HOW TO USE A REGULATOR TO REDUCE TIME DELAY IN AN ANALYTICAL SYSTEM

By Doug Nordstrom and Dean Slejko

Process measurements are instantaneous but analyzer responses never are. From the tap to the analyzer, there is always a time delay. Unfortunately, this delay is often underestimated or misunderstood.

Time delay is defined as the amount of time it takes for a new sample to reach the analyzer. One way to control time delay is with a regulator. Regulators control pressure, and pressure in an analytical system is closely related to time. In the case of gas systems with a controlled flow rate, the lower the pressure, the shorter the time delay.

Delay may occur in any of the major parts of an analytical instrumentation (AI) system (Figure 1), including the process line, tap and probe, field station, transport line, sample conditioning system, stream switching system, and analyzer.

Time delay is cumulative. It consists of the *total amount of time* it takes for fluid to travel from the process being monitored to the analyzer, including time required for analysis in the analyzer.

For now, we will focus on the field station and the important role of a regulator in reducing time delay there.
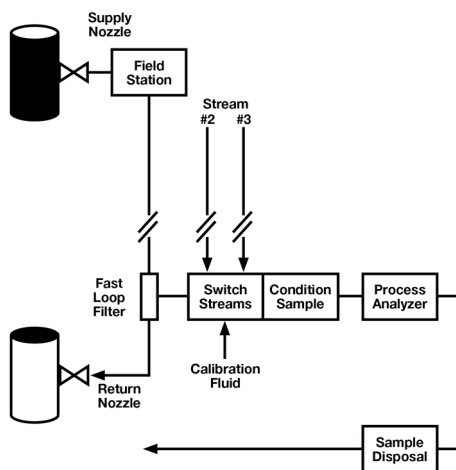

Figure 1. Basic sections of a process analyzer sampling system.

Before the Field Station

Minimizing time delay begins with the location of the tap. It is best to locate the tap as close to the analyzer as possible, but it should be upstream of sources of delay, such as drums, tanks, dead legs, stagnant lines, or redundant or obsolete equipment.

When sampling a liquid, pressure at the tap should be sufficient to deliver the sample through the transport lines or fast loop without a pump, an expensive component that introduces performance variables.

In many cases, you may not be able to dictate the location of the tap. You may have to make do with an existing tap location,

and often, an existing analyzer shed location as well.

If the tap is a long distance from the analyzer, a fast loop is recommended as a means of quickly delivering fluid to the analyzer and returning the unused portion to the process.

In most analytical instrumentation systems, another source of time delay is the probe. The larger the probe's volume, the greater the delay. Volume will be affected both by the length and width of the probe. Therefore, when attempting to minimize time delay, choose a low-volume probe

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At the Field Station

In cases where the analyzer requires a liquid sample, a regulator in the field station is not employed. It is better to keep liquids at high pressure to avoid the formation of bubbles.

In the case of a gas sample, a field station is used as a means of reducing pressure in the transport lines. Time delay decreases in direct proportion to absolute pressure. At half the pressure, you will get half the time delay.

The field station is located as close to the tap as possible. The sooner the pressure is dropped, the better.

Let's look at three possible applications for a regulator. With each, the regulator is configured somewhat differently.

In the first application, the objective is to reduce gas pressure. The pressure drop is not expected to produce condensation. Therefore, a simple pressure-reducing regulator may be used.

A pressure-reducing regulator maintains constant pressure at the outlet. A thin metal diaphragm within the regulator flexes in response to downstream pressure, allowing a cone-shaped poppet to regulate the size of the orifice through which the gas passes. As the diaphragm flexes up in response to higher pressure, the opening is smaller. As the diaphragm relaxes with lower pressure, the opening is larger. A handle on the regulator allows the operator to set the outlet pressure.

A metal diaphragm is ideal in applications where the inlet pressure does not vary sharply. However, in applications where the pressure may be inconsistent or spike, a piston-style regulator may be more appropriate.

In our second regulator application, the pressure drop is expected to cause condensation. With a drop in pressure, almost all gases lose heat, which is known as the Joule-Thomson effect. If the gas is close to its dew point, the result from this cooling is condensation. In some cases, the loss of heat may be great enough to cause the regulator to freeze up.

Because of the Joule-Thomson effect, a heated regulator may be required to keep the temperature of the gas above the dew point. A heated regulator is a pressure-reducing regulator in which the system fluid flows over a heated element. A heater cartridge is required.

You can calculate the number of watts required of the heater cartridge so you buy one in the right power range. Every gas has a Joule-Thomson coefficient, which is plugged into a formula along with the pressure drop and flow rate to produce the number of watts required. [1]

In our third regulator application, a liquid must become a gas before it can be analyzed by a gas chromatograph or other analyzer. In this case, a vaporizing regulator is used.

Vaporizing regulators are tricky but if properly sized and installed, they can be a reliable means of preparing a liquid sample for analysis in a gas analyzer.

The objective of a vaporizing regulator is to instantly flash the entire sample into a gas, which requires a lot of heat in just the right location. The heat must be applied at the precise location of the pressure drop.

With vaporizing regulators, one must pay close attention to temperature and vapor flow rate. If the flow is too great, the sample will be only partially vaporized and liquids will flow through the regulator and toward the analyzer. If the vaporizer temperature is too high, the liquid sample upstream will be vaporized.

Finally, be sure to set up your vaporizing regulator correctly or you will create considerable time delay. As the fluid changes from liquid to gas, volume will increase dramatically. The rate of increase will depend on the liquid's molecular weight.

Typically, the measured vapor flow after the regulator will be > 300 times the liquid flow before the vaporizing regulator. For example, with a vapor flow of 600 cm^3/min., liquid flow may be less than 2 cm^3/min. Therefore, the liquid will take 25 minutes to travel through 3 meters (approximately 10 feet) of 6 mm (1/4 in.) tubing. To reduce this time, we must reduce the volume of the tubing preceding the regulator. For example, with only one foot of one-eighth inch tubing, it would take only 30 seconds for the liquid to reach the regulator. To this time, however, we must add time delay in the probe. The narrower the probe, the faster the response.

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Another means of attaining a faster response is to move the vaporizer closer to the analyzer with the aid of a liquid fast loop. In Figure 2, the regulator is located after the fast loop filter with a second liquid slow loop ensuring that good liquid flow continues right up to the vaporizing regulator. The objective is to minimize slow-moving liquid volume going to a vaporizing regulator.
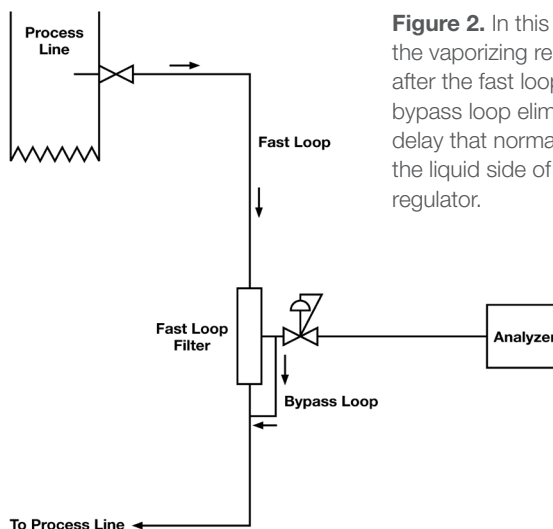
Figure 2. In this configuration, the vaporizing regulator is located after the fast loop filter. A second bypass loop eliminates the long delay that normally occurs on the liquid side of the vaporizing regulator.

Conclusion

A regulator is a critical tool in addressing time delay in an analytical system. The lower the pressure in a gas system, the faster the response time. In general, the sooner the pressure can be dropped in a system, the better.

In cases where a liquid is being vaporized, consider a liquid fast loop followed by a slow loop. The objective is to keep the liquid moving right up to the vaporizing regulator.

The field station is one place in a complex analytical system where time delay can be significantly reduced, but the approach to time delay must always be comprehensive. To reduce time delay, all potential causes of delay in the system must be scrutinized.

Endnotes

[1] The formula for calculating required wattage is $Pw = Qn\ Cp\ \Delta T$, where the wattage (Pw) is proportional to molar flow (Qn), heat capacity (Cp), and the amount of cooling from the Joule-Thomson effect (ΔT). Additional heat may be required to keep the vaporizer above ambient temperature.

Resource
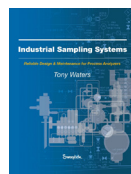
For more information, see the Swagelok book *Industrial Sampling Systems* (2013), the definitive sampling systems reference guide by expert Tony Waters.

Author Biographies

Doug Nordstrom is product manager for general industrial valves for Swagelok Company, focusing on advancing the company's involvement and success with valves sold into the oil and gas, chemical, refining, power, and general industry market segments. He previously worked as the pressure regulator product manager, chemical market manager, and in new product development for Swagelok and earned a number of Swagelok patents in products, including the Swagelok® stream selector valve (SSV) and modular platform components (MPC). Nordstrom graduated with a bachelor's degree in mechanical engineering from Case Western Reserve University and earned a master's degree in business administration from Kent State University.

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