

Principles of Series Regulation and Monitor Regulators

Series Regulation

Series regulation is one of the simplest systems used to provide overpressure protection by containment. In the example shown in Figure 1, the inlet pressure is 100 psig, the desired downstream pressure is 10 psig, and the maximum allowable operating pressure (MAOP) is 40 psig. The setpoint of the downstream regulator is 10 psig, and the setpoint of the upstream regulator is 30 psig.

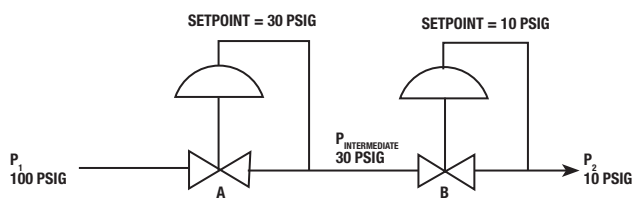


Figure 1. Series Regulation

Failed System Response

If regulator B fails, downstream pressure (P_2) is maintained at the setpoint of regulator A less whatever drop is required to pass the required flow through the failed regulator B. If regulator A fails, the intermediate pressure will be 100 psig. Regulator B must be able to withstand 100 psig inlet pressure.

Regulator Considerations

Either direct-operated or pilot-operated regulators may be used in this system. Should regulator A fail, $P_{\text{Intermediate}}$ will approach P_1 so the outlet rating and spring casing rating of regulator A must be high enough to withstand full P_1 . This situation may suggest the use of a relief valve between the two regulators to limit the maximum value of $P_{\text{Intermediate}}$.

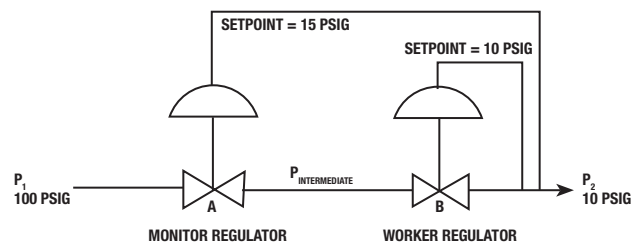
Applications and Limitations

A problem with series regulation is maintaining tight control of P_2 if the downstream regulator fails. In this arrangement, it is often impractical to have the setpoints very close together. If they are, the pressure drop across regulator B will be quite small. With a small pressure drop, a very large regulator may be required to pass the desired flow.

Because of the problem in maintaining close control of P_2 , series regulation is best suited to applications where the regulator station is reducing pressure to a value substantially below the maximum allowable operating pressure of the downstream system. Farm taps are a good example. The problem of low-pressure drop across the second regulator is less pronounced in low flow systems.

Upstream Wide-Open Monitors

The only difference in configuration between series regulation and monitors is that in monitor installations, both regulators sense downstream pressure, P_2 . Thus, the upstream regulator must have a control line.



IN WIDE-OPEN MONITOR SYSTEMS, BOTH REGULATORS SENSE DOWNSTREAM PRESSURE. SETPOINTS MAY BE VERY CLOSE TO EACH OTHER. IF THE WORKER REGULATOR FAILS, THE MONITOR ASSUMES CONTROL AT A SLIGHTLY HIGHER SETPOINT. IF THE MONITOR REGULATOR FAILS, THE WORKER CONTINUES TO PROVIDE CONTROL.

Figure 2. Wide-Open Upstream Monitor

System Values

In the example shown in Figure 2, assume that P_1 is 100 psig, and the desired downstream pressure, P_2 , is 10 psig. Also assume that the maximum allowable operating pressure of the downstream system is 20 psig; this is the limit we cannot exceed. The setpoint of the downstream regulator is set at 10 psig to maintain the desired P_2 and the setpoint of the upstream regulator is set at 15 psig to maintain P_2 below the maximum allowable operating pressure.

Normal Operation

When both regulators are functioning properly, regulator B holds P_2 at its setpoint of 10 psig. Regulator A, sensing a pressure lower than its setpoint of 15 psig tries to increase P_2 by going wide-open. This configuration is known as an upstream wide-open monitor where upstream regulator A monitors the pressure established by regulator B. Regulator A is referred to as the monitor or standby regulator while regulator B is called the worker or the operator.

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Worker Regulator B Fails

If regulator B fails open, regulator A, the monitor, assumes control and holds P_2 at 15 psig. Note that pressure $P_{\text{Intermediate}}$ is now P_2 plus whatever drop is necessary to pass the required flow through the failed regulator B.

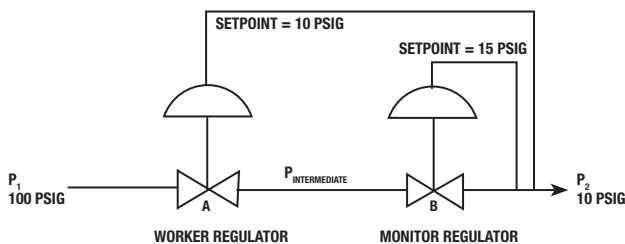
Equipment Considerations

Wide-open monitoring systems may use either direct- or pilot-operated regulators, the choice of which is dependent on other system requirements. Obviously, the upstream regulator must have external registration capability in order to sense downstream pressure, P_2 .

In terms of ratings, $P_{\text{Intermediate}}$ will rise to full P_1 when regulator A fails, so the body outlet of regulator A and the inlet of regulator B must be rated for full P_1 .

Downstream Wide-Open Monitors

The difference between upstream and downstream monitor systems (Figure 3) is that the functions of the two regulators are reversed. In other words, the monitor, or standby regulator, is downstream of the worker, or operator. Systems can be changed from upstream to downstream monitors, and vice-versa, by simply reversing the setpoints of the two regulators.



THE ONLY DIFFERENCE BETWEEN UPSTREAM WIDE-OPEN MONITOR SYSTEMS AND DOWNSTREAM WIDE-OPEN MONITOR SYSTEMS IS THE ROLE EACH REGULATOR PLAYS. WORKERS AND MONITORS MAY BE SWITCHED BY SIMPLY REVERSING THE SETPOINTS.

Figure 3. Wide-Open Downstream Monitor

Normal Operation

Again, assume an inlet pressure of 100 psig and a controlled pressure (P_2) of 10 psig. Regulator A is now the worker so it maintains P_2 at its setpoint of 10 psig. Regulator B, the monitor, is set at 15 psig and so remains open.

Worker Regulator A Fails

If the worker, regulator A, fails in an open position, the monitor, regulator B, senses the increase in P_2 and holds P_2 at its setpoint of 15 psig. Note that $P_{\text{Intermediate}}$ is now P_1 minus whatever drop is taken across the failed regulator A.

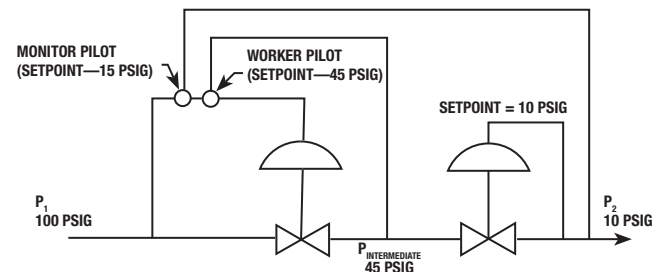
Upstream Versus Downstream Monitors

The decision to use either an upstream or downstream monitor system is largely a matter of personal preference or company policy.

In normal operation, the monitor remains open while the worker is frequently exercised. Many users see value in changing the system from an upstream to a downstream monitor at regular intervals, much like rotating the tires on an automobile. Most fluids have some impurities such as moisture, rust, or other debris, which may deposit on regulator components, such as stems, and cause them to become sticky or bind. Therefore, occasionally reversing the roles of the regulators so that both are exercised is sometimes seen as a means of ensuring that protection is available when needed. The job of switching is relatively simple as only the setpoints of the two regulators are changed. In addition, the act of changing from an upstream to a downstream monitor requires that someone visit the site so there is an opportunity for routine inspection.

Working Monitors

Working monitors (Figure 4) use design elements from both series regulation and wide-open monitors. In a working monitor installation, the two regulators are continuously working as series regulators to take two pressure cuts.



WORKING MONITOR SYSTEMS MUST USE A PILOT-OPERATED REGULATOR AS THE MONITOR, WHICH IS ALWAYS IN THE UPSTREAM POSITION. TWO PILOTS ARE USED ON THE MONITOR REGULATOR; ONE TO CONTROL THE INTERMEDIATE PRESSURE AND ONE TO MONITOR THE DOWNSTREAM PRESSURE. BY TAKING TWO PRESSURE DROPS, BOTH REGULATORS ARE ALLOWED TO EXERCISE.

Figure 4. Working Monitor

Principles of Series Regulation and Monitor Regulators

Downstream Regulator

The downstream regulator may be either direct or pilot-operated. It is installed just as in a series or wide-open monitor system. Its setpoint controls downstream pressure, P_2 .

Upstream Regulator

The upstream regulator must be a pilot-operated type because it uses two pilots; a monitor pilot and a worker pilot. The worker pilot is connected just as in series regulation and controls the intermediate pressure $P_{\text{Intermediate}}$. Its setpoint (45 psig) is at some intermediate value that allows the system to take two pressure drops. The monitor pilot is in series ahead of the worker pilot and is connected so that it senses downstream pressure, P_2 . The monitor pilot setpoint (15 psig) is set slightly higher than the normal P_2 (10 psig).

Normal Operation

When both regulators are performing properly, downstream pressure is below the setting of the monitor pilot, so it is fully open trying to raise system pressure. Standing wide-open, the monitor pilot allows the worker pilot to control the intermediate pressure, $P_{\text{Intermediate}}$ at 45 psig. The downstream regulator is controlling P_2 at 10 psig.

Downstream Regulator Fails

If the downstream regulator fails, the monitor pilot will sense the increase in pressure and take control at 15 psig.

Upstream Regulator Fails

If the upstream regulator fails, the downstream regulator will remain in control at 10 psig. Note that the downstream regulator must be rated for the full system inlet pressure P_1 of 100 psig because this will be its inlet pressure if the upstream regulator fails. Also note that the outlet rating of the upstream regulator, and any other components that are exposed to $P_{\text{Intermediate}}$, must be rated for full P_1 .

Sizing Monitor Regulators

The difficult part of sizing monitor regulators is that $P_{\text{Intermediate}}$ is needed to determine the flow capacity for both regulators. Because $P_{\text{Intermediate}}$ is not available, other sizing methods are used to determine the capacity. There are three methods for sizing monitor regulators: estimating flow when pressure drop is critical, assuming $P_{\text{Intermediate}}$ to calculate flow, and the Fisher® Monitor Sizing Program.

Estimating Flow when Pressure Drop is Critical

If the pressure drop across both regulators from P_1 to P_2 is critical (assume $P_{\text{Intermediate}} = P_1 - P_2/2 + P_2$, $P_1 - P_{\text{Intermediate}} \geq P_1$, and $P_{\text{Intermediate}} - P_2 \geq 1/2 P_{\text{Intermediate}}$), and both regulators are the same type, the capacity of the two regulators together is 70 to 73% of a single regulator reducing the pressure from P_1 to P_2 .

Assuming $P_{\text{Intermediate}}$ to Determine Flow

Assume $P_{\text{Intermediate}}$ is halfway between P_1 and P_2 . Guess a regulator size. Use the assumed $P_{\text{Intermediate}}$ and the C_g for each regulator to calculate the available flow rate for each regulator. If $P_{\text{Intermediate}}$ was correct, the calculated flow through each regulator will be the same. If the flows are not the same, change $P_{\text{Intermediate}}$ and repeat the calculations. ($P_{\text{Intermediate}}$ will go to the correct assumed pressure whenever the flow demand reaches maximum capacity.)

Fisher® Monitor Sizing Program

Emerson Process Management - Regulator Technologies offers a Monitor Sizing Program on the Regulator Technologies Literature CD. Call your local Sales Office to request a copy of the CD. To locate your local Sales Office, log on to: www.emersonprocess.com/regulators.