APPLICATION NOTE

High-pressure calibration and characterization in a production process

Manufacturing pressure measurement devices must include a step to compare the devices' output against a known, accurate pressure measurement. This step can happen in multiple different points in the process.

Depending upon the device being manufactured, it might be necessary to perform a characterization to correct for temperature influences (or other influences) on the output. Characterization is normally done by placing the device in an environmental chamber and comparing the device to a standard at multiple pressure points at multiple temperatures. The characterization process is time consuming and thus often done in batches with the devices not always in their final state.

The production process may also include a final calibration step. The final calibration is normally only performed at one temperature (ambient) and may require fewer pressure test points than were needed during the characterization process. The final calibration is the last opportunity to confirm the quality of the device being manufactured. It provides the actual measurement traceability of the final product. In this application note, we talk about characterization and calibration separately; however, in some circumstances, it may be acceptable to combine them into one process.

Selecting media

Pressure is transmitted between the device being manufactured and the pressure standard through some fluid, either gas or liquid. For very high pressures above 100 MPa (15,000 psi), a liquid media is almost always used. For lower pressures, gas is preferred. This is especially true when the device being manufactured is general purpose in nature and could be used in a variety of different processes. Any liquid residue could be incompatible with that process and thus it is easier to use a gas medium, then to thoroughly clean the device before shipment.

Liquid has also been used at lower pressures because of limitations in available equipment and safety considerations. As the performance of high-pressure pneumatic standards has improved, they now can be used for these lower pressures as well as the higher pressures.

Automation

In today's manufacturing world, automation plays a vital role. Automating the characterization and calibration processes is important, and not just to reduce labor cost. Automation removes user dependencies from the process and can improve the overall quality of the product being manufactured.

A deadweight tester or similar manual device might be used in low volume applications, areas with low labor costs, or in dated production processes where the equipment has not been upgraded in years. An automated solution like a pressure controller is preferable. For applications that require higher accuracy, automated piston gauges are available.

Pressure settling time

Pressure changes do not happen instantly. If data is being collected at multiple pressure points, the time required to reach each pressure point may consume a significant portion of the overall manufacturing process. It's possible to reduce the time required, but be careful to ensure that there are no negative effects on process quality.

A change in the pressure at one place in an enclosed system is transmitted throughout the entire system. Delays can occur when there are significant flow restrictions in the system. Sometimes these flow restrictions are necessary. High-pressure tubing generally has a smaller internal diameter than low-pressure tubing.

How do you determine how much time is necessary to wait for stabilization? Unfortunately, there is no one simple, straightforward answer that works in all applications. The required time depends on the overall system design and the technology being used. The best approach is to determine the stabilization time via experimentation. When designing your process, perform multiple calibrations using ever increasing stabilization times. You can then evaluate the data to find where the results are repeatable and thus find the minimum acceptable stabilization time.

The media choice can also impact settling time. In most cases, a pneumatic pressure controller can reach a stable pressure faster than a hydraulic controller. Gas media is less influenced by temperature effects than hydraulic media, making it easier for the pressure to stabilize. If using a liquid system, it's extremely important to remove any gas from the system using a purge-and-fill process. The pressure generation method for a hydraulic controller is dependent on the medium being liquid and non-compressible. Gas systems do not require a purge-and-fill process, reducing the overall process time.

Pressure stability

To make a valid pressure measurement, the pressure must be sufficiently stable. However, pressure is inherently unstable, as it is affected by changes in temperature and any leaks in the system. Therefore, it is a best practice to find and remove any leaks from the pressure system. An automated controller will attempt to maintain a stable pressure. There are limitations to its ability due to the resolution and response time of the measurement sensor and the mechanics of the valves used. There are different terms used to specify these factors, including control precision and control stability. These specifications are normally provided as a function of either the full scale of the controller or the full scale of the measurement range. Because of this, take care that the stability of the pressure is sufficient when controlling lower pressures. With an automated system, control instability can be included in your overall measurement uncertainty by taking multiple measurements, averaging those measurements for the recorded measurement, and including the standard deviation in your uncertainty.

Measurement performance impact on characterization

The characterization process is used to linearize the reference standard, eliminating impacts from variables like temperature. Any non-linearity in the reference standard will be transferred to the device being manufactured. Therefore, it is important to consider linearity when choosing a reference standard. Linearity is commonly included in the precision specification. Non-linearity can potentially occur when two or more pressure sensors are used to cover the overall range. The two pressures can be individually linear, but if they have different slopes, the overall range will be non-linear. In most applications, if the pressure sensors are routinely calibrated, the two lines will be in agreement and the overall range will be sufficiently linear. If characterization and calibration are done separately, the overall uncertainty of the reference standard isn't the greatest concern. The goal is linearity, which can be obtained even if the span of the reference standard has drifted. If characterization and calibration are done using the same equipment (or the equipment has multiple pressure sensors) then routine calibration is a necessity.

Measurement performance impact on calibration

The measurement performance of the reference standard has a direct impact on the performance and quality of the devices being manufactured. The overall uncertainty of the reference standard must be sufficient to validate the performance of the manufactured devices. Different applications require different levels of uncertainty, but a common rule of thumb is a 4:1 ratio between the device under test and the reference standard.

Maintenance considerations

Maximizing uptime is imperative for high volume production lines. Money is lost when a malfunction causes the production line to go down. Therefore, it is imperative to use reference standards that are robust, reliable, and easy to maintain. This is especially true when working with high pressures. High pressure puts more stress on the control components. At high pressure, leaks are also more prevalent, putting more stress on the system. Robust design is a necessity. To better support maintainability, many pressure controllers now use a modular design. Proper modularity allows measurement and control components to be easily removed and replaced. Measurement modules can be easily removed for recalibration. Control functionality can also be modularized, allowing the control module to be easily replaced for preventive maintenance or repair. Modularity also may allow for the easy re-ranging (or range expansion) of a controller, providing for more flexibility in production cell design.

Selecting a pressure standard

When selecting a pressure standard for manufacturing environments, here are some things to consider.

Media. Where feasible, a gas medium is preferable as it will not contaminate the freshly manufactured devices. A liquid medium leaves residue that potentially limits the application space for the product. For extremely high pressures, greater than 100 MPa (15,000 psi), hydraulic is predominately used.

Range. What is the highest pressure that must be tested? What is the lowest? Can both be attained using one controller? Does the controller provide flexibility by allowing for the easy expansion of additional range coverage?

Measurement performance. Measurement performance must be sufficient for the application. For characterization applications, is the sensor sufficiently linear? For calibration applications, is the overall uncertainty sufficient? Is the controller provided with an accredited calibration and can it be recalibrated with an accredited calibration?

Control Performance. Will the pressure be sufficiently stable at all pressures where you need to test? Will it control pressure quickly enough? Are there any unique things about your system

setup that will affect control? This includes large test volumes, flow restrictions, or extreme leaks.

Reliability. Is the controller reliable? Will downtime be minimized?

Maintainability. Can measurement and control modules be removed easily, even when the unit is installed in the production process? Can new pressure modules be installed easily, allowing for range expansion? Are the modules priced so that it is feasible to have spare modules, rotating out modules to eliminate downtime caused by recalibration? Is there sufficient documentation available so that you can handle simple maintenance and repairs in-house?

Conclusion

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