FLUKE
Calibration

TECHNICAL NOTE

Guide to determining pressure measurement uncertainty for PM200, PM500, and PM600 Pressure Measurement Modules

This technical note is a product uncertainty analysis of PM200, PM500 and PM600 pressure modules delivered with the 2271A and 6270A pressure controller calibrator. The purpose of this document is to help provide the user of a 2271A or 6270A controller with information to be able to calculate measurement uncertainty based on the specifications defined for PM200, PM500 and PM600 Pressure Measurement Modules (PMM).

PM600 modules are a version of Q-RPT (Quartz Reference Pressure Transducers) that are primarily addressed in the technical note “Guide to determining pressure measurement uncertainty for Q-RPT based products”[1] found on the Fluke Calibration website. However, they only have a specification that is equal to the “standard class” specification. No other specification options are available for the PM600 modules (not premium, standard mid or standard high). There are a few differences between the PM600s and the Q-RPT based products defined in the technical note. These are:

- Mounting of the transducer is different to be able to accommodate the PMM form.
- 6270 introduces a new automated zeroing process used to limit the amount of absolute mode zero drift (offset).
- Absolute sensors used in gauge mode have higher uncertainty, but this only affects the two lowest absolute ranges.
- BRM600-BA100K barometric modules have a lower uncertainty based on a large population study of recalibrated BA100K barometers.
- The PM600-A20M is specified as standard class, not standard mid as in [1].

Since the differences are minimal for PM600 modules and Q-RPT standard class products, only the differences are discussed here for PM600 modules. A full description of their influences can be found in [1].

PM500 modules are new to the Fluke Calibration pressure product line. PM500s are silicone based, strain gauge transducers that are highly characterized to meet specifications claimed. Depending on the range, PM500 specifications can be percent of full scale, percent of reading or a variant of both.

PM200 modules are a lower cost/accuracy module. PM200s utilize the same sensing technology as PM500s (silicone based, strain gauge transducers) and are characterized to meet the specifications claimed. PM200 specifications are entirely expressed in percent of full scale.

This technical note is divided into three sections. The first section provides all the information to create instrumental measurement uncertainties by listing all the uncertainties and the reasoning behind the application of those uncertainties. The second section takes the information from the first section and defines specifications based on an uncertainty budget table. The third section shows how the specifications can be applied to the 2271A and 6270A uncertainty settings for onboard uncertainty calculations.

It is important to note that, although this uncertainty analysis is appropriate for the population of PMMs, it is likely that the uncertainty of an individual PMM will be less than that of the population. It is our hope that this technical note will suffice as a guide for users of 2271A and 6270A to calculate uncertainties for individual PMMs.

NOTE: Overall compliance of the PMM is determined by review of the overall 1-year specification in pressure. There may be situations where, for example, one influence is more than the uncertainty shown in this document, but other influences are less than uncertainties listed in this document. But as long as the PMM meets the overall 1-year pressure measurement specification presented in this document, it is considered compliant.

General uncertainty considerations

Because of the possible variances in use and calibration, it is necessary to define the boundaries on conditions that affect the final uncertainty of the PMMs.

- Operating mode
- Fluid media
- Environment
- Orientation
- Reference Uncertainty
- Calibration frequency
- Dwell
- Zeroing

Operating mode

The operating modes supported by this uncertainty analysis are:

- Absolute
- Gauge
- Negative gauge (vacuum)

The operating modes will have some influence on the final uncertainty published in this document. For the most part the differences in the final uncertainties are small, but not negligible.

Fluid media

The fluid used to transmit pressure has some influence on the final uncertainty calculated for the modules. This is primarily due to head corrections made by the user of the 6270A controller. The fluids used with a 6270A are:

- Nitrogen
- Air (clean and dry)

Environment

As long as humidity is such that it is non-condensing, the only limits required are for vibration, temperature and the rate at which the temperature changes. The limits for temperature for this uncertainty analysis are:

- Temperature: 15 °C to 35 °C (59 °F to 95 °F)
- Temperature change: Less than 5 °C (9 °F) per hour
- Vibration: Meets MIL-T-28800E

Orientation

The PM200's sensitivity to orientation has been found to be insignificant. This is also true for PM500 and PM600 modules as long as they are calibrated and used in approximately the same orientation as used in the 6270A. Though not quantified, PM500's sensitivity to orientation is realized as a pressure offset and can be eliminated by zeroing.

Reference uncertainty

The reference uncertainty requirement for this analysis is intended to be as conservative as possible to allow the operators of the equipment to have flexibility with available references. However, it is assumed that a piston gauge is used as the reference for PM600s as stated in [1].

For all PMMs it is not necessary to choose a reference that has an uncertainty four times lower than the PMM specification since it is included as an influence in this uncertainty analysis. The reference uncertainty only needs to be equal to or less than what is specified for that uncertainty influence.

Calibration frequency

This analysis assumes a recalibration interval of 1-year. There is not extensive data or information that other intervals will prorate the uncertainties due to drift over time to be proportional to the interval. Studies have been performed on PM200, PM500 and PM600s to justify the uncertainties from drift based on 1 year. That does not mean that PMMs will not be better in 6 months or less, but there is not a guarantee for anything other than 1 year.

Dwell (stabilization time)

All static pressure measuring systems and components have an inherent time to achieve equilibrium or stabilize. This is particularly important for high-level calibration applications and is the reason why a dwell time is recommended between setting pressure and making comparisons. In the case of PM500 and PM600, a stabilization time of 30 seconds is required after any significant instantaneous pressure change to ensure stability of the PMM and the system for comparisons within the stated uncertainty. For PM200s it is assumed a ten-second dwell is observed.

Zeroing

It is assumed that all PMMs that are in gauge mode are zeroed before each use. It may be found that this is not necessary depending on the zero stability of each PMM. For PM200 and PM600 absolute PMMs it is not assumed they are zeroed between calibrations. For absolute PM500s, zeroing at an interval of 30 days is recommended to reduce zero drift uncertainty in order to maintain compliance to 1-year specifications.

Abbreviations

Throughout this document, some abbreviations are used. To clarify…

% FS = Percent full scale (maximum indication)

% Span = Maximum – minimum pressure range

RSS = root-sum-square

PM200 and PM500 uncertainties

This section defines the uncertainty influences that apply to PM200s and PM500s. A brief explanation of each uncertainty is given. All uncertainties for PM200s are expressed as a % FS and at 95 % confidence. Uncertainties for PM500 are expressed as % FS, % of reading or a combination of both at 95 % confidence. The influences discussed are:

- Reference
  - Precision
  - Conformance
- Repeatability
- Temperature
- Zero Drift
- Stability
- Pressure Head
- Absolute mode uncertainty using a gauge (G) or bi-directional gauge (BG) PMM
- Gauge mode uncertainty using an absolute PMM

Reference

The uncertainty in pressure contributed by the reference is dependent upon the PM200 or PM500 range. Most PM200 ranges have an instrumental measurement uncertainty of ±0.02 % FS for one year at 95 % confidence. For these PM200s the uncertainty for the reference is set to ±0.0075 % of FS at 95 % confidence. For other PM200 ranges the reference uncertainty requirement is expanded due to the magnitude of the other uncertainty contributions. For PM500 ranges, estimates for reference uncertainty is listed in Tables 5 through 8.

Precision

One of the most important characteristics of a PMM as a secondary standard is precision. Precision is the combination of linearity, hysteresis and repeatability and is used as a tolerance for an as left state of a PM500. The combination of linearity and hysteresis without repeatability is called conformance. Conformance is used as an adjustment specification for PM200s and is listed separately from repeatability in this uncertainty analysis. Resolution is ±0.0001 % FS, which is also considered separately and becomes insignificant when combined with other precision characteristics.

Conformance

Conformance is the combination of linearity and hysteresis since they both influence deviations from a perfect fit. This combination is used as an uncertainty and a tolerance for an as left state for PM200s.

Hysteresis is the uncertainty from an influence that is dependent upon a pressure transducer's mechanical memory. For example, if a pressure measurement is made at one pressure, and then increased to a higher pressure, it might be in error by a little less coming from the lower pressure. The reverse may happen in decreasing pressures. The influence may be dependent on the amount of time the transducer was at the previous pressure, or the amount of the pressure change.

Linearity is an uncertainty from deviations from a perfectly linear output over its pressure/temperature range. PM200s and PM500s are well characterized over the given temperature specification. Since the model of the fit is the same over the temperature range the characterization is applied, the linearity is assumed to be the same at different temperatures. However, there is still an uncertainty for temperature to account for overall changes in zero or span throughout the temperature range.

Conformance for PM200s is no less than ±0.01 % FS. It is important to note that the conformance tolerance used for as left results in a calibration is at the approximate ambient temperature during the calibration. If there is a significant temperature change from where the PM200 met this tolerance, but still within limits, the PM200 may not be within the conformance tolerance. However, it should still be well within the 1-year specification.

Conformance for PM500s depends on pressure range and is listed in Tables 5 through 8 for each PM500.

Repeatability

Repeatability is the ability of the PMM to repeat a pressure when subjected to the same pressure and conditions. Repeatability can only be measured by reproducing a test point in the same manner more than once. Usually this means that full pressure cycles performed the same way must be used to measure repeatability at individual points throughout the calibrated range. For PM200s repeatability is no less than ±0.005 % FS and for PM500s, repeatability is no less than ±0.003 % of reading.

Temperature

PM200s and PM500s are characterized when they are new over the full pressure range and a temperature range greater than the temperature range given. For PM200s there is an overall uncertainty of no less than ±0.005 % of FS from 18 °C to 28 °C (64.4 °F to 82.4 °F). If used outside of this ambient operating temperature range an additional ±0.003 % of FS/°C should be added for all ranges, but should not go outside of the specified temperature range of 15 °C to 35 °C (59 °F to 95 °F).

For PM500s, the ambient operating range is from 15 °C to 35 °C (59 °F to 95 °F). Temperature related uncertainty for PM500s are listed in Tables 5 through 8.

Zero drift

PM200s and PM500s that measure bi-directional gauge (BG) or gauge (G) are assumed to be zeroed before use. However, the zero can drift during use. For PM200s, an uncertainty of ±0.002 % FS is assigned to zero drift during a test, i.e. before there is the opportunity to zero again. For PM500s, zero drift is range dependent but is no less than ±0.001 % FS.

Absolute PM200 modules are not zeroed. Zero drift for these are considered to be ±0.05 % FS for 1 year.

Absolute PM500 modules should be zeroed every 30-days to maintain their 1 year specification. Zero drift for absolute PM500 modules is dependent on PMM range and is listed in Tables 5 and 8 at a 30-day uncertainty. It is recommended to zero absolute PM500 modules with full scales of 700 kPa or less at a pressure of 0.08 kPa absolute but zeroing can be performed at any pressure as long as the absolute reference uncertainty is sufficient at the zeroing pressure. For absolute PM500 modules with full scales greater than 700 kPa, zeroing is performed at atmosphere. Without zeroing, an additional uncertainty for zero drift is considered no less than the 1-year zero drift uncertainty listed in Table 1. The zero drift uncertainty is combined with the 1-year specification as follows:

It is important to note that the calibration certificates for recalibrations on absolute PM500s from Fluke Calibration will include the 1-year specification based on a 30-day zero.

$$\text{Specification}_{\text{w/o zero}} = \sqrt{\left(\frac{\text{1 year specification}}{2}\right)^2 + \left(\frac{\text{1 year zero drift uncertainty}}{2}\right)^2} \times 2$$

PM500 Model	1 year specification ±	1 year zero drift uncertainty ±
BA120K	0.01 % rdg	0.05 % FS
A120K	0.01 % rdg or 0.005 % FS	0.05 % FS
A160K		
A200K		
A350K	0.01 % rdg or 0.005 % FS	0.025 % FS
A700K		
A1.4M	0.01 % rdg or 0.005 % FS	0.015 % FS
A2M		

Table 1. PM500 1-year zero drift uncertainty

Stability (1-year span drift)

The output of PM200s and PM500s can change over time due to natural material changes of the transducer and supporting electronics from age or use. Extensive studies were performed during the development of PM200 and PM500 sensor technology on the drift of these pressure transducers over time. For PM200 modules, the uncertainty for 1 year drift is no better than ±0.01 % FS. This uncertainty is conservatively given in % of FS for G and BG PM200 modules but is actually a % of reading since these are zeroed when vented, so realistically is always span drift. For PM500 modules, the uncertainty for 1 year drift is no better than ±0.005 % of reading for ranges greater than 2.5 kPa and ±0.01 % of reading for ranges 2.5 kPa or less. For strictly % FS PM500s, (BG100K through BG700K) the % of reading stability uncertainty is conservatively applied as % FS uncertainty which is no better than ±0.005 % FS.

Head pressure

Because of the possibility that a device being calibrated by a pressure controller/calibrator can be at a height that is significantly different than the controller, the uncertainty contributed by head pressure is not included in this analysis when considering the 1-year specification. If an uncertainty for head height is needed to be included it is fairly easy to do for a 2271A or 6270A since the media is limited to Air and nitrogen gas (N2). For Air and N2 a close approximation to head height is 0.0003 % of reading (gauge or absolute) per inch of head height (approximately 0.00012 % per centimeter). The uncertainty in head height, in terms of height (centimeters or inches) is an influence captured by the on board pressure uncertainty calculator. This includes the uncertainty in head when units are used in system mode and is simply the addition of the device under test (DUT) height uncertainty and the uncertainty of the head height from auxiliary to primary platform.

Measuring absolute pressure with a G or BG PMM

Gauge or bi-directional gauge PM200s and PM500s can measure absolute pressure if there is an appropriate absolute PMM installed. The uncertainty in this case is simply the RSS of the uncertainty of the gauge or bidirectional gauge PMM and the absolute PM200, PM500 or PM600 at ATM. Absolute PMMs that can be used are PM200-A100K, PM200-A200K, PM500-BA120K, PM500-A120K, PM500-A160K, PM500-A200K and BRM600-A100K.

Measuring gauge pressure with an absolute (A) PMM

Absolute PM200s and PM500s can measure gauge pressure if there is an appropriate absolute PMM installed to perform dynamic barometric compensation to the active PMM while in gauge mode. The uncertainty in this case is simply the RSS of the uncertainty of the active PMM and the absolute PM200, PM500 or PM600 at ATM. Absolute PMMs that can be used to perform dynamic gauge mode compensation are PM200-A100K, PM200-A200K, PM500-BA120K, PM500-A120K, PM500-A160K, PM500-A200K and BRM600-A100K.

PM600 uncertainties

As stated earlier in this document PM600s are Q-RPTs with a "Standard" 1-year specification as described in the Technical Note "Guide to the uncertainty of Q-RPT pressure based products"[1]. This section only covers the differences in PM600s from other Q-RPT based products.

Zero stability (drift over 1 year)

For PM600 absolute modules there is an uncertainty associated with zero drift over the 1-year calibration interval. For each absolute range an additional uncertainty of ±0.007 % of span is root sum squared (RSS) with the one year specification of ±(0.01 % of reading or 0.003 % Q-RPT span, whichever is greater).

The zero drift uncertainty component can be reduced significantly using a 6270A automated feature that allows the user to designate and use a different PMM as an AutoZero reference. This can be any absolute PMM but the idea is to use the PMM that is the most stable. By definition, lower range absolute PM600s should be more stable with the BRM600-BA100K being the most stable of all. This feature is enabled by turning on AutoZero and specifying the module to use as the AutoZero reference. The correction happens when vented much like the automated gauge zero when at vent. If AutoZero is off then there is the option to manually enter a reference value for barometric pressure that will be used to correct all absolute PMMs when vented. The uncertainty used is the uncertainty that is stored with the atmospheric pressure value in the instrument settings menu.

Figure 1 shows the uncertainty at atmospheric pressure for four examples of PM600s in a 6270A at the same time with AutoZero off and AutoZero on. The values for AutoZero off are the standard class specification RSS with 0.007 % Q-RPT span of each range. The values for AutoZero on are the standard class specification RSS with 10 Pa since 10 Pa is the uncertainty of the BRM600-BA100K when measuring barometric pressure.

Figure 1 shows the significant reduction of uncertainty

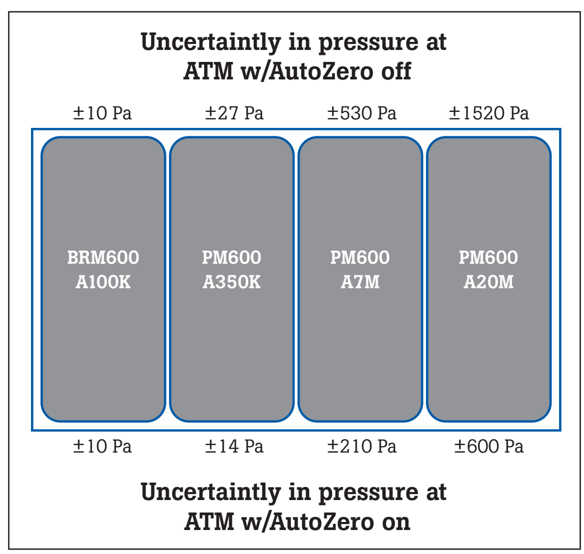

Figure 1. Uncertainty of PM600 modules in absolute mode at atmospheric pressure with AutoZero off and AutoZero on.

using the BRM600-BA100K as a PMM zeroing reference. This is among the best results that one could obtain without using a primary standard and manual AutoZero. It is important to note that the calibration certificates for recalibrations on absolute PM600 from Fluke Calibration will use the full 1-year specification including the RSS of the 0.007 % of Q-RPT span since it is unknown what was used as the AutoZero reference.

Absolute PM600 used in gauge and negative gauge mode

In the Q-RPT uncertainty technical note there is a section on using absolute Q-RPTs to measure gauge pressure. In this section it describes the uncertainty as the normal standard class specifications, but the absolute value of the pressure is used in case the pressure being measured is negative gauge, then 1 Pa is added. For absolute PM600 modules used in gauge or negative gauge it is a similar calculation but 7 Pa is RSS with the threshold uncertainty. This only significantly affects the two lowest ranges; A100K and A200K. These end up with a specification in gauge mode that is ±(0.01 % of the absolute value of reading or 0.0074 % of span, whichever is greater) for the A100K, and ±(0.01 % of absolute value of reading or 0.0043 % of span, whichever is greater) for A200K with span being the full absolute range (full negative to positive gauge range). Figure 2 shows these specifications graphically.

BRM600 BA100K uncertainty

A reliability study was performed on a significant sample of BA100K Q-RPTs from RPM4 pressure monitors in the field. As suggested in [2] the stability of the barometric Q-RPTs are better than Q-RPTs that are continuously cycled through their range. Reliability was very good using a 1-year specification of 0.01 % of reading for the range of 70 kPa to 110 kPa. The uncertainties are given in upper part of Table 9 as relative uncertainties, but these are close to being % of FS since the range is limited to 70 kPa to 110 kPa.

Resolution (All PMMs)

The best resolution available from the front panel of the 2271A or 6270A and from a remote query is 0.0001 % of span of the module. For all models this is insignificant so is not included. The user should be careful when decreasing the resolution to a higher percent of span if they are using the displayed value. For instance, if 0.1 % of FS is selected the displayed value would have a much higher uncertainty than the PMMs at normal resolution. The on-board uncertainty calculator described at the end of this document is a good way to make sure the user has selected sufficient resolution. If the resolution decreases on the displayed value, so does the displayed uncertainty. If there are two significant digits shown on the displayed uncertainty, then it is at an appropriate resolution based on the current PMM uncertainty.

Uncertainty budget tables

Tables 2 (PM200) and 4 (PM500) give the range in psi and kPa and the 1-year specification for PM200s and PM500 respectively.

Uncertainty budgets for the following PMMs are as follows:

PM200–Table 3

PM500–Tables 5 through 8

PM600–Table 9

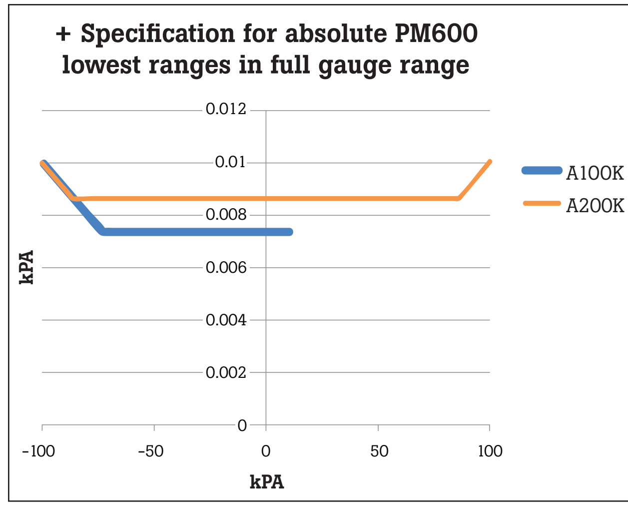

Figure 2. Absolute PM600 used in gauge mode, two lowest ranges.

Model	Range (psi)	Range (kPa)	Published 1 year spec. ±
PM200-BG2.5K	-0.36 to 0.36	-2.5 to 2.5	0.20 % FS
PM200-BG35K	-5 to 5	-35 to 35	0.05 % FS
PM200-BG40K	-6 to 6	-40 to 40	0.05 % FS
PM200-BG60K	-8.7 to 8.7	-60 to 60	0.05 % FS
PM200-A100K	0.3 to 15	2 to 100	0.10 % FS
PM200-BG100K	-15 to 15	-100 to 100	0.02 % FS
PM200-A200K	0.3 to 30	2 to 200	0.10 % FS
PM200-BG200K	-15 to 30	-100 to 200	0.02 % FS
PM200-BG250K	-15 to 36	-100 to 250	0.02 % FS
PM200-G400K	0 to 60	0 to 400	0.02 % FS
PM200-G700K	0 to 100	0 to 700	0.02 % FS
PM200-G1M	0 to 150	0 to 1000	0.02 % FS
PM200-G1.4M	0 to 200	0 to 1400	0.02 % FS
PM200-G2M	0 to 300	0 to 2000	0.02 % FS
PM200-G2.5M	0 to 360	0 to 2500	0.02 % FS
PM200-G3.5M	0 to 500	0 to 3500	0.02 % FS
PM200-G4M	0 to 580	0 to 4000	0.02 % FS
PM200-G7M	0 to 1000	0 to 7000	0.02 % FS
PM200-G10M	0 to 1500	0 to 10000	0.02 % FS
PM200-G14M	0 to 2000	0 to 14000	0.02 % FS
PM200-G20M	0 to 3000	0 to 20000	0.02 % FS

Table 2. PM200 1-year specifications

PM200 Modules					
Variable or parameter	**Distribution**	**BG100K through G20M**	**BG35K, BG40K, BG60K**	**A100K, A200K**	**BG2.5K**
Reference	normal	0.0038 %	0.0038 %	0.0100 %	0.0100 %
Resolution	rectangular	0.0003 %	0.0003 %	0.0003 %	0.0003 %
Conformance	normal	0.0050 %	0.0050 %	0.0100 %	0.0250 %
Repeatability	normal	0.0025 %	0.0050 %	0.0125 %	0.0100 %
Temperature	normal	0.0025 %	0.0050 %	0.0050 %	0.0100 %
Zero Drift	rectangular	0.0012 %	0.0023 %	0.0289 %	0.0058 %
Stability	rectangular	0.0058 %	0.0231 %	0.0144 %	0.0866 %
Combined		**0.0093 % FS**	**0.0251 % FS**	**0.0377 % FS**	**0.0920 % FS**
Combined and expanded for (k=2)		**0.019 % FS**	**0.050 % FS**	**0.075 % FS**	**0.18 % FS**

Table 3. PM200 Uncertainty Budget – See Table 2 for 1-year specification

Model	Range (psi)	Range (kPa)	Published 1 year spec. ±
PM500-BG1.4K	-0.2 to 0.2	-1.4 to 1.4	0.03 % FS + 0.02 % rdg
PM500-G2.5K	0 to 0.4	0 to 2.5	0.03 % FS + 0.02 % rdg
PM500-BG2.5K	-0.4 to 0.4	-2.5 to 2.5	0.03 % FS + 0.02 % rdg
PM500-BG3.5K	-0.5 to 0.5	-3.5 to 3.5	0.01 % FS + 0.01 % rdg
PM500-G7K	0 to 1	0 to 7	0.01 % FS + 0.01 % rdg
PM500-BG7K	-1 to 1	-7 to 7	0.01 % FS + 0.01 % rdg
PM500-G14K	0 to 2	0 to 14	0.01 % FS + 0.01 % rdg
PM500-BG14K	-2 to 2	-14 to 14	0.01 % FS + 0.01 % rdg
PM500-G20K	0 to 3	0 to 20	0.01 % FS + 0.01 % rdg
PM500-BG25K	-4 to 4	-25 to 25	0.01 % FS + 0.01 % rdg
PM500-G35K	0 to 5	0 to 35	0.01 % FS + 0.01 % rdg
PM500-BG40K	-6 to 6	-40 to 40	0.01 % FS + 0.01 % rdg
PM500-BG60K	-9 to 9	-60 to 60	0.01 % FS + 0.01 % rdg
PM500-G70K	0 to 10	0 to 70	0.01 % FS + 0.01 % rdg
PM500-NG100K	0 to -15	0 to -100	0.01 % FS + 0.01 % rdg
PM500-BG100K	-15 to 15	-100 to 100	0.01 % FS
PM500-G100K	0 to 15	0 to 100	0.01 % rdg or 0.005 % FS
PM500-BA120K	8 to 17	60 to 120	0.01 % rdg
PM500-A120K	0.01 to 17	0.08 to 120	0.01 % rdg or 0.005 % FS
PM500-A160K	0.01 to 23	0.08 to 160	0.01 % rdg or 0.005 % FS
PM500-BG200K	-15 to 30	-100 to 200	0.01 % FS
PM500-G200K	0 to 30	0 to 200	0.01 % rdg or 0.005 % FS
PM500-A200K	0.01 to 30	0.08 to 200	0.01 % rdg or 0.005 % FS

Model	Range (psi)	Range (kPa)	Published 1 year spec. ±
PM500-BG250K	-15 to 36	-100 to 250	0.01 % FS
PM500-G250K	0 to 36	0 to 250	0.01 % rdg or 0.005 % FS
PM500-BG350K	-15 to 50	-100 to 350	0.01 % FS
PM500-G350K	0 to 50	0 to 350	0.01 % rdg or 0.005 % FS
PM500-A350K	0.01 to 50	0.08 to 350	0.01 % rdg or 0.005 % FS
PM500-BG400K	-15 to 60	-100 to 400	0.01 % FS
PM500-G400K	0 to 60	0 to 400	0.01 % rdg or 0.005 % FS
PM500-G600K	0 to 90	0 to 600	0.01 % rdg or 0.005 % FS
PM500-BG700K	-15 to 100	-100 to 700	0.01 % FS
PM500-G700K	0 to 100	0 to 700	0.01 % rdg or 0.005 % FS
PM500-A700K	0.01 to 100	0.08 to 700	0.01 % rdg or 0.005 % FS
PM500-BG1M	-15 to 150	-100 to 1000	0.01 % rdg or 0.005 % FS
PM500-BG1.4M	-15 to 200	-100 to 1400	0.01 % rdg or 0.005 % FS
PM500-A1.4M	5 to 200	35 to 1400	0.01 % rdg or 0.005 % FS
PM500-BG2M	-15 to 300	-100 to 2000	0.01 % rdg or 0.005 % FS
PM500-A2M	10 to 300	70 to 2000	0.01 % rdg or 0.005 % FS
PM500-BG2.5M	-15 to 400	-100 to 2500	0.01 % rdg or 0.005 % FS
PM500-BG3.5M	-15 to 500	-100 to 3500	0.01 % rdg or 0.005 % FS
PM500-BG4M	-15 to 600	-100 to 4000	0.01 % rdg or 0.005 % FS
PM500-BG7M	-15 to 1000	-100 to 7000	0.01 % rdg or 0.005 % FS
PM500-BG10M	-15 to 1500	-100 to 10000	0.01 % rdg or 0.005 % FS
PM500-BG14M	-15 to 2000	-100 to 14000	0.01 % rdg or 0.005 % FS
PM500-BG20M	-15 to 3000	-100 to 20000	0.01 % rdg or 0.005 % FS

Table 4. PM500 1-year specifications

PM500 "% of reading type module"		
Variable or parameter	**Distribution**	**PM500-BA120K**
% of reading uncertainties		**% of reading**
Reference	normal	0.0010 %
Resolution	rectangular	0.00003 %
Conformance	normal	0.0020 %
Repeatability	normal	0.0015 %
Temperature	normal	0.0021 %
Stability	rectangular	0.0029 %
Zero drift	rectangular	0.0012 %
Absolute zeroing reference	normal	0.0017 %
Combined		**0.0049 % of reading**
Combined and expanded for (k=2)		**0.099 % of reading**

Table 5. PM500-BA120K Uncertainty Budget–See Table 4 for 1-year specification

PM500 "% of Full Scale type module"							
Variable or parameter	**Distribution**	**PM500-BG100K**	**PM500-BG200K**	**PM500-BG250K**	**PM500-BG350K**	**PM500-BG400K**	**PM500-BG700K**
% of reading uncertainties		**% of full scale**					
Reference	normal	0.0010 %	0.0010 %	0.0010 %	0.0010 %	0.0010 %	0.0010 %
Resolution	rectangular	0.00003 %	0.00003 %	0.00003 %	0.00003 %	0.00003 %	0.00003 %
Conformance	normal	0.0020 %	0.0020 %	0.0020 %	0.0020 %	0.0020 %	0.0020 %
Repeatability	normal	0.0015 %	0.0015 %	0.0015 %	0.0015 %	0.0015 %	0.0015 %
Temperature	normal	0.0030 %	0.0030 %	0.0030 %	0.0030 %	0.0030 %	0.0030 %
Stability	rectangular	0.0029 %	0.0029 %	0.0029 %	0.0029 %	0.0029 %	0.0029 %
Zero drift	rectangular	0.0006 %	0.0006 %	0.0006 %	0.0006 %	0.0006 %	0.0006 %
Combined		**0.0050 % FS**	**0.0050 % FS**	**0.0050 % FS**	**0.0050 % FS**	**0.0050 % FS**	**0.0050 % FS**
Combined and expanded for (k=2)		**0.010 % FS**	**0.010 % FS**	**0.010 % FS**	**0.010 % FS**	**0.010 % FS**	**0.010 % FS**

Table 6. PM500 "% FS" type module Uncertainty Budget–See Table 4 for 1-year specification

PM500 "% of Full Scale + % of reading type module"				
Variable or parameter	**Distribution**	**PM500-BA120K**	**PM500-BG1.4K**	**PM500-BG2.5K**
% FS uncertainties		**% of full scale**		
Reference	normal	0.0015 %	0.0027 %	0.0015 %
Resolution	rectangular	0.00003 %	0.00003 %	0.00003 %
Conformance	normal	0.0075 %	0.0075 %	0.0075 %
Temperature	rectangular	0.0058 %	0.0058 %	0.0058 %
Zero Drift	rectangular	0.0058 %	0.0058 %	0.0058 %
Combined		**0.011 % FS + 0.010 % of reading**	**0.011 % FS + 0.010 % of reading**	**0.011 % FS + 0.010 % of reading**
Combined and expanded for (k=2)		**0.022 % FS + 0.020 % of reading**	**0.023 % FS + 0.020 % of reading**	**0.022 % FS + 0.020 % of reading**
% of reading uncertainties		**% of reading**		
Reference	normal	0.005 %	0.005 %	0.005 %
Repeatability	normal	0.005 %	0.005 %	0.005 %
Temperature	normal	0.0038 %	0.0038 %	0.0038 %
Stability	rectangular	0.0058 %	0.0058 %	0.0058 %
PM500 "% of Full Scale + % of reading type module"				
Variable or parameter	**Distribution**	**G7K through G70K**	**BG3.5K through BG60K**	**PM500-NG100K**
% FS uncertainties		**% of full scale**		
Reference	normal	0.0013 %	0.001 %	0.0003 %
Resolution	rectangular	0.00003 %	0.00003 %	0.00003 %
Conformance	normal	0.0025 %	0.0025 %	0.0025 %
Temperature	rectangular	0.0029 %	0.0029 %	0.0029 %
Zero Drift	rectangular	0.0006 %	0.0006 %	0.0006 %
Combined		**0.004 % FS + 0.005 % of reading**	**0.004 % FS + 0.005 % of reading**	**0.004 % FS + 0.005 % of reading**
Combined and expanded for (k=2)		**0.008 % FS + 0.010 % of reading**	**0.008 % FS + 0.010 % of reading**	**0.008 % FS + 0.010 % of reading**
% of reading uncertainties		**% of reading**		
Reference	normal	0.0015 %	0.0015 %	0.0015 %
Repeatability	normal	0.0025 %	0.0025 %	0.0025 %
Temperature	normal	0.0028 %	0.0028 %	0.0028 %
Stability	rectangular	0.0029 %	0.0029 %	0.0029 %

Table 7. PM500 "% FS plus % of reading" type module Uncertainty Budget–See Table 4 for 1-year specification

PM500 "% of reading OR % of FS type module" absolute modules						
Variable or parameter	**Distribution**	**< A200K**	**A200K**	**A350K**	**A700K**	**>700K**
% of reading uncertainties		**% of reading**				
Reference	normal	0.0010 %	0.0010 %	0.0010 %	0.0010 %	0.0013 %
Conformance	normal	0.0030 %	0.0030 %	0.0030 %	0.0030 %	0.0030 %
Repeatability	normal	0.0015 %	0.0015 %	0.0015 %	0.0015 %	0.0015 %
Temperature	normal	0.0020 %	0.0020 %	0.0020 %	0.0020 %	0.0020 %
Stability	rectangular	0.0029 %	0.0029 %	0.0029 %	0.0029 %	0.0029 %
Combined		**0.005 % of reading or 0.0025 % FS**	**0.005 % of reading or 0.0022 % FS**	**0.005 % of reading or 0.0025 % FS**	**0.005 % of reading or 0.0025 % FS**	**0.005 % of reading or 0.0023 % FS**
Combined and expanded for (k=2)		**0.010 % of reading or 0.0050 % FS**	**0.010 % of reading or 0.0045 % FS**	**0.010 % of reading or 0.0050 % FS**	**0.010 % of reading or 0.0050 % FS**	**0.010 % of reading or 0.0047 % FS**
% FS uncertainties		**% of full scale**				
Reference	normal	0.00008 %	0.00005 %	0.00014 %	0.00007 %	0.00011 %
Resolution	rectangular	0.00003 %	0.00003 %	0.00003 %	0.00003 %	0.00003 %
Conformance	normal	0.0017 %	0.0017 %	0.0017 %	0.0017 %	0.0017 %
Temperature	rectangular	0.0006 %	0.0006 %	0.0006 %	0.0006 %	0.0006 %
Zero drift	rectangular	0.0012 %	0.0016 %	0.0012 %	0.0006 %	0.0003 %
Absolute zeroing Reference	normal	0.0013 %	0.0006 %	0.0013 %	0.0017 %	0.0015 %

PM500 "% of reading OR % of FS type module" gauge modules			
Variable or parameter	**Distribution**	**G100K through G700K**	**BG1M through BG20M**
% of reading uncertainties		**% of reading**	
Reference	normal	0.0010 %	0.0010 %
Conformance	normal	0.0030 %	0.0030 %
Repeatability	normal	0.0015 %	0.0015 %
Temperature	normal	0.0020 %	0.0025 %
Stability	rectangular	0.0029 %	0.0029 %
Combined		**0.005 % of reading or 0.0021 % FS**	**0.005 % of reading or 0.0021 % FS**
Combined and expanded for (k=2)		**0.010 % of reading or 0.0042 % FS**	**0.010 % of reading or 0.0042 % FS**
% of reading uncertainties		**% of full scale**	
Reference	normal	0.00010 %	0.00010 %
Resolution	rectangular	0.000029 %	0.000029 %
Conformance	normal	0.0017 %	0.0017 %
Temperature	rectangular	0.0012 %	0.0012 %
Zero drift	rectangular	0.0006 %	0.0006 %

Table 8. PM500 "% FS or % of reading" type module Uncertainty Budget–See Table 4 for 1-year specification

PM600 standard class absolute mode			
Variable or parameter	**Distribution**	**Absolute**	**BRM600 BA100K**
Relative uncertainties		**% of reading**	
Reference	normal	0.0015 %	0.0015 %
Conformance	rectangular	0.0033 %	0.0033 %
Repeatability	normal	0.0020 %	0.0020 %
Temperature	normal	0.0006 %	0.0006 %
Stability	rectangular	0.0029 %	0.0029 %
Combined		**0.005 % of rdg or 0.0012 % Q-RPT span**	**0.005 % of rdg**
Combined and expanded for (k=2)		**0.010 % of rdg or 0.0024 % Q-RPT span**	**0.010 % of rdg**
% FS uncertainties		**% Q-RPT span**	
Reference	normal	0.00003 %	
Resolution	rectangular	0.00003 %	
Precision	normal	0.0012 %	
Temperature	rectangular	0.0003 %	
Stability	rectangular	RSS of lowest range PM600 at ATM	

PM600 standard gauge mode						
Variable or parameter	**Distribution**	**PM600-BG15K**	**Gauge PM600-A100K**	**Gauge PM600-A200K**	**Gauge > A200K**	**PM600 G100K/ G200K**
Relative uncertainties		**% of reading**				
Reference	normal	0.0015 %	0.0015 %	0.0015 %	0.0015 %	0.0015 %
Conformance	rectangular	0.0033 %	0.0033 %	0.0033 %	0.0033 %	0.0033 %
Repeatability	normal	0.0020 %	0.0020 %	0.0020 %	0.0020 %	0.0020 %
Temperature	normal	0.0006 %	0.0006 %	0.0006 %	0.0006 %	0.0006 %
Stability	rectangular	0.0029 %	0.0029 %	0.0029 %	0.0029 %	0.0029 %
Line pressure	rectangular	0.0005 %	N/A	N/A	N/A	N/A
Combined		**0.005 % of rdg or 0.0009 % Q-RPT span**	**0.005 % of rdg or 0.0037 % Q-RPT span**	**0.005 % of rdg or 0.0022 % Q-RPT span**	**0.005 % of rdg or 0.0012 % Q-RPT span**	**0.005 % of rdg or 0.0012 % Q-RPT span**
Combined and expanded for (k=2)		**0.010 % of rdg or 0.0018 % Q-RPT span**	**0.010 % of rdg or 0.0074 % Q-RPT span**	**0.010 % of rdg or 0.0044 % Q-RPT span**	**0.010 % of rdg or 0.0024 % Q-RPT span**	**0.010 % of rdg or 0.0024 % Q-RPT span**
% FS uncertainties		**% Q-RPT span**				
Reference	normal	0.00003 %	0.00003 %	0.00003 %	0.00003 %	0.00003 %
Resolution	rectangular	0.00003 %	0.00003 %	0.00003 %	0.00003 %	0.00003 %
Precision	normal	0.0008 %	0.0012 %	0.0012 %	0.0012 %	0.0012 %
Temperature	rectangular	0.0003 %	0.0003 %	0.0003 %	0.0003 %	0.0003 %
Line Pressure	rectangular	0.0002 %	N/A	N/A	N/A	N/A
Dynamic Baro Compensation	rectangular		0.0035 %	0.0018 %	N/A	N/A

Table 9. PM600–Q-RPT standard class uncertainty budget

Q-RPT ranges: G100K, G200K, A100K, A200K, A350K, A700K, A1.4M, A2M, A3.5M, A7M, A10M, A14M and A20M.

1-year specification ± (0.01 % of reading or 0.003 % of Q-RPT span, whichever is greater) for absolute RSS with absolute AutoZero reference module uncertainty at atmospheric pressure, or 0.007 % of Q-RPT span if an AutoZero reference PMM is not used.

The uncertainty budget tables show the influence, type of distribution, standard uncertainty (k=1) reduced by either 2, for normal, or by the square root of 3 for rectangular distributions, and the combined and expanded uncertainty. The expansion was based on a factor of 2. With the conservative approach in determining the influences described for the population of the PMMs, effective degrees of freedom is estimated to be large enough to assume that the expansion is a good representation of 95 % confidence.

Onboard pressure uncertainty calculator

The 2271A and 6270A Pressure Controller/Calibrators include the ability to do real time calculation of the estimated uncertainty. This tool is extremely useful due to the flexible configurations allowed by the variety of pressure measurement modules available.

The uncertainty calculation uses a number of variables, some of which are stored in each pressure module and some that are stored in the main chassis (2271A or 6270A).

Uncertainty values stored in the pressure measurement module

These values come pre-loaded from the factory with the default instrument specifications. To view or edit these values from the front panel, press [SETUP][Module Information][Slot x][Uncertainty]. These values are password protected. All uncertainty values entered are treated as 95 % confidence level.

U_{THRESH} = Threshold Uncertainty –The uncertainty component of the module that is expressed as a constant pressure value.

U_{READ} = Relative Uncertainty– The uncertainty component of the module that is relative to the measured pressure.

U_{ABS} = Uncertainty associated with the zero instability over time (absolute mode modules only)

Combination Method = Defines how the Threshold Uncertainty and the Relative Uncertainty are combined together to give the overall uncertainty associated with the module.

Uncertainty values stored in the main chassis

These values affect the uncertainty independent of the measurement module used. To view or edit these values from the front panel, press [SETUP][Instrument Setup][Uncertainty].

U_{HEAD} = Uncertainty of head height measurement in millimeters, centimeters, or inches. Default value is 0.

U_{ADD1} = User defined additional Uncertainty Value (value in pressure). Default value is 0.

U_{ADD2} = User defined additional Uncertainty Value (value in % reading). Default value is 0.

Include Control Uncertainty = When set to Yes the additional uncertainty associated with the instability in the control is included. An example of when this should be set to Yes is if the user is observing the ready indicator only, and not observing the actual measured pressure. The default setting is "No."

Show Uncertainty = Allows the user to turn off the indication of measurement uncertainty. The default setting is Yes.

Other values used in the calculation of pressure

The following values are also used during the calculation of the uncertainty.

ρ_{MEDIA} = Density of the gas media

ρ_{AIR} = Ambient air density

G_{STD} = Standard acceleration of gravity (9.80665 m/s2)

P_{CURR} = The currently measured pressure (absolute value)

Calculation of Uncertainty

The following calculations are performed in order to determine the total estimated uncertainty.

U_{MODULE} =

When set to "Greater of Mode": $MAX[(U_{READ} \times P_{CURR}), U_{THRESH}$

When set to "Addition": $U_{READ} \times P_{CURR} + U_{THRESH}$

$U_{CONTROL}$ = Uncertainty due to control noise. When Include Control Uncertainty is set to Yes and the controller is in dynamic mode it equals the Ready Tolerance. In all other cases it equals 0.

U_{ABS} = Additional uncertainty component when operating in absolute mode.

When using inherently gauge mode sensors in absolute mode by addition of atmospheric pressure, UABS equals the uncertainty of the atmospheric pressure measurement. If atmospheric pressure is a manual entry, then it is the value entered on the [SETUP][Measure Setup][Atmosphere] screen. If atmospheric pressure is being read by a barometric reference module, then it is the calculated uncertainty of that measurement.

When using inherently absolute mode modules with AutoZero off, then it is equal to the UABS value for that module. When AutoZero is off the user has the option to enter a manual AutoZero. In this case the uncertainty used is from the atmospheric manual entry [SETUP][Measure Setup][Atmosphere] screen. The value entered for manual atmospheric pressure AutoZero is also used for the current manual atmospheric pressure.

When using inherently absolute mode modules with AutoZero on, then it is equal to the calculated uncertainty of the selected zeroing reference PMM at atmospheric pressure.

FLUKE ®
Calibration

Final uncertainty calculations

Uncertainty in gauge mode

$$U_{TOTAL} = \sqrt{\left(\frac{U_{MODULE}}{2}\right)^2 + \left(\frac{U_{HEAD} \times G_{STD} \times (\rho_{MEDIA} - \rho_{AIR})}{2}\right)^2 + \left(\frac{U_{CONTROL}}{\sqrt{3}}\right)^2 + \left(\frac{U_{ADD1}}{2}\right)^2 + \left(\frac{U_{ADD2} \times \rho_{CURR}}{2}\right)^2} \times 2$$

Uncertainty in absolute mode (no AutoZero)

$$U_{TOTAL} = \sqrt{\left(\frac{U_{MODULE}}{2}\right)^2 + \left(\frac{U_{ABS}}{\sqrt{3}}\right)^2 + \left(\frac{U_{HEAD} \times G_{STD} \times \rho_{MEDIA}}{2}\right)^2 + \left(\frac{U_{CONTROL}}{\sqrt{3}}\right)^2 + \left(\frac{U_{ADD1}}{2}\right)^2 + \left(\frac{U_{ADD2} \times \rho_{CURR}}{2}\right)^2} \times 2$$

Uncertainty in absolute mode (with AutoZero on or when using a gauge mode module with the addition of atmospheric pressure)

$$U_{TOTAL} = \sqrt{\left(\frac{U_{MODULE}}{2}\right)^2 + \left(\frac{U_{ABS}}{2}\right)^2 + \left(\frac{U_{HEAD} \times G_{STD} \times \rho_{MEDIA}}{2}\right)^2 + \left(\frac{U_{CONTROL}}{\sqrt{3}}\right)^2 + \left(\frac{U_{ADD1}}{2}\right)^2 + \left(\frac{U_{ADD2} \times \rho_{CURR}}{2}\right)^2} \times 2$$

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Fluke Calibration
PO Box 9090, Everett, WA 98206 U.S.A.

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands
Web access: http://www.flukecal.eu

For more information call:
In the U.S.A. (877) 355-3225 or
Fax (425) 446-5716
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) 446-6110 or
Fax +1 (425) 446-5716
Web access: http://www.flukecal.com

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