

## PG7000 DIFFERENTIAL MODE FOR DEFINING LOW AND NEGATIVE DIFFERENTIAL PRESSURE AT VARIOUS STATIC PRESSURES

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### FOREWORD

Conventional piston gauges have limitations in the lowest pressure that can be defined, in defining negative differential pressures (i.e. differential pressures that are under the static pressure) and in defining pressures at a static pressure other than atmosphere or vacuum.

Traditionally, the minimum pressure that can be defined by a piston gauge is the pressure that results when the minimum mass load (the piston alone) is loaded on the piston-cylinder effective area. The pressure can be referenced to atmosphere (gauge pressure) or vacuum (absolute pressure) by enclosing the mass load under a bell jar. This low point tends to be poorly defined due to poor mass load distribution and low rotational momentum; it is often not low enough and cannot be defined reliably at static pressures other than atmosphere or vacuum.

One method for defining differential pressures lower than the normal limit has been to use two piston gauges. One is "tared" against the other at a static pressure and then small differential pressures are defined by increasing the pressure on one of them. This method roughly doubles system cost and space as two piston gauges are needed; it requires operating at an elevated static pressure and it is tedious and highly operator dependent.

Pressures measured relative to atmosphere but lower than atmosphere ("negative gauge pressures") have sometimes been defined by switching pressure ports on a bell jar equipped piston gauge so that atmospheric pressure (the static pressure) is supplied under the piston and the negative gauge pressure is established under the bell jar. This method requires calculating air buoyancy on the mass load at varying pressures. It also requires different configurations for "positive" and "negative" pressures which complicates the system hardware, is inconvenient to use and can lead to calibration discontinuities when calibrating

compound ranges that include pressure both below and above the static pressure going through zero.

PG7000 Differential Mode is a new technique designed to improve the coverage of low differential pressures with a piston gauge.

### DIFFERENTIAL MODE PRINCIPLE

The differential mode principle is to define differential pressure as the difference between the absolute pressure defined by a piston gauge and the static pressure measured by a high precision, digital Reference Pressure Monitor (RPM). A simple offsetting procedure is used to offset the RPM relative to the piston gauge at the static pressure so that only the resolution and short term repeatability of the RPM contribute to the uncertainty in the differential pressure definition.

### DIFFERENTIAL MODE OPERATION

Differential mode operation can be selected directly on the PG7000 terminal in the same manner as gauge or absolute mode. PG7000's on-board integrated data acquisition and reduction capabilities are used to manage differential mode operation. The RPM is interfaced directly with the PG7000 and read automatically in real time.

The PG7000 Differential Mode Interconnections Kit provides the necessary interconnections and valving for differential mode operation (see **EQUIPMENT REQUIRED FOR PG7601 DIFFERENTIAL MODE OPERATION.**)

From a practical standpoint, differential mode operation is identical to operation in absolute by vacuum mode. Vacuum under the PG7601 bell jar must be established at each increment. In addition, the RPM offsetting procedure must be performed, preferably at the beginning of each test run or each time the static pressure is changed.

**CALCULATIONS**

The differential pressure,  $PG_{dif}$ , defined by the PG7000 at static pressure,  $PG_{RPMstart}$ , is calculated by the following:

$$PG_{dif} = PG_{abs} - RPM_{current} - RPM_{offset}$$

Where:

$$PG_{dif} = \text{Differential pressure defined by PG7601}$$

$$PG_{abs} = \text{Absolute pressure defined by PG7601}$$

$$RPM_{current} = \text{Current RPM reading of static pressure}$$

$$RPM_{offset} = PG_{RPMstart} - RPM_{Indicate}$$

and:

$$PG_{RPMstart} = \text{the static pressure value, applied by PG7601 to the RPM at the start of the test to determine the RPM offset at the static pressure}$$

$$RPM_{Indicate} = \text{RPM reading when } PG_{RPMstart} \text{ is applied to RPM test port}$$

**SPECIFICATIONS**

Specifications assume the piston gauge used is a PG7601 with a 10 kPa/kg (35 mm) piston-cylinder and a 35 kg mass set and the static pressure monitor is an RPM3-A0015.

**Static Pressure Range:**

15 to 100 kPa absolute (2.2 to 15 psia)

**Differential Pressure Range:**

Positive and negative around the static pressure with a minimum of 15 kPa absolute (0.7 psia) and a maximum of 350 kPa absolute. For example, if the static pressure is 100 kPa, the minimum differential pressure is - 85 kPa (- 12.3 psi) and the maximum differential pressure is + 250 kPa (+ 36.3 psi). Includes positive and negative values at and near zero.

**Repeatability:**

$\pm 0.3 \text{ Pa (0.000044 psi)}$

**Accuracy:**

$\pm (0.3 \text{ Pa} + 20 \text{ ppm})$

**UNCERTAINTY ANALYSIS**

The uncertainty analysis assumes the piston gauge used is a PG7601 with a 10 kPa/kg (35mm diameter) piston-cylinder and a 35 kg mass set and the static pressure monitor is an RPM3-A0015.

The uncertainty in the differential pressure defined is the uncertainty in the definition of absolute pressure with a vacuum reference adjusted to take into account; a) definition of the pressure with respect to the relative value of static pressure measured by the RPM rather than the absolute value of static pressure measured by the vacuum gauge and, b) a reduction of uncertainties associated with low mass loads.

The uncertainty of PG7601 in absolute by vacuum reference mode is analyzed in **DHI Technical Note 7920TN01**, "Uncertainty Analysis for Pressure Defined by A PG7201 or PG7601 Piston Gauge." The standard accuracy specification with a coverage factor of two is  $\pm (0.2 \text{ Pa} + 20 \text{ ppm})$ .

The uncertainty on differential mode pressure definitions is the uncertainty in absolute by vacuum reference mode modified by:

- **Reduction of the uncertainty on vacuum (see B7 of the Technical Note 7920TN01):** In differential mode, the contribution of vacuum measurement is the repeatability of the vacuum gauge, not the absolute value of the vacuum measurement. Differences in the measurement of vacuum when determining  $RPM_{offset}$  and when making subsequent differential pressure measurements will offset the measurements. One standard uncertainty of the repeatability of the vacuum gauge for subsequent measurements within  $\pm 1 \text{ Pa}$  of each other is estimated to be 0.03 Pa.
- **Reduction of uncertainties associated with low mass loads (see B1 of the uncertainty analysis):** In differential mode, the uncertainty on the mass load corresponding to the static pressure is eliminated in the RPM offset



procedure. The only remaining mass uncertainty is the relative uncertainty on the differential mass load corresponding to the differential pressure. The most significant aspect of this uncertainty reduction is the elimination of constant uncertainties on the piston and mass loading bell masses.

- **The uncertainty on  $RPM_{offset}$ :** This uncertainty is a function of the resolution and short term stability (the time of the differential mode test sequence) of the RPM at the static pressure value. By statistical experience with a population of RPM-A0015 instruments, one standard uncertainty is estimated to be 0.15 Pa.

The “Absolute w/ Application of Vacuum” column of the **10 KPA/KG PISTON-CYLINDER RANGE** uncertainty table of Technical Note 7920TN01 is modified to arrive at the uncertainty on differential pressure definitions. The standard uncertainty of the vacuum measurement (B7) is changed to 0.03 Pa and the  $RPM_{offset}$  uncertainty parameter of 0.15 Pa is added. Recombining these results in a combined

and expanded uncertainty, with a coverage factor of two, of  $\pm (0.31 \text{ Pa} + 17.5 \text{ ppm})$ . This value is rounded to a Standard Accuracy Specification for differential mode operation of:

$$\pm (0.3 \text{ Pa} + 20 \text{ ppm})$$

### EQUIPMENT REQUIRED FOR PG7601 DIFFERENTIAL MODE OPERATION

- (1) PG7601 piston gauge platform
- (1) PC-7600-10 gas operated piston-cylinder module
- (1) MS-7001-35 mass set
- (1) VA-7601-REF, vacuum package for PG7601 reference (or equivalent)
- (1) MPC1 or PPC1, pressure controller
- (1) VA-PPC/MPC-REF, vacuum package for MPC1 or PPC1 (or equivalent)
- (1) RPM3-A0015, reference pressure monitor
- (1) PK-7600-DIF, interconnections kit with differential mode controller
- (1) PK-7600-DIF-VOL, static pressure reference volume (optional)

### DIFFERENTIAL MODE SCHEMATICS

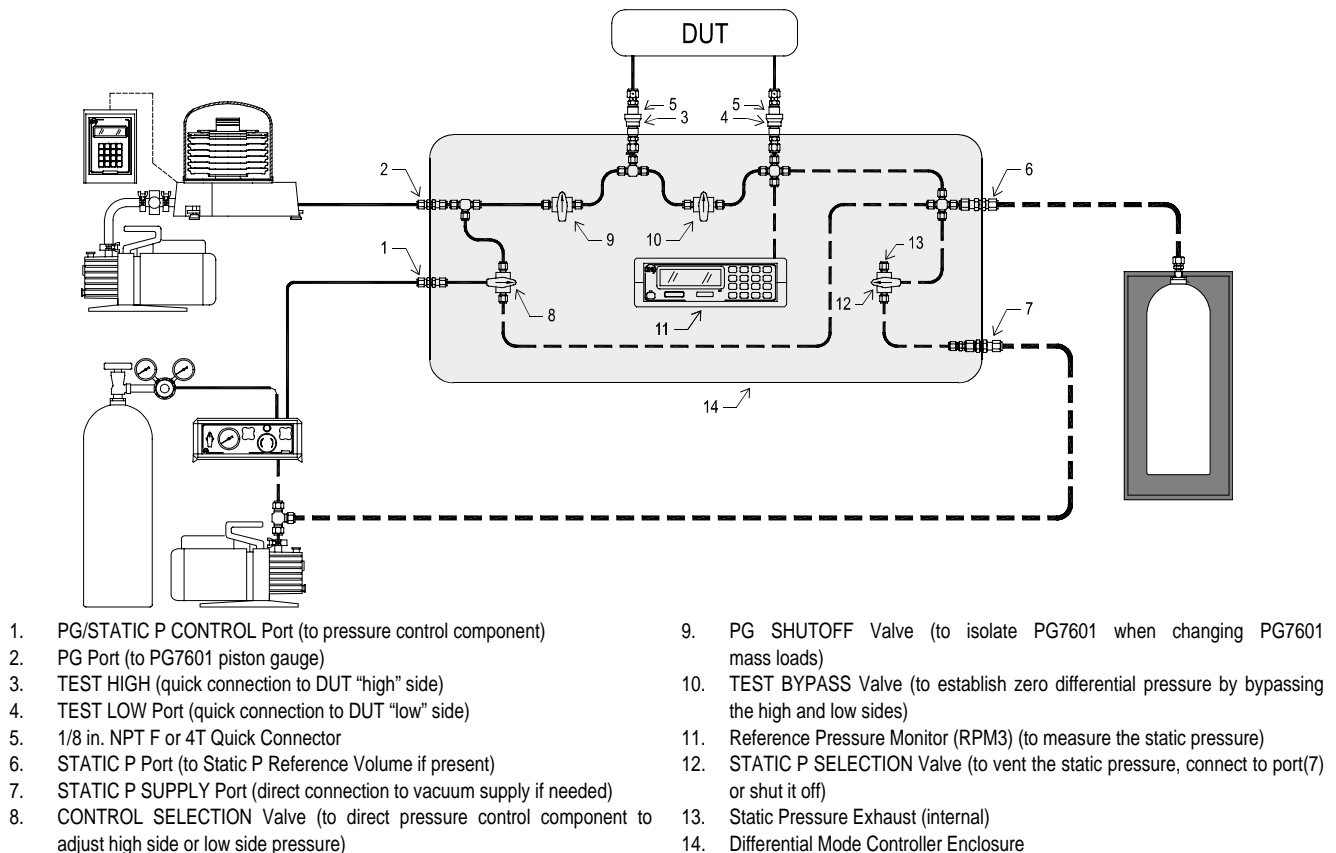


Figure 1. Differential Mode Schematic

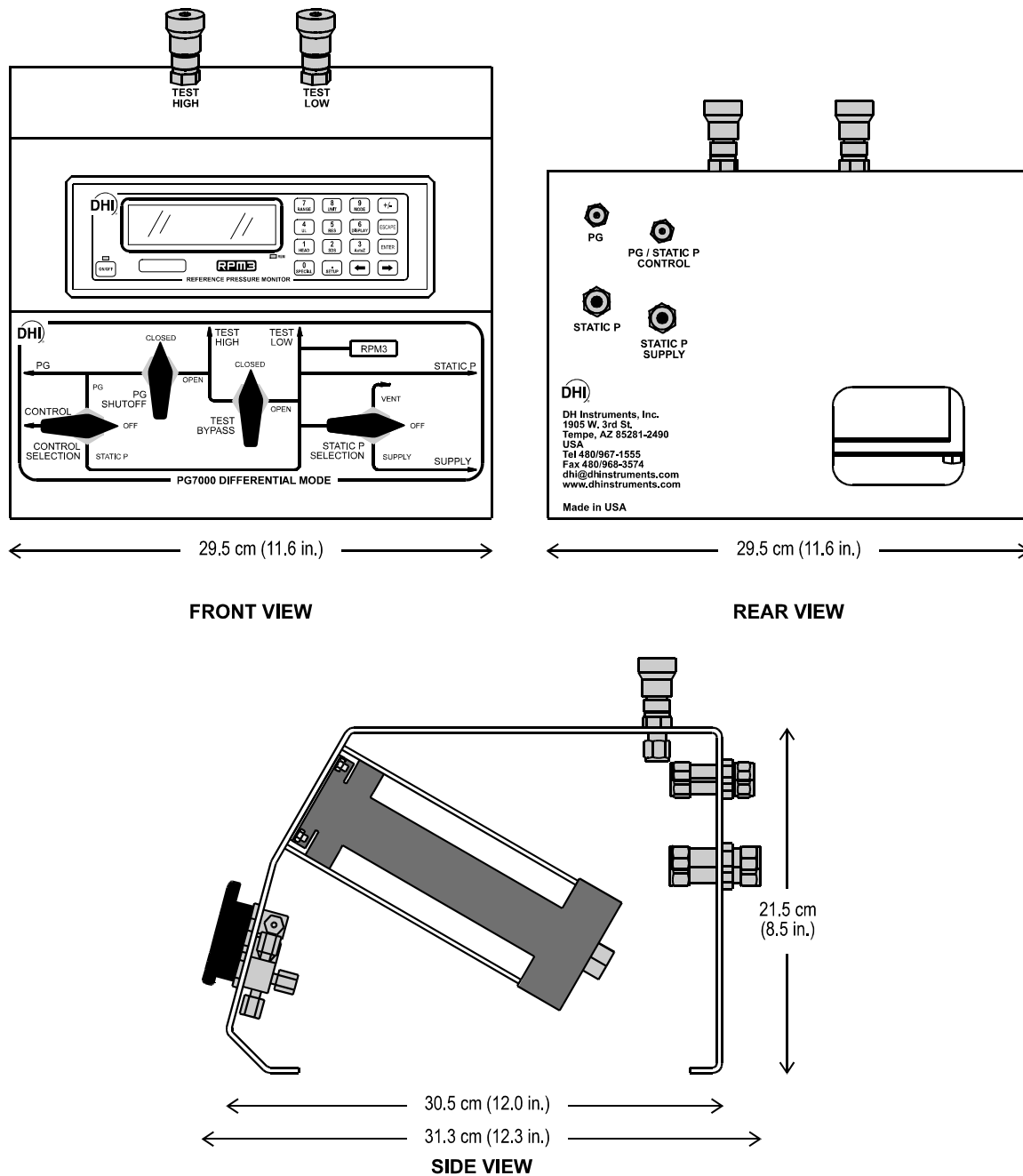


Figure 2. Differential Mode Controller  
(Included in PK-7600-DIF)