FLUKE®
Calibration

Expanding the Use of a Piston Gauge – Differential and Negative Gauge Modes

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Expanding the Use of a Piston Gauge

You have a Piston Gauge.

You need to calibrate a low pressure device, **BUT**…

- You lack a specialized low pressure calibrator
- You have a low pressure calibrator, but need greater stability & accuracy

What are your options?

Expanding the Use of a Piston Gauge

Options…

a) Buy a specialized low pressure calibrator

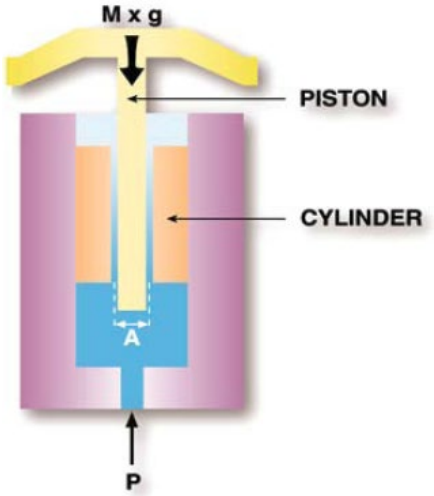
b) Send your device to a third party calibration lab

c) Utilize your Piston Gauge in a method which it's not traditionally used

Expanding the Use of a Piston Gauge

c) Utilize your Piston Gauge in a method which it's not traditionally used...

- A Piston Gauge operates on the DWT principle of P = F / A
- Solves the Fundamental Pressure Equation using the downward force of (mass x gravity) acting on the effective area of the piston-cylinder
- Lowest pressure defined = minimum mass. (e.g.: the piston, or piston + bell)



Limitation!

Expanding the Use of a Piston Gauge – Differential and Negative Gauge Modes

- Piston Gauge Differential Mode
- Piston Gauge Negative Gauge Mode

- ~~Dual P.G. or High Line Pressure Differential Mode.~~

This method is not addressed in this presentation

Terminology

All measurements are differential in nature.

$$d\text{Meas} = (\text{Ending Pt.}) - (\text{Starting Pt.})$$

All pressure measurements are differential in nature.

$$dP = (\text{Meas. Pressure}) - (\text{Reference Pressure})$$

$$dP_{gauge,0} = (101.325\ \text{kPa}) - (101.325\ \text{kPa})$$

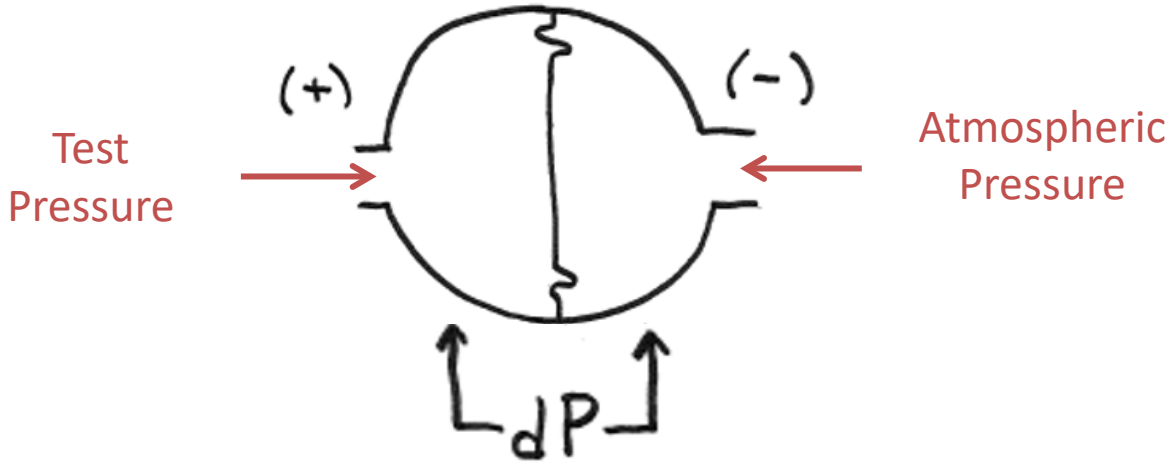
$$dP_{abs,Baro} = (101.325\ \text{kPa}) - (0\ \text{kPa})$$

For convenience, we give names for two common conditions:

- Gauge pressure
- Absolute pressure

Terminology

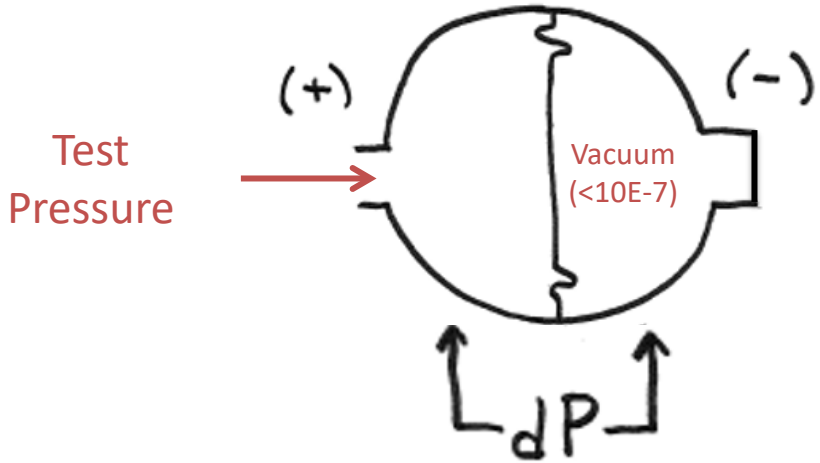
Gauge pressure



dP = Test(+) – Test(-)
= Test Press - Atms

Terminology

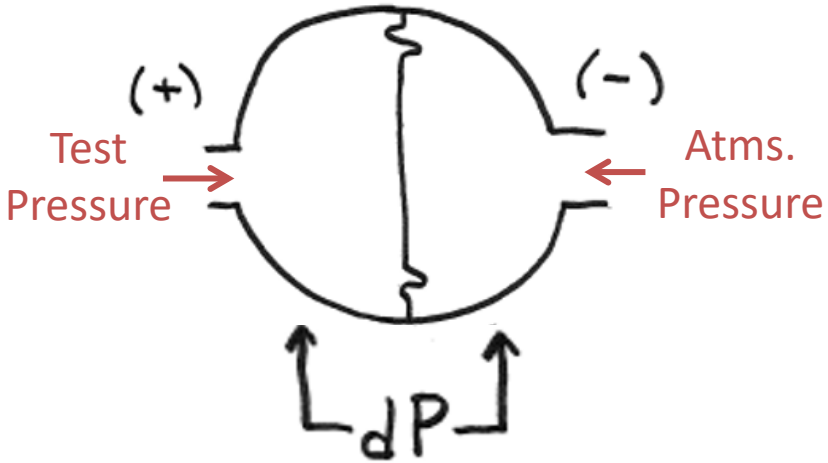
Absolute pressure



dP = Test(+) – Test(-)
= Atms P - 0

Terminology

“Differential” pressure



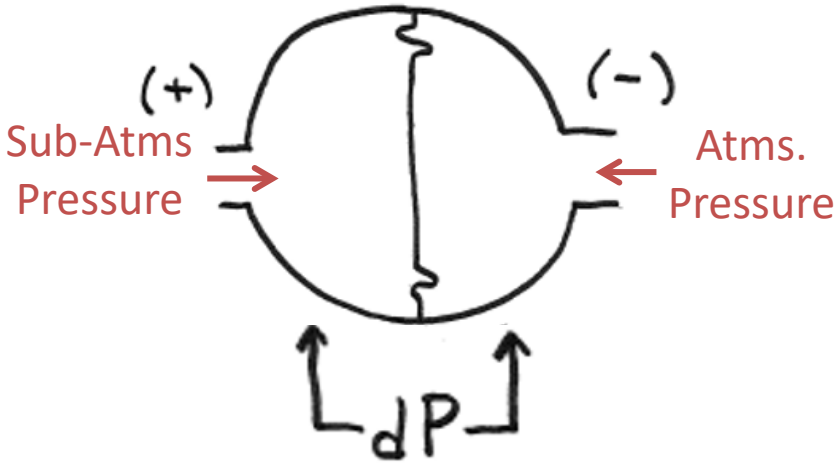
dP = Test(+) – Test(-)
= Test Press - Atms

- Associated with a small magnitude of pressure
- Typically, relative to atmosphere
- “Inches of Water”; “mbar”

- Commonly, if a technician sees two pressure port connections on a low pressure sensor, call it a “differential sensor”

Terminology

“Negative Gauge” / “Vacuum” pressure



dP = Test(+) – Test(-)
= Test Press - Atms

“Negative Gauge”

- dP whose TEST(+) pressure is less than atmospheric pressure
- “-5 psig”; -10 InHg

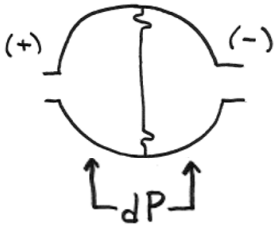
“Vacuum”

- Industrial term, not common in metrology labs
- “10 Inches of Vacuum” ➔ ~1/3 below atmospheric pressure (ie: -5 psig)

Overview

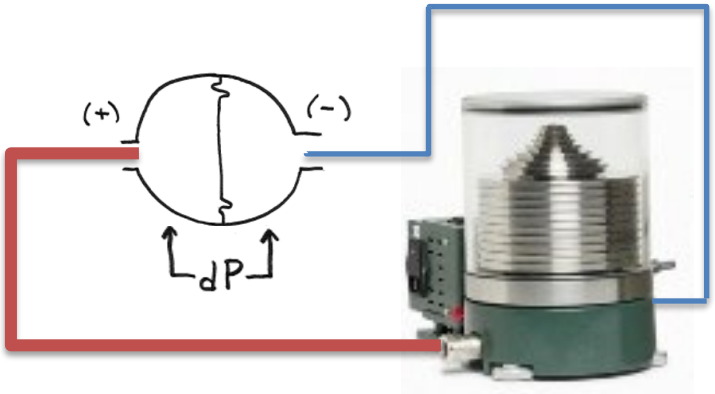
Method 1: “PG Differential Mode”

- PG is operated under reference vacuum conditions
- A digital barometer is used to measure static (atmospheric) pressure
- Static value is subtracted from the PG value
- $dP = PG_{Abs} – Static_{Abs}$
- Positive and Negative pressures



Method2: “PG Negative Gauge Mode”

- Test port connections are reversed
  - Piston to DUT (-) port
  - Bell jar to DUT (+) port
- Piston is floated at atmospheric pressure
- Pressure (vacuum) under the bell jar is adjusted to define the dP
- dP = (Bell Jar_{vac}) – ($Piston_{Atms}$)
- Negative pressure only



PG Differential Mode method

Available with the PG7601 and the 2465

Allows for a positive and negative distribution of dP around atmosphere.

PG7601*:

- Known as “differential” mode
- Standard feature of the PG7000 embedded firmware
- External software is not required
- External high precision barometer is required, RS232 link to PG7601

2465**:

- Known as “Very Low Gauge mode”
- Standard feature of the WinPrompt software
- Uses barometer from the 2465A autofloat controller

PG Differential Mode method

Concept:

- The PG7601 operates as if it were in Absolute by Vacuum – defines an absolute pressure relative to reference vacuum under the bell jar
- A high accuracy digital barometer measures the static reference pressure – typically atmospheric pressure
- The barometer is electronically connected to the PG7601 via RS232
- Static pressure is mathematically subtracted from the PG7601's pressure to arrive a net differential value…

  …and displayed on the PG Terminal screen.

PG Differential Mode method

Concept:

$$PG_{dP} = PG_{Abs.} - Barometer_{Abs.}$$

Example:

$$0.10\ kPad = 101.425\ kPaa - 101.325\ kPaa$$

PG Differential Mode method

Barometer Calibration: a single point comparison against the floating piston at / near the static (atmospheric) pressure.

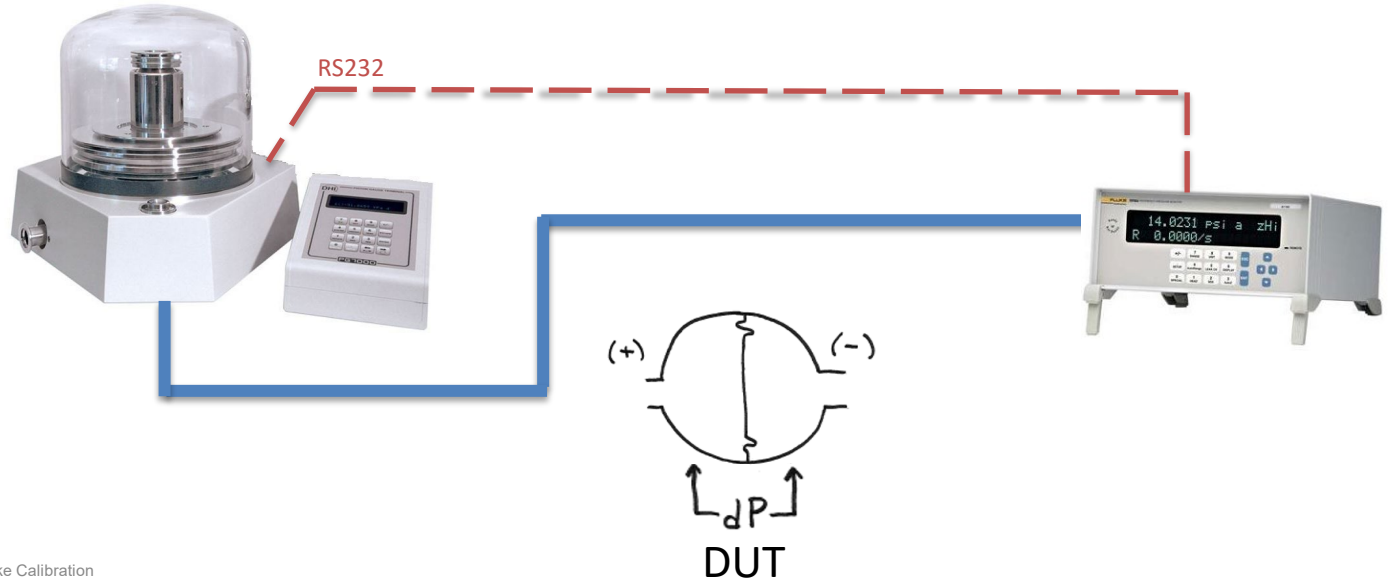
- Piston is brought into float, pressure is applied to the Barometer
- The difference in pressure between the PG and Barometer is recorded as the *Barometer Offset*.
- Cancels the long term drift component of error, allowing only the resolution and short term repeatability of the barometer to contribute to the uncertainty of the calculated differential pressure.

$$PG_{dP} = PG_{Abs.} - Barometer_{Abs.} - Baro_{offset}$$

PG Differential Mode method

Barometer Offset determination plumbing

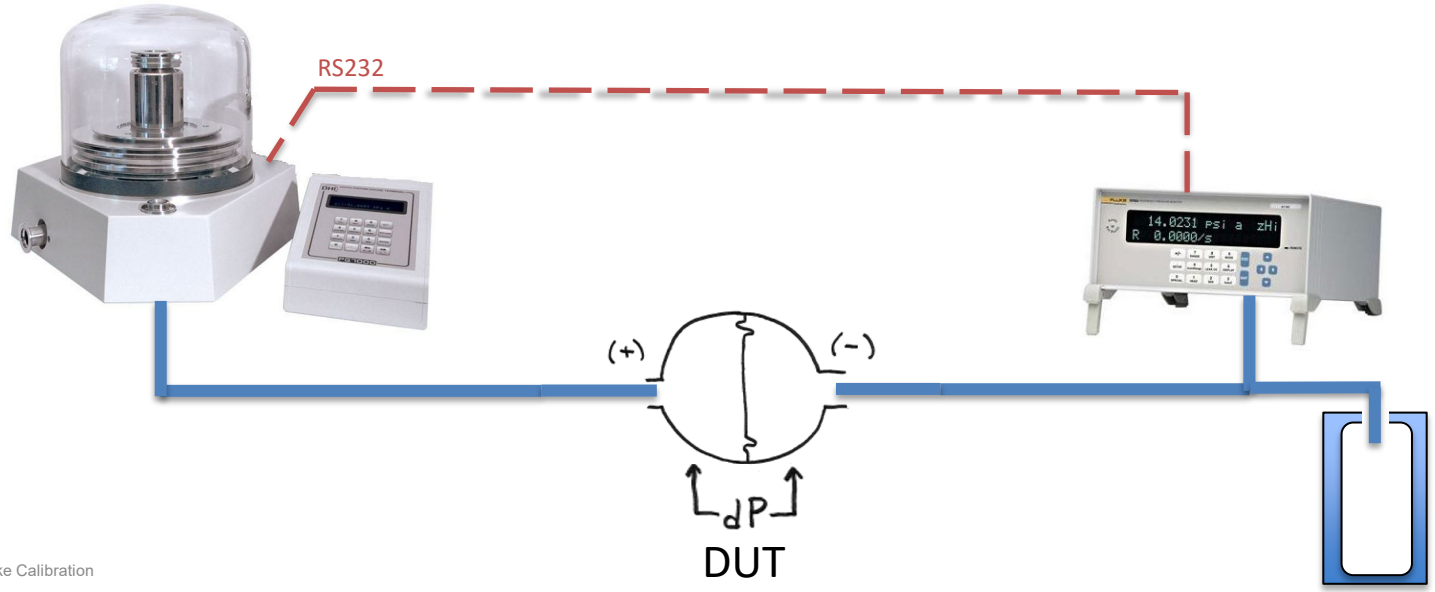
- This is the first step that must be performed before dP mode can be used.



PG Differential Mode method

PG7601 plumbing arrangement for regular dP operation

- Help stabilize static side pressure by adding volume. This is an optional setup step.



PG Differential Mode method

Sequence (PG7601):

1. Configure the PG's COM2 port for communication with the Barometer
2. Select the Differential mode from the PG Terminal [MODE] button
3. The PG Terminal displays a message asking if you want to determine a new offset
   a) Make the plumbing connection to the Barometer,
   b) Load the required mass on the piston, establish reference vacuum
   c) Float the piston, wait for Ready condition
4. The PG Terminal display will show old and new offset values. Press [ENTER] to activate
5. Change plumbing, connect to DUT
6. From the PG Terminal, use [SET P] to request the desired dP target

PG Differential Mode method

Overview (2465):

- Measurement mode “Very Low Gauge”
- Requires use of the autofloat controller and WinPrompt software
- Valves internal to the controller cut the barometer in / out of the circuit as needed.
- Barometer Offset determination step identified as “R” in the calibration sequence.
  - Double-click the “R” sequence selection
  - Use the Barometer measurement (bottom status line in WinPrompt) as the float target value
  - Establish reference vacuum, autofloat the piston, click “OK” to accept the offset
- Continue the test using the desired dP as the target values

PG Differential Mode – Pro / Con

Pros:

- Allows for positive and negative differential pressure
- Relatively easy, minimal operator influence on results
- Maintains same static pressure on DUT TEST(-) port for both directions
  - i.e.: do not have to change test port connections when crossing over from positive to negative pressure
- Define dP relative to different static pressure

Cons:

- Lowest negative pressure limited to minimum mass of the piston

$$NegP_{low} = (-1)(Static\ P - Min\ Mass\ P)$$

- Added uncertainty from the barometer

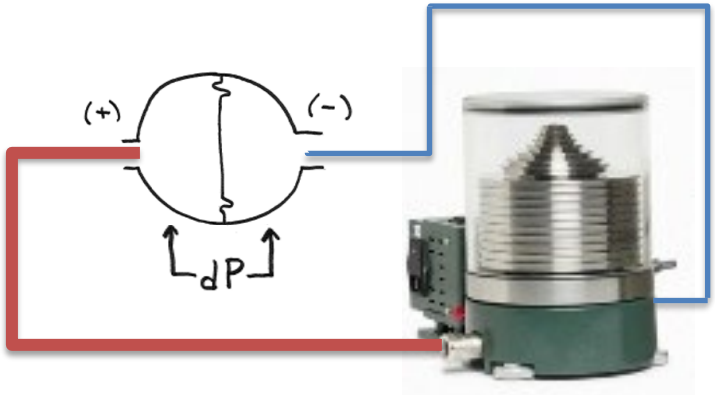
PG Negative Gauge Mode method

- For use with the 2465
- Supported via WinPrompt and COMPASS for Pressure software
- Only supports negative pressure (sub-atmospheric)

- Barometer is not used
- Differential defined relative to a static pressure under the piston

$$dP = (\text{Bell Jar}_{vac}) - (\text{Piston}_{StaticP})$$

-50 kPag = (51.325 kPaa) – (101.325 kPaa)



PG Negative Gauge Mode method

Concept:

- 2465's pressure connections are reversed from traditional applications
  - 2465 TEST(+) ➔ DUT TEST(-)
  - 2465 Bell Jar vent port ➔ DUT TEST(+)
- Static pressure is defined and maintained by floating piston
- Pressure (vacuum) under the bell jar is changed to change the dP
- Software determines mass load, calculates pressure
- Control hardware required for both circuits:
  - Set / Maintain piston float
  - Set / Maintain bell jar pressure
  - Model 3990 supports both circuits

PG Negative Gauge Mode method

Setup Plumbing – if using the 3990:

- Connect the plumbing to the rear panel as per the labeled ports
- Move the front panel selector knob into “Negative Gauge” position

- Only requires one vacuum pump – might find it convenient to use the utility pump as it’s plumbed into the 3990.

PG Negative Gauge Mode method

Sequence (with 3990):

1. Open the REF VENT valve – exposes DUT(-) and Piston to atmosphere.
2. Load masses as per the software to define dP
3. Close the REF VENT valve
4. Use VACUUM SUPPLY valve to lower the bell jar pressure to float the piston
5. Use variable volume to fine tune float position if needed.
    1. Note: this becomes more important the larger the -dP becomes due to the thermal changes in the lower-density gas under the bell jar.

PG Negative Gauge Mode – pro / con

Pros:

- Attain largest possible negative pressure… approximately -1 atms.
- Lower uncertainty than PG Diff mode
  - the barometer is not used, no added uncertainty

Cons:

- Ability to maintain piston float becomes more difficult with larger –dP
- Best suited for DUTs with two test ports where tubing can be connected
- Smallest –dP limited by minimum mass of piston

Summary

- If you have a PG then you already have the primary piece for dP work
- PG7601 has native support for PG Differential Mode
  - (PG7601, PG7607, PG9602, PG9607)
  - Add a high precision barometer and minor plumbing modifications
  - No external software required
  - Allows for positive and negative pressure distribution around the static pressure

Summary

- You already have the primary piece!
- 2465 can be used with either PG Differential or Negative Gauge method if existing hardware is available
  - PG Diff method requires an existing autofloat controller
  - PG Negative Gauge mode is made convenient with the 3990 control box
  - WinPrompt or COMPASS for Pressure software support for Neg. Gauge mode

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