gain will increase the outlet pressure. This is a phenomena commonly referred to as inlet effect.

DROOP

Spring regulators have a characteristic called “DROOP,” “DEVIATION,” or “OFFSET.” It is a change that occurs in outlet pressure as flow increases. At minimum flow, outlet pressure is at a maximum. At maximum flow, outlet pressure is at a minimum. The pressure change difference between the two is the droop value. Droop will vary dependent upon the spring, regulator, and product design. Droop results from the spring expanding as it increases in length during the valve opening process. As the spring expands, its compression decreases. For equilibrium between opening and closing forces, the closing force from the diaphragm must decrease at the same rate. This decrease is produced by a drop in the outlet pressure. The reverse occurs as the valve closes, and thus pressure varies between low and high limits as the regulator strokes between fully open and closed.

The characteristic of the spring is called “SPRING EFFECT” and the resulting droop is compounded by what is called the “DIAPHRAGM EFFECT.” It is a characteristic that causes the diaphragm’s effective area to increase while the spring compression is decreasing, and vice versa. This creates more droop . . . a further change in outlet pressure.

“ROLL-OUT” DIAPHRAGM

The “ROLL-OUT” diaphragm was developed to eliminate the diaphragm effect by forcing the diaphragm area to decrease as the regulator valves were opening. By causing the diaphragm area to decrease instead of increase, the diaphragm effect was not only eliminated, but some of the spring effect was also eliminated. While perfect coordination between the two effects is impractical, it is sufficiently close so that the excess droop is eliminated. This change allowed usage of the diaphragm operated regulators to higher outlet pressures were heretofore excessive levels of the droop usually made performance unacceptable.

BOOST

Boost is another method of counteracting droop. Some products are designed with respect to flow pattern and outlet pressure sensing that causes the outlet pressure to elevate above its actual setting by creating a false pressure under the diaphragm. The service regulator employs valve design, boost tubes, body rings, venturi tubes, etc. to create the boosting characteristic. The design must prevent excessive boosting which could result in loss of regulator control.

TEMPERATURE

Pressure differential results in a refrigeration effect of approximately 7 degrees Fahrenheit temperature loss per 100 psig pressure differential. Therefore, at elevated pressure differential media conditioning or injection of an anti-freezing agent may be required to prevent problems.

SELF-OPERATED REGULATORS

The basic regulator for pressure control is a self-operated regulator. Self-operated regulators are the simplest units. The typical regulator consists of valves attached to a diaphragm which is spring loaded. The outlet pressure acts on the diaphragm opposite the spring. The diaphragm must withstand the full outlet pressure as one side is exposed to the atmosphere. The diaphragm size is varied to provide a range of desired delivery pressures. The smaller the diaphragm, the higher the outlet pressure range given the same weight or spring force. The self-operated regulator is commonly referred to as fail open. This is true if the diaphragm should fail. However, no regulator can be classified as fail open or closed. If the right conditions exist, a regulator can fail in any mode.

The spring loaded regulator has actually emerged as the acceptable self-operated unit. Spring loaded regulators are similar to the older weight loaded in ease of adjustment and simplicity. The big advantage is that the spring loaded unit can be easily sealed against tampering. In addition, when properly vented, the spring loaded unit can be used where flooding conditions may occur.

The “roll-out” diaphragm greatly improved the performance of the spring operated regulator. The unit displays very little outlet pressure loss throughout its capacity range, and closely approaches the performance displayed by pressure loaded units. The drawback to the diaphragm type self-operated regulator is the pressure limitations due to diaphragm strengths and the spring size required for high outlet pressures. Various valve sizes can be employed in a spring operated unit; however, the small diaphragms for high pressure cannot generate sufficient power to control very large valves.

PROTECTION

Protection is a subject that has not been given sufficient concern in past years by the gas industry or the manufacturers. However, there is a growing awareness across the country for the need for overpressure protection.

The problems faced by the gas industry is “how safe is safe enough.” And the answer is an unknown factor. The problem then faced by the manufacturer is supplying the needs of the gas industry which is dealing in a confusing array of solutions to overpressure protection.

We will attempt to note some of the various methods of overpressure protection including internal relief valves, back pressure regulators, monitoring, and relief valves.

INTERNAL RELIEF VALVES

The Internal Relief Valve (IRV) is a relief valve designed into a regulator product. It does not operate until the outlet pressure exceeds the delivery pressure by a certain amount. The buildup in outlet pressure is dependent upon a number of factors including inlet pressure, type of blockage or leakage, IRV spring and normally the rate of the main spring. There have been other designs in the past. However, the basic design employed on service style regulators is the IRV which must overcome the main spring’s force to open. The outlet pressure spring effects relief buildup, and therefore the actual relief buildup curve is dependent upon the outlet pressure spring and failure simulated. The higher outlet pressures require larger spring forces and higher spring rates and results in a greater outlet pressure buildup.

The IRV, when opened, will discharge gas to atmosphere through the vent and/or vent line. We do not recommend combining regulator vent lines into a common discharge header. Those regulators not relieving will become pressure loaded units when common vent lines are employed.

BACK PRESSURE REGULATORS

The regulator products provide a method of controlling flow rate and pressure reduction. However, a number of regulator products can be assembled and employed as a back pressure regulator or relief valve. The back pressure regulator is designed with the main valves in a normally closed position and the low pressure chamber is piped to the inlet side of the regulator. On remote control regulators and on internal control regulators, the normal outlet chamber is piped to receive the inlet pressure. The manufacturer may remove the normal flow arrow from the body and add a new flow arrow in the opposite direction, unless the body has bi-directional capability.

MONITORING

The practice of monitoring has been employed for quite some time. A monitoring system has two regulators. One regulator is the operator or the unit that is controlling the media flow into the downstream system. The second regulator is the monitor or standby regulator which will not come into operation until an overpressure condition is experienced. The monitor regulator is set at a slightly higher pressure than the operator so that it is wide open. Some utilities prefer to employ a working monitor which means that the two regulators are set closer together to ensure movement of the standby regulator so that it will function when called upon. The monitor regulator can be either upstream or downstream of the operator. There are advantages and disadvantages to both configurations, so it is company preference and experience which governs the location. Monitoring, when employed using pilot operated regulators, normally requires load limiting regulators between the inlet pressure and the pilot inlet to minimize the inlet pressure to the pilot when it is trying to operate in a wide open condition. When sizing monitor systems, the capacity of the system will be equal to the capacity of the smaller regulator in the system times 70%. The reduction of 30% is due to the pressure conditions created at higher flow rates and the intermediate pressure between the two regulators.

The monitor or standby regulator will prevent over-pressurization of the downstream piping system by automatically coming into service and controlling the media flow into the downstream at a slightly higher pressure, and, if the cause of the overpressure corrects itself, the system will return to normal operation automatically.

RELIEF VALVES

One of the oldest forms of protection is by using relief valves. There have been many styles of relief valves over the years. However, they all open at a preset relief point and discharge the media to atmosphere. The relief valve will only open far enough to balance off the excess flow into the downstream system. If the overpressure cause is corrected or self-corrects, the relief valve will blow down and reseal. The relief valve can be a pop type relief valve typical of a cork in a bottle, a pop type with an assisting diaphragm typical of the Rockwell 250 Style Relief Valve, a diaphragm activated typical of the 257S Relief Valve, and/or Pilot operated units.

SAFETY

The discharge of natural gas to atmosphere can cause a safety problem. Therefore, care should be exercised in placing the Relief Valve discharge in a safe location. The discharge should be in a remote area away from buildings, people, and open flames.

The safety of the products in the piping system dictates the need for safety devices to prevent overpressurization. Preventing overpressurization of the pressure system can be accomplished by many means as noted above and/or a combination of the noted practices.

There is not a recommended procedure or standard practice for prevention of outlet pressure buildup. However, the allowable overpressure on our regulator products was defined and the values generated in the mid 1970's as noted and documented by Bulletin RDS-1498.

The standard practice is to design products to withstand a pressure of 5 to 6.67 times the product's maximum working pressure prior to bursting. The pressure containing components, prior to shipment to a customer, are tested to a pressure of 1.5 or 2 times the component's maximum working pressure. The variation is based on material and/or processes employed to obtain parts. Care should be exercised in the determination of maximum working pressures on the product. In addition, prior to installation of a product, the manufacturer's bulletin should be carefully reviewed to determine the maximum applicable pressure. Maximum pressures can be inlet loading, outlet relief, etc. and they can vary with body material orifice size, case size, case material, etc.

The protection of the public is very important and every effort should be made to properly install the product to prevent a hazard due to improper installation, application, and usage. The discharge of natural gas to atmosphere can create a potential hazard if not properly discharged into a safe area to prevent ignition.

Regulator products are mechanical devices which can fail. Therefore, every effort should be made to ensure that the product is working properly through a preventative maintenance, testing and inspection program. The functionality of overpressure protection equipment should be tested on a periodic basis to ensure that the product functions properly or will function when necessary. The frequency of testing and inspection would depend upon a number of factors including federal codes, state codes, company standards, etc. However, if no codes or standards presently exist, Equimeter feels one should be established by the gas company.

SIZING AND SELECTION

The sizing and selection of regulators can be accomplished by various methods. However, the factors involved are the same regardless of the methods used.

The rules for regulator sizing apply equally whether large capacity or small capacity.

The only difference is in the fact that the large capacity regulator is sized for a specific installation whereas the small regulator is sized covering a group or category of similar installations. The gas pressure regulators are extremely versatile and often handle conditions far beyond the normal sized for so that mistakes rarely show.

Sizing is not an art. However, obtaining and determining the required capacity and conditions can be considered an art. Sizing is the determination of the proper valve size to obtain the desired capacity at the inlet and outlet pressures of the installation. To determine the proper valve size, it is necessary that the maximum required flow be known, the inlet pressure range be established, and the required delivery pressure is known. Getting this information is far harder than using it to size the regulator. Each manufacturer provides “valve coefficients” or capacity tables so that by proper use of these tables and coefficients, the flow for a given valve size can be determined. The required maximum capacity of any given regulator must be used with the minimum inlet pressure conditions to properly size the port openings.

If the conditions at the installation are known, the foregoing is normally very easy. The capacity required at an installation will usually cause problems due to the way it is determined, unless it is an existing location and all conditions are known from past operating records. New station requirements are based on a load survey of the service area or the estimated requirements of the equipment installed in a large industrial plant. At this point, we are faced with estimating present load requirements and also estimating future load requirements for the plant or area. The normal reflex is to add excess capacity to be sure the installation will have sufficient capacity. The results are normally a regulator sized far too big and one that will cause trouble in maintaining control. Fortunately, there are ways of handling the uncertainty of future demands. The best method is a parallel run where one unit is installed with reduced valves. Sizing a regulator with reduced valves should be considered a two-step effort. The first step would be to consider the future and install sufficient body size of these requirements. The second step is to consider the immediate demands and install the valve size accordingly.

The second problem in sizing, after determination of the installation capacity, is determining the inlet pressure range. The gas industry faces the problem of having greatest flow when the least pressure is available. The minimum inlet pressure can be determined by line loss calculations and the conditions at the source. It is possible to arrive at a very accurate estimate of the inlet pressure conditions. The maximum inlet pressure must be known to properly determine the required body strength and the amount of turndown that will be handled. The maximum capacity coupled with the maximum inlet pressure can indicate the possibility of stability problems. Normally a regulator will handle turndown ratios of 10:1 without problems and 20:1 are common; however, very high ratios will indicate potential stability problems and should be avoided by parallel runs or installation of “V” port wings if available to improve turndown ratio of approximately 40:1.

The type of control must be considered for the accuracy and stability. The control must be capable of providing the outlet pressure required. The type and condition of the gas must be considered to properly select valve materials and if necessary, provide auxiliary equipment to protect against hydrates. Noise pollution is becoming more and more important and must be given consideration. Flooding, corrosive gases, and various codes must also be considered as they apply to a given installation.