

Why control precision matters

Introduction

Pressure controller/calibrators are used to calibrate pneumatic process measurement instruments or field calibration devices. Although these instruments generally include control hardware and a precision transfer pressure standard (transducer), they often are referred to simply as “pressure controllers” since they are normally used to deliver a controlled pressure to the unit under test (UUT), at which the nominal controller set point and/or the reference pressure transducer’s measurement can be compared to the measurement of the UUT.

The performance of pressure controller/calibrators is most often compared based on the measurement precision and uncertainty characteristics of the reference pressure transducers used in the calibrator. Another important performance specification, which is reported but sometimes under-emphasized, is the calibrator’s control precision. Control precision has an impact on the calibration accuracy realized by the user. As shown in this application note, control errors can become as significant as the measurement uncertainty in some cases. The importance of control precision is increasing with the recent trend for covering multiple pressure ranges with a single calibrator/controller.

Types of pressure control

When using pressure controller/calibrators, users generally have two options for the type of control used in the test.

Static control, also sometimes referred to as a passive or measure mode, employs the pressure controller to bring the test system pressure to the approximate desired test point until some limit of proximity to the target pressure is reached. At this point, the reference pressure transducer and the UUT measurements are compared in a relatively static environment after most adiabatic or other transient effects from the rapid pressure change subside. Data is taken after the user, or the calibrator/controller (using programmed criteria), determines that the pressure is stable enough to make a good measurement.



PPC4 Pressure Controller/Calibrator with advanced user interface

In the Fluke DHI PPC4 controller/calibrator's static control mode, there is a control hold limit (see Figure 1), but it is normally set to keep the pressure from drifting too far away from the nominal value while waiting for pressure stability. In this case, the indications of both the reference and UUT may settle some distance away from the requested target pressure due to changes in temperature, transient pressure effects or leaks in the system. Therefore, there is no way to ensure that data is taken at nominal test points, or to avoid drift of the pressure indications during data acquisition and averaging inside the hold limit. The controller stops actively controlling the pressure and won't re-set it until the pressure moves outside of the control hold limit.

Dynamic control, or active control, is used frequently for calibrations using pressure controller/calibrators. In this mode, the controller brings the pressure in the test system to the requested target pressure and then continues to actively control the pressure around the target while measurements of the reference and UUT are recorded. Dynamic control allows calibrations to be performed faster, since transient pressure effects are overcome by the controller to produce a relatively stable pressure in a short time—often less than 30 seconds. Dynamic control allows calibration points to be taken precisely at nominal pressure values, which may be a procedural requirement for some users.

Uncertainty considerations related to static and dynamic control

In dynamic control, the controller's ability to maintain a stable, precise pressure has a direct effect on the quality of the comparison between the reference and UUT pressure measurements. In contrast, uncertainties contributed by static control are based solely on the leak integrity of the pressure circuit and transient and environmental influences.

Static test modes have the apparent advantage that any instability introduced by active control is eliminated; so, theoretically, the reference and UUT can be compared without any additional error beyond the uncertainties of each measuring device.

But an important distinction between static and dynamic pressure control uncertainties is related to something called the standard deviation of the mean. When recording an average pressure value with control stability that is random, as in dynamic control, the standard deviation of the mean pressure is reduced (divided) by the square root of the number of points taken (n) to determine the mean. If the pressure instead moves at a steady rate in one direction, as is possible in static control mode, the stability is not considered random and the standard deviation should not be reduced by the square root of ' n '.

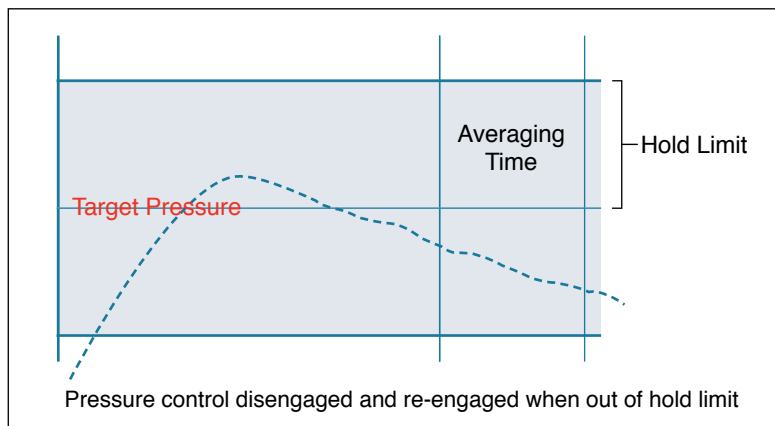


Fig 1. Static pressure control

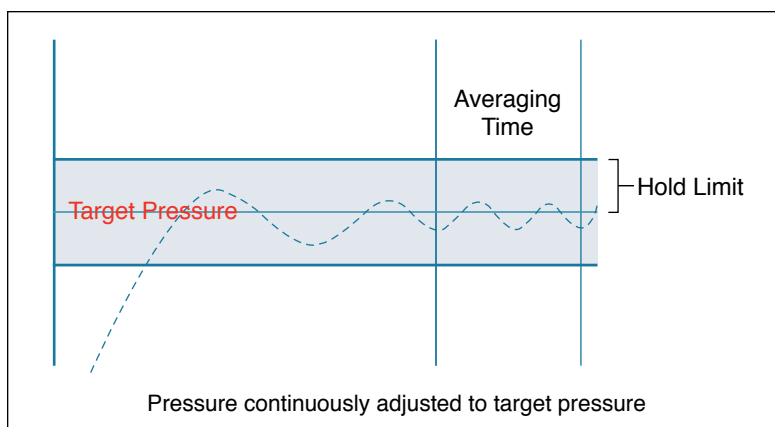


Fig 2. Dynamic pressure control

As a result, precise dynamic pressure control can produce a smaller uncertainty related to stability of the measured pressure. This, in addition to the benefit of speed and the ability to maintain control at nominal pressure points, makes dynamic control a popular mode of operation.

Dynamic control precision and pressure uncertainty

The specification used to describe the smallest value within which a controller/calibrator can maintain the system pressure around a target value is called control precision. It may also be referred to as control stability or control error. The uncertainty due to control precision is similar to uncertainty from measurement resolution, because when the controlled pressure is within a defined limit, a controller/calibrator generally displays only the nominal requested pressure, and the operator does not know where inside the limit the pressure really is.

For the PPC4 controller/calibrator, the defined control limit is called the hold limit (see Figure 2).

The hold limit is user-adjustable, but we can consider the smallest usable hold limit value over the PPC4’s range to be equal to its control precision specification, which is $\pm(0.0004\%$ of active Q-RPT span, or 0.00004% of Hi Q-RPT span, whichever is greater). Note: Q-RPT is the name for Fluke/DHI’s exclusive reference pressure transducer module.

Delivered pressure uncertainty is an uncertainty value that can be calculated and displayed real-time by the PPC4 controller/calibrator. It defines the total uncertainty of the pressure applied to the UUT, including both the reference measurement uncertainty and the error introduced by control precision.

An assumption related to the calculation of delivered pressure uncertainty is that the value used as the reference pressure in UUT error calculations is the nominal requested target pressure, which is displayed on the controller/calibrator while taking data in dynamic control mode. With PPC4 it is possible to record and average the actual measured pressure from the reference pressure transducer during dynamic control by reading that value via remote interface with PC-based software. When this is done, the contribution of uncertainty from control stability is only that related to the standard deviation of the mean as described earlier. But since the use of the requested target pressure as the reference pressure is a common practice, it is useful to consider the impact of control precision in that case.

For simplicity, the example below shows only the calculated error contribution of control precision and not overall delivered pressure uncertainty. DHI Technical Note 8050TN11 includes an explanation of how control precision may be properly combined with measurement uncertainty to calculate delivered pressure uncertainty.

Control precision example

Specifications among competing controller/calibrator models vary in terms of both measurement uncertainty and control precision. In addition to offering the lowest measurement uncertainty available, the PPC4 controller/calibrator stands alone in delivering ± 4 ppm ($\pm 0.0004\%$), dynamic control precision. The typical control precision offered by competing models is ± 10 ppm. As a simple example of the significance of that difference alone, Table 1 shows just the contribution of uncertainty from control precision at pressures down to 10%

Effect of control precision on dynamic control error		
Example: 1000 psi (7 MPa) reference transducer range		
@ 1000 psi (7 MPa)	PPC4 (± 4 ppm control precision)	Typical (± 10 ppm control precision)
Control error	± 0.005 psi	± 0.012 psi
Control error as % of reading	$\pm 0.0005\%$	$\pm 0.0012\%$
@ 100 psi (700 kPa)	PPC4 (± 4 ppm control precision)	Typical (± 10 ppm control precision)
Control error	± 0.005 psi	± 0.012 psi
Control error as % of reading	$\pm 0.005\%$	$\pm 0.012\%$

Table 1. Dynamic control error is greatly reduced by PPC4’s ± 4 ppm control precision.

of the span of the calibrator’s active reference pressure transducer. The uncertainty contribution is calculated as $(2x [\text{control precision spec}]/[\text{square root of } 3])$ for $k=2$ coverage factor, as described in DHI Technical Note 8050TN11.

At 10% of span, the control error resulting from ± 10 ppm of span control precision is $\pm 0.012\%$ of reading, which is greater than the entire measurement uncertainty specification of some precision controller/calibrator models. This illustrates that users cannot realize the performance expected from precise reference measurements over wide pressure ranges without the support of very precise control performance.

Multi-ranging and control precision

In some controller/calibrator models, multiple reference pressure transducers can be included in the system to extend the calibrator’s accurate measurement range. It is vital to this extension of range that the dynamic control precision offered is sufficient to support the measurement uncertainty that the user expects.

In models that offer multi-ranging, generally the control precision is specified as a percent of the span of the active reference transducer. Due to the control precision performance required to meet those specifications, some models do not offer multiple ranges, and others must limit the ranges to a ratio of 10 to 1, but PPC4’s patented control module with ± 4 ppm control precision allows true usable multi-ranging performance, using a single controller and a single test port for the UUT.

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Fluke Corporation
DH Instruments Division
 4765 East Beautiful Lane
 Phoenix, AZ 85044-5318 U.S.A.
 Phone 1-602-431-9100
 Fax 1-602-431-9559

Fluke Europe B.V.
 PO Box 1186, 5602 BD
 Eindhoven, The Netherlands

For more information call:
 In the U.S.A. (800) 443-5853 or
 Fax (425) 446-5116
 In Europe/M-East/Africa +31 (0) 40 2675 200 or
 Fax +31 (0) 40 2675 222
 In Canada (800)-36-FLUKE or
 Fax (905) 890-6866
 From other countries +1 (425) 446-5500 or
 Fax +1 (425) 446-5116
 Web access: <http://www.dhinstruments.com>

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