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ADVANCED PRESSURE TECHNOLOGY

Product Note, PN 413
Regulator Outlet Pressure Overshoot Upon Initial Pressurization

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Introduction

It is common for the outlet pressure of a pressure regulator to rise above the adjusted set point of the device upon initial pressurization, such as connecting to a full source cylinder. If a regulator is adjusted to a given outlet pressure, meaning the device is open across the seat, and high pressure is applied to the inlet with the device dead ended (no flow), the outlet pressure may overshoot the adjusted set pressure by a noticeable amount. Once flow is enabled through the device by opening a valve downstream, the outlet pressure will decrease to the set point.

Pressure Overshoot Defined

Pressure overshoot is the amount of outlet pressure rise above the adjusted or preset outlet pressure set point. Overshoot upon initial pressurization occurs when a new source cylinder is connected and the regulator pressurized from vacuum or 0 psig. An example would be a full cylinder of nitrogen is connected to a gas system due to the current cylinder being consumed, empty. The regulator is left adjusted and set to deliver 50 psig of outlet pressure with 2,200 psig of inlet pressure. The full cylinder is installed with a pressure of 2200 psig and the regulator is then pressurized with a valve shut downstream. The regulator's outlet pressure is expected to be at the 50 psig set point, but instead it is 60 psig. The 10 psig difference (60-50) is the pressure overshoot. Pressure overshoot is common to most all pressure regulators, though the amount of overshoot will vary based on the specific design of the regulator and the procedures used when opening a new cylinder to the gas system.

Please note that pressure overshoot is not the same as pressure regulator creep. Creep is also an increase in outlet pressure beyond the set point, but it is an increase in outlet pressure after flow shut-off. For example if a regulator is set to deliver 50 psig in the zero flow condition, meaning gas flow has stopped; any pressure rise above 50 psig when flow is ceased is considered pressure creep.

Pressure Overshoot Due to Regulator Response Time

Like all mechanical devices, pressure regulators have a given response time. The response time of a regulator is the amount of time that it takes for the regulator to adjust to changing conditions, whether it is a change in inlet pressure or a change in flow demand. Most pressure regulators have a response time that is a fraction of a second. This is quite fast, but at times not fast enough.

In the example above, when the new cylinder of nitrogen is opened to the gas system the gas rushes into the regulator and the regulator achieves an outlet pressure set point and shuts off. The response time of the regulator is slower, in essence, than the speed of the gas passing through the regulator, meaning the pressure builds up faster than the regulator can respond and shut off. Once there is flow demand through the gas system this excess pressure bleeds off and the regulator returns to the desired set point of 50 psig.

The pressure overshoot caused by the regulator response time can be significantly reduced if the cylinder is opened to the gas system at a very slow rate. In general opening the gas cylinder at a slow rate is a wise practice, allowing a check for gas leaks as the gas system is pressurized. It also helps minimize the heat generated due to adiabatic compression. Later, it will be discussed how to totally eliminate the pressure overshoot.

Pressure Overshoot Due to Supply Pressure Effect (SPE*)*

Supply pressure effect also contributes to outlet pressure overshoot when installing a new gas cylinder in a gas system. Normally one thinks of supply pressure effect as only being a factor as a cylinder of gas is consumed, but it is also a factor, with a reverse effect, when changing a gas cylinder. Supply pressure effect is a function of the regulator orifice size and effective area of the sensing element. It typically ranges from a low of 0.25 psi rise per 100 psi drop in supply pressure to 5 psi or more rise per 100 psi drop in supply pressure. For example, assuming the best case of 0.25 psi SPE and a cylinder of nitrogen that is full at 2200 psig and considered empty at 200 psig, the regulator outlet pressure would rise 5 psi ((2200-200)/100) X 0.25 = 5 from a full to empty cylinder due to SPE. The reverse also holds true, in that if a pressure regulator with a SPE of 0.25 is adjusted to 50 psig outlet with 200 psig inlet, the outlet pressure will decrease by 5 psi if 2,200 psig is applied to the inlet without readjusting the regulator. Once flow commences, which would bleed off any pressure rise due to overshoot, the regulator will establish its new outlet pressure set point at 45 psig due to the 2200 psig inlet pressure. For a more detailed explanation of supply pressure effect please refer to product note PN 403 available at www.aptech-online.com in the Tech Brief section.

When a pressure regulator is pressurized from vacuum or 0 psig to a given inlet pressure, the pressure to the inlet increases to the source pressure. The inlet pressure rise may appear instantaneous, but it is not. As the inlet pressure becomes higher than the regulator's adjusted outlet pressure, the regulator closes, establishing an outlet pressure. This outlet pressure may be higher than the set point due to supply pressure effect, but once flow begins through the regulator the excess outlet pressure is bled off. What occurred is that the regulator shut off when the outlet pressure reached the set pressure, which occurred as the inlet pressure reached the set pressure. The regulator shut off with very low inlet pressure. Flow enabled the outlet pressure to drop relative to the higher, final inlet pressure.

Prevention of Outlet Pressure Overshoot

The only way of preventing or limiting regulator outlet pressure overshoot is to make sure that the regulator outlet pressure set point is set to zero (regulator control wheel turned fully counterclockwise) prior to pressurization, but after venting the regulator. If the regulator is turned fully off, the poppet in the regulator is in the closed position, sealed against the seat, which prevents overshoot upon pressurization. There is no overshoot related to the speed of the gas relative to the response of the regulator nor SPE. Once the cylinder is fully open the regulator can be adjusted to the desired outlet pressure without overshoot.

If a fully closed regulator has vacuum applied to its downstream side, the diaphragm may be sucked downward by the vacuum pushing the poppet away from the seat causing the regulator to be open in essence. This condition will be dependent on the regulator size and design. Some regulators are drawn open by vacuum, others are not. If the regulator is of the type that is drawn open by vacuum, the regulator response time will cause some pressure overshoot. In this situation, the amount of overshoot should be much less than if the regulator were adjusted to a given set point. Generally speaking, the amount of overshoot upon pressurization of an adjusted closed regulator pulled open across the seat by vacuum is much less than the ultimate set point the regulator will be adjusted to. This means the regulator can still be adjusted to set point without the need of bleeding off excess pressure which probably wouldn't be the case if the regulator were adjusted to a set point upon pressurization.

Conclusion

If a new gas cylinder is installed on a gas system having a pressure regulator that has an established outlet pressure set point you will see regulator outlet pressure overshoot. The amount will depend upon the size of the pressure regulator and the procedures used while opening the new gas cylinder to the gas system.

In order to minimize the regulator outlet pressure overshoot, the regulator must be fully closed before opening the new gas cylinder to the gas system.