Calibrating draft range pressure sensors with a PPC4 Gas Pressure Controller/Calibrator

DHI DH Instruments
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Application Note

Introduction

Draft range pressure sensors are used to measure low gauge and differential pressure in a wide variety of industries, including hospitals, pharmaceutical production facilities, semiconductor and fiber optics manufacturing, as well as in research and development. Most of the applications involve preventing an environment or manufacturing process from being contaminated. Because the pressures measured by these types of sensors are very low, calibrating them accurately can be a challenge.

This application note discusses some of the issues that must be addressed when calibrating draft range pressure sensors. It also explains why the PPC4 Gas Pressure Controller/Calibrator can be an excellent solution for calibrating this type of workload.

Figure 1. Examples of typical instruments that are used to monitor DP in a clean room environment (DHI does not indorse these products)

Low gauge versus high gauge pressure calibration

Draft range pressure sensors make low gauge pressure measurements that are typically no greater than ± 2.5 kPa (± 10 in H_2O, ± 25 cm H_2O). Most are ± 1.25 kPa (5 in H_2O, 12.5 cm H_2O) or less. Very minor levels of instability in the reference or test pressure -- that would be irrelevant in high gauge pressure calibration -- can cause critical errors in very low gauge pressure measurements.

Unstable reference pressure

All pressures are expressed as the difference between two pressures. In other words, one pressure is always measured relative to another. (In this sense, every pressure measurement is a differential measurement.) For example, the pressure measured inside the tires of a car may be 220 kPa (32 psi). This measurement is the difference between the gas pressure inside the tire and the surrounding ambient pressure outside the tire.

Two common types of differential pressure measurements are absolute and gauge. Absolute pressure is measured relative to the pressure that would occur at absolute vacuum (note, absolute vacuum is never achieved). Gauge pressure is measured as the difference in pressure inside a system and the surrounding atmosphere.

Notice the reference points (⊙) for the vertical arrows in figure 2. The reference for absolute mode pressure measurements is flat over time, because the reference is a vacuum. But in the gauge mode graph, the reference changes over time because the reference is atmospheric pressure, which is inherently unstable.

During a low gauge calibration, the measured test pressure (pressurized gas) may be very stable, but the reference (atmospheric pressure) may be moving.

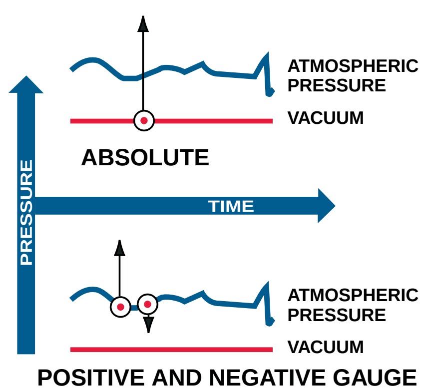

Figure 2. The stability of reference in two common types of the differential pressure

When that happens, the pressure indicated on the device under test will be unstable. This is particularly true when the differential pressure is very small and the reference is moving by a large amount.

Unstable test pressure

Instability of the test pressure medium can increase the challenges in a low pressure calibration. When a fluid such as gas is static, it does not flow. It can only flow when there is differential pressure acting on it. Therefore, if the gas in a calibration circuit is not static, then there probably is a differential pressure between the calibrator and the device under test (DUT) which often leads to errors.

The ideal gas law tells us of the relationship between a pressure and the associated volume it is contained in, the number of gas molecules in the volume and the temperature of the pressurized gas following the equation:

$PV = nRT$

Where P = pressure
V = volume
nR = the quantity of gas
T = temperature

Because they are all interrelated, we must consider what happens if volume, temperature, and/or quantity of gas in the system changes as we perform calibrations.

Most pressure systems have a considerable amount of plumbing, including valves, fittings, tubing, manifolds, adaptors, volumes, and so forth. These items are frequently constructed from various different materials. The pressurized gas must flow to fill all of the system components until the pressure is uniform throughout the circuit. It takes time for this to happen and stabilize within the required tolerance. How much time depends on the type of gas being used, total volume, restrictions within the system, the measured pressure and the uncertainty of the measurement.

Why these unstable conditions matter

Remember that draft range sensors measure pressure ranges of ± 1.25 kPa and less. Many of today's instruments claim uncertainties on low gauge measurements in the range of ± 0.05% to ± 0.15% of span. Some are as low as 0.015% of span.

If the span is 500 Pa (2 in H_2O) and the uncertainty specification is ± 0.1% of span, the maximum allowable error is ± 0.5 Pa. Maintaining a 4:1 test uncertainty ratio (TUR) means the calibration uncertainty cannot be more than one fourth of this (0.125 Pa). This, in turn, means that the amount of uncertainty allowed by environmental instability should not exceed about 0.05 Pa which represents about 0.5 ppm on atmospheric pressure. An air conditioner turning on or off, a door opening or closing, even a windy day or someone walking past the calibration system can have a larger than 0.05 Pa effect on the value of the reference pressure.

Rapid temperature changes need to be avoided wherever possible. A temperature change as small as 0.5 °C in any size volume of gas near atmospheric pressure will change the pressure by about 171 Pa (0.7 in H_2O). This is a big change compared to the pressures that are typically being measured. What might cause the temperature of the gas to change? Common sources include air conditioners being turned on and off, and nearby electronic equipment or computers with fans that cycle. Even human hands touching the plumbing can change the gas temperature significantly.

Gas flow inside the pressure circuit also must be avoided or minimized to within the required tolerance. Things that cause flow include leaks into and out of the circuit, as well as localized temperature changes in one part of the circuit. These effects are amplified by flow restrictions within the circuit such as filters, small diameter tubing, and needle valves. These conditions can create differential pressures that affect the calibration. This is especially significant when you are attempting to set zero gauge pressure, since all other pressures are relative to zero. If zero is wrong, every pressure indicated by the device will be wrong by the same amount (see Figure 3).

Simple, practical solutions to stabilize the reference and test pressure

Stabilizing the reference pressure

There are two issues to consider:

- Fluctuations in atmospheric pressure
- Changes in ambient temperature

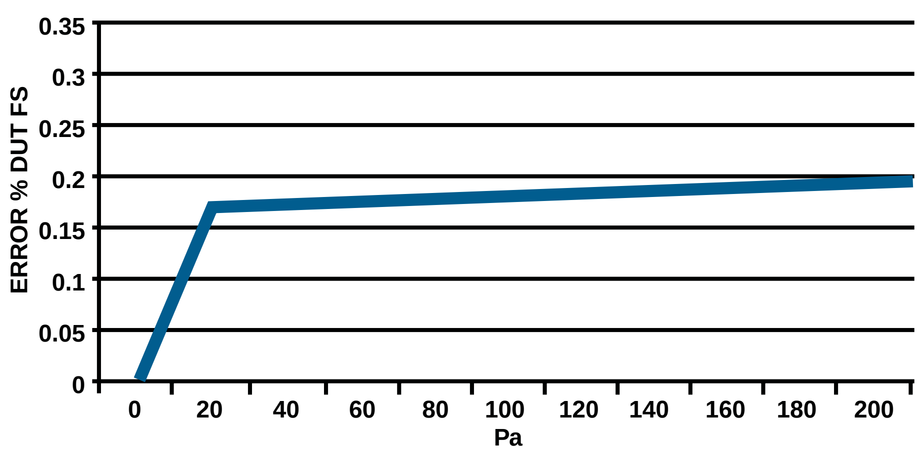

Figure 3. Error caused by poor zero

To eliminate the influence of a noisy reference pressure, simply connect the reference ports of the devices together, isolating them from the ambient pressure. Doing this results in measuring all differential pressures relative to “sealed gauge.” This is completely acceptable because the sealed gauge reference pressure is within the normal range of barometric pressure in that environment (see Figure 4).

Moving ambient temperature affects the sealed gauge pressure. As mentioned earlier, a change in gas temperature of 0.5 °C will change the pressure by 171 Pa. A temperature change of 3 °C – which is not uncommon – results in a pressure change of more than 1 kPa. This kind of change, by itself, is not normally a concern, since the pressures set and measured are differential and relative to the sealed gauge pressure. However, how quickly they change can be a concern.

The relationship between pressure and temperature is unaffected by volume. That is, a volume of 1 cc and a volume of 1000 cc at the same starting pressure will each change by the same amount if the temperatures of both change by 1 °C. But a large volume will take longer to change than will a small volume. So having a large thermally protected volume is desirable, such as that provided by a dual volume unit (DVU). In addition, the plumbing used in the test system should be thermally insulated. Since pressures are normally low, thick walled plastic tubing is recommended for its thermal properties.

Stabilizing the test pressure

Stabilizing the test pressure requires the elimination or control of the gas flow within the pressurized circuit, or enough wait time to establish equilibrium. Two causes of flow can be significant in low gauge pressure measurements:

- Localized temperature changes acting on parts of the circuit
- Leaks into or out of the circuit

System design and moving any heat sources away from the plumbing become critical to controlling flow to levels that won’t affect the measurements significantly.

It is also important to remove restrictions between the volumes that exist within the system. Volumes can be manifolds, filter housings even the device under test (DUT). Restrictions include small inside diameter tubing, needle valves and filters.

Using a PPC4 to perform draft range pressure calibrations

The PPC4 Pressure Controller/Calibrator is the latest generation of pressure transfer standards to be developed by DH Instruments, a Fluke Company. It includes individually characterized, quartz

Tech Tips:

Manage the temperature. Keep the electronics away, especially laptop computers that have fans that cycle. When heat blows onto the plumbing, it heats up the gas and it will move, creating flow. Divert air conditioning and heating away from the system. Keep your hands off. Don’t touch that tubing with your hands. Use plastics such as PFA (Perfluoroalkoxy) tubing and other materials with thermal insulating properties.

Think BIG. Big tubing and ball valves both aid in stabilizing the pressure quickly. Avoid needle valves and filters and small diameter tubing. Also avoid fittings and adaptors with small diameter passages.

WAIT. Don’t rush. It takes time for the pressure to equalize in a system using a viscous fluid. The lower the differential pressure the slower things move. You have to wait enough time.

Figure 4. PPC4, DVU and DUT connected

Figure 5. PPC4 front view and rear view showing BG15K Q-RPT test connections

reference pressure transducer (Q-RPT) modules to precisely measure pressure and specialized hardware to control pressure.

Q-RPTs come with a choice of three performance levels. For draft range pressure calibrations, the best choice is a G15K or BG15K Q-RPT (see Figure 5), along with a Dual Volume Unit (DVU, part number 3070389). This configuration includes the connections you will need in the right materials to limit environmental influences.

Do not use filters such as a Self Purging Liquid Trap (SPLT) for this application unless it is absolutely necessary. If it is, change the filter frequently – don't just purge it.

Be sure to connect the TEST (-) port of the PPC4 to the low, or reference side of the DUT and DVU and the TEST (+) to the high side of the DUT and DVU (see Figure 4).

We normally recommend that you connect a ball valve (also called a bypass valve) between the high and low side tubes. This valve is used to ensure that a good zero differential pressure is established. It may be used to avoid the influence of fluctuating atmospheric pressure on zero.

To use the ball valve, vent the PPC4 and open the ball valve. Wait for "Ready". Then perform the appropriate zeroing procedure for the DUT.

Tech Tip:

It is generally accepted practice to average readings of the DUT and the PPC4. But, averaging should only be done if both can be averaged over the same period of time. Avoid averaging one instrument and not the other and avoid averaging one instrument and then the other. Averaging should be:

PPC4 – DUT – PPC4 – DUT – PPC4 – DUT–PPC4 – DUT etc.

Averaging in this way will minimize or eliminate the effect of drift.

Step through the calibration points, making sure to wait long enough after the "Ready" indication to stabilize the pressure between the DUT and the PPC4. Note that waiting an additional 30 to 60 seconds after ready is indicated is common for draft range calibrations to ensure reliable measurements are made.

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