Hydraulics & Pneumatics

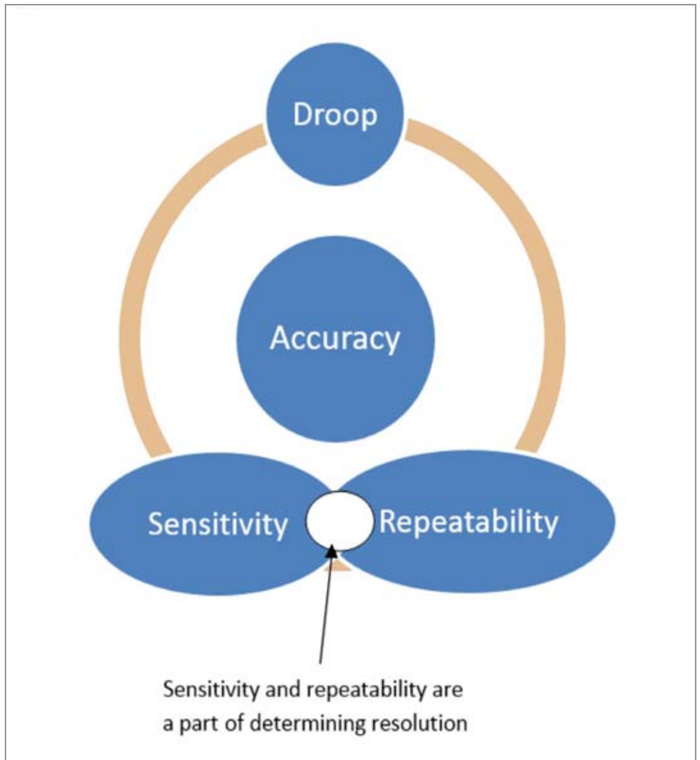
Basics of Design

RECOGNIZING WHEN YOU NEED A PRECISION REGULATOR AND WHAT TO DO ABOUT IT

A discussion about “accuracy” and how it relates to regulator operation and performance.

Pressure regulators offer many, many choices when it comes to selection. Most applications are well-served by general-purpose regulators. These come in many different types, port sizes, pressure ranges, and pressure and flow capacities. Adding different material types and accessories makes the decision even more complex.

But even with all these choices, sometimes you may need a regulator that undergoes less fluctuation than the general-purpose variety can provide. Any of several clues can indicate when you should consider a precision regulator over a general-purpose product. But before exploring those clues, we need to understand the basic performance differences between precision and general-purpose regulators. We first need to focus on performance characteristics, rather than size or features.



Repeatability goes hand-in-hand with sensitivity, and both affect resolution.

Our first challenge is to venture beyond the commonly used term *accuracy*. A more precise discussion considers the common elements associated with accuracy—*sensitivity*, *repeatability*, *resolution*, and *droop*. These terms can sometimes cause confusion and be used incorrectly. To make matters even more cloudy, some of these characteristics are interdependent—change one, and you change others.

What is Accuracy?

Accuracy is a generic term often used for many facets of machine performance. Most people tend to use this term when "looking for a better regulator". The determination of a more-precise regulator depends on the application and the shortcomings of the current regulator. For this discussion, we will focus on sensitivity, repeatability, resolution, and droop.

Sensitivity is a measure of how much the downstream pressure has to change before the regulator's internal mechanisms compensate to bring pressure back to the previous setpoint. Most manufacturers state this specification in inches of water column (in. H2O). The smaller the number, the more sensitive the regulator. Most precision regulators can react to a pressure change of roughly 0.25 in. of water column or less, whereas most general-purpose regulators require pressure to change by at least 1in.

Of course, specific conditions affect the sensitivity of a regulator, such as diaphragm design and materials, valve and valve seat materials, flow rates for a particular valve, and even downstream volume requirements.

This sensitivity usually comes at a price. Precision regulators have some nominal amount of air consumption (generally less than 0.5% of flow capacity) that allows the unit to stay in a dynamic state. There are two basic components of air consumption: engineered consumption to increase sensitivity, and leakage caused by imperfect valve seats and transition areas between atmosphere and pressurized volumes.

Regulator mechanisms adjust pressure of the downstream air by tapping into supply pressure to *increase* downstream pressure or bleeding outlet air to atmosphere to *decrease* downstream pressure. Internal springs compressing or relaxing, supply valves opening or closing, and relief valve operation add variation to the system. The regulator's ability to continually react to increases and decreases in downstream pressure and return to the original setpoint pressure is **repeatability**. Repeatability is the ability of a regulator to produce the same output under identical conditions time after time.

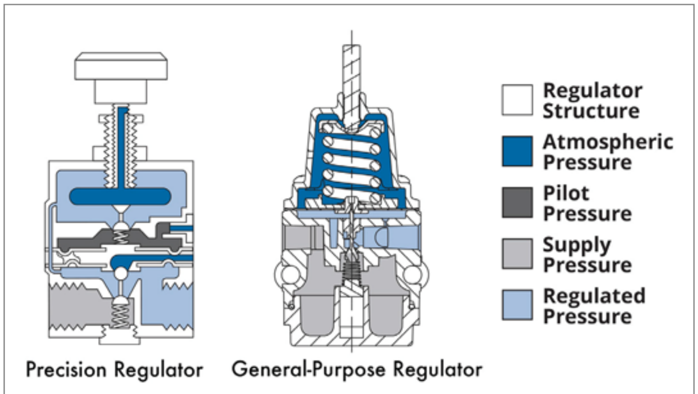
Resolution is a fairly simple concept: How fine can you adjust the regulator and have output pressure react to your input changes? Can it be adjusted to ±0.1 psi or only ±1.0 psi? The answer lies in the *spring range* of the regulator.

General-purpose regulators rely on an internal spring to exert a force counterbalance for adjusting downstream pressure. The output pressure range is tied directly to the spring range. The larger this range, the lower the resolution for adjusting downstream pressure. This is a working relationship between spring constant and thread resolution of the adjustment screw.

Precision regulators may have smaller ranges (perhaps 0 to 2 psi instead of a standard 0 to 120 psi) to help with fine adjustment. Precision regulators may also use something other than an internal spring as force-balance mechanism. This can improve resolution and reduce in *hysteresis*.

Hysteresis can occur when spring force varies depending on whether it is being compressed or relaxed. For example, three clockwise turns of a general-purpose regulator's adjusting screw may increase output pressure by, say, 10 psi. But three counter-clockwise turns may not return output pressure to the original setting—it may be slightly higher or lower. This error (hysteresis) is caused by the spring and can exert a higher or lower force depending on whether the adjusting screw is being tightened or loosened.

Some precision regulators, on the other hand, use a form of barometric capsule that adjusts pressure in a pilot-pressure chamber. Combining the sensitive capsule and pilot chamber to balance force allows the regulator to react to smaller changes downstream pressure, thus improving resolution and sensitivity.



Sectional views show a precision regulator with capsule, left, and a general-purpose regulator with a spring to control downstream pressure.

Resolution not only is associated with a regulator's spring range but also its sensitivity. The more sensitive the regulator, the less likely operators will have to readjust to find the "perfect setpoint". Repeatedly adjusting pressure higher and lower than the setpoint to find the optimum pressure is known as *hunting*, a common occurrence with an improperly set servo loop. With a manually adjustable regulator, the operator serves as the servo loop controller and must physically fine-tune a setpoint pressure. Furthermore, if a regulator is only repeatable to ± 0.25 psi, it will be futile to try to maintain a resolution of ±0.1 psi.

We recommend staying within the middle 2/3 of a spring range to achieve the best performance. Therefore, if the anticipated range of operating pressure is 10 to 20 psi, then a regulator with a range of 0 to 30 psi would be most appropriate. Some precision regulators have an assortment of special ranges, more than those normally found in general-purpose regulators (0 to 30, 0 to 60, and 0 to 120 psi).

As flow through a valve increases—and all else being equal—the output pressure decreases. This condition is known as **droop**, which is the deviation from setpoint as flow increases through a regulator. Droop is affected by valve design, flow, and probably most importantly, spring range. The larger a regulator's spring range, the greater the effect of droop. A standard flow curve shows that as flow increases, the output pressure decreases. Increasing flow beyond the regulator's specified flow range causes pressure to rapidly drop.

Evidence That You Need a Precision Regulator

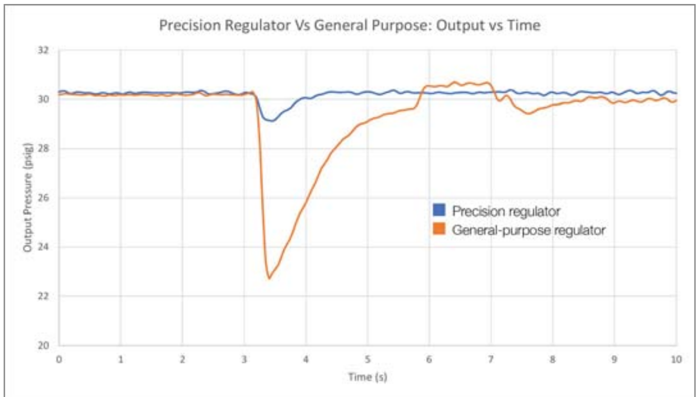
Understanding all these conditions can help you identify when you should replace a general-purpose regulator with a precision model. If any of the following conditions occur in a machine, chances are a precision regulator will solve the problem.

Condition #1: *You cannot adjust the regulator to a specific setpoint because the pressure jumps to either above or below the required setpoint*.

This condition indicates that the regulator does not have high-enough resolution. This could be caused by too wide a spring range or repeatability or sensitivity that's too low. The regulator is not reacting quickly enough to commands, causing it to reset itself to a higher or lower pressure than needed. Another potential cause could be exhaust capacity that's too low, which can make it difficult to adjust large flows of regulated air.

Condition #2: *Wide variations in downstream pressure occur with air flow and temperature changes, even though regulator settings have gone untouched*.

Left unchecked, changes in air flow or temperature will increase or decrease downstream pressure. General-purpose regulators often cannot compensate for these changes effectively. Standard flow curves (droop curves) provided by manufacturers can illustrate this condition. The accompanying illustration shows performance of ControlAir's Type-100 precision regulator Type-850 general-purpose regulator.



This graph shows the performance differences between a general-purpose and a precision regulator at a nominal output pressure of 30 psi. A sudden flow surge begins at about the 3-sec mark. The general-purpose regulator reacts with a sharp droop of about 7 psi that isn't corrected until about 2½ sec. Even then, overshoot and hunting occur. Droop for the precision regulator, however, is only about 1 psi, and it recovers within one sec.

Condition #3: *Fluctuations in supply pressure cause slow, sluggish, or erratic operation of downstream components*.

If the plant air supply provides adequate flow and pressure for all downstream devices, then the existing regulator may not be properly sized. This condition often occurs when downstream components are added to a circuit branch but the supply line and regulator are not upgraded. If droop curves for a particular regulator show a steep dropoff in output pressure as flow increases, replacing the current regulator with a precision one will likely solve the problem. A precision regulator can more effectively compensate for increased flow than a general-purpose type can.

If downstream flow is not an issue, then consider exhaust flow requirements. Some regulators have only 0.2% relief (exhaust) flow capacity compared to their downstream flow capacity.

Answers to Common Questions about Regulators

Whether you are replacing an existing regulator or starting a new project, having answers to the following questions will help you specify the appropriate regulator for an application. The accompanying checklist covers the wide range of sizes, ratings, and options available for general-purpose and precision regulators and stainless-steel models for hostile ambient environments.

1.What are the normal supply and regulated pressures?

All regulators have a maximum supply pressure. The spring range selected for output pressures should be based on the regulated pressure range needed. For best results, the output pressure setting should be in the middle of that spring range.

2.What medium is being controlled (air, oxygen, inert gases, natural gas, etc.)?

Media other than air may require special materials for internal components. Therefore, be as specific as possible when corresponding with a supplier.

3. Do you need specific port sizes?

Picking a port size for a new project should not be the determining factor, but you should know the port size and thread configuration when replacing an existing regulator.

4. What are the flow volume requirements?
The number, size, and type of downstream components determine an application's required air flow capacity. Performance characteristics can change as flow approaches a regulator's maximum capacity. Droop, accuracy, and sensitivity can be downgraded by high flow.

5. Are there exhaust capacity requirements?
In some applications—such as counterbalancing a force—quick and rapid movements of air cylinders might require a large amount of air to be displaced from the cylinder and back through the regulator as exhaust.

6. Does the application require any special environmental considerations?
Is the regulator being used in a hazardous environment? Is it going to be exposed to corrosive materials, such as salt water, extremely contaminated ambient air, washdown solutions, bleach, or water?

7. Does your application go through large- or small-scale pressure changes?
A precision regulator is usually the best choice for applications with small-scale pressure changes requiring accurate and repeatable adjustments. When large pressure changes occur, and lower accuracy is needed, a general-purpose regulator may suffice.

When picking a regulator, understand not only your specific application parameters, but the simple characteristics of the regulator being used. As always, a brief description of what you are trying to accomplish will help as well. Also consider any special mounting requirements or other governing factors.

For more information on precision and general-purpose regulators, please visit *www.controlair.com/products/air-pressure-regulators*.