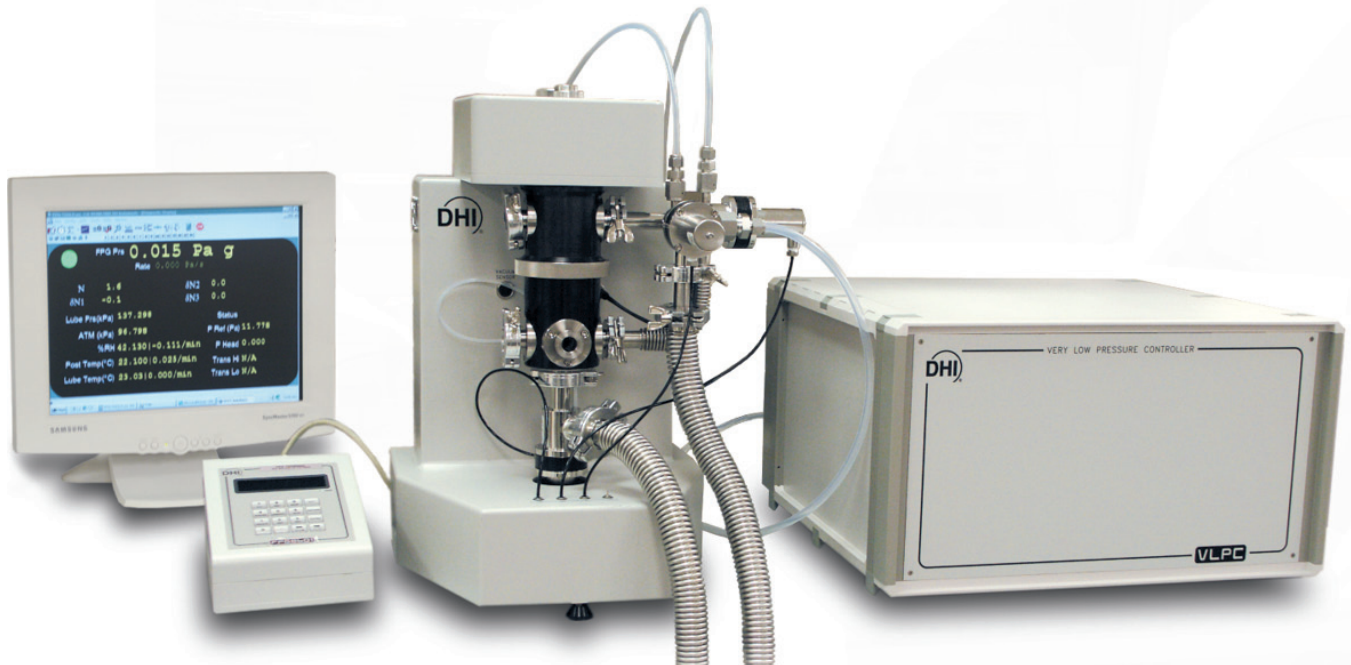


# FPG8601™

## Forced Balanced Piston Gauge

## Technical Data



### Reference level calibration system for very low pressure

#### The solution to very low pressure traceability

FPG8601 addresses the need for a means of maintaining long term traceability with very low uncertainty in the pressure range under that covered by conventional piston gauges.

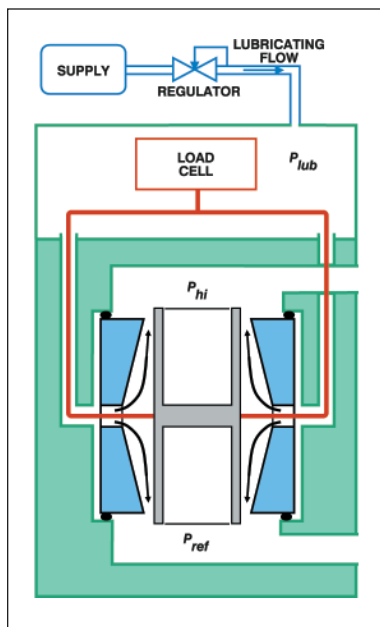
The measurement range covered is from zero (0.5 Pa in absolute) to 15 kPa (112 Torr, 2.2 psi) in both gauge and absolute modes. Measurement uncertainty is the combination of  $\pm 30$  ppm of reading and a low end threshold component low enough to support the calibration of typical transfer standards with ranges as low as 130 Pa (1 Torr, 0.5 in. H<sub>2</sub>O), and even 13 Pa (100 mTorr, 0.05 in. H<sub>2</sub>O).

FPG8601's measurement uncertainty is documented in a complete uncertainty analysis. The instrument's stability over time is dependent on the stability of a tungsten carbide piston-cylinder and stainless steel mass, allowing FPG8601's calibration interval to be the same as that of conventional piston gauges with no other special maintenance requirements.

In addition to its excellent metrological performance, FPG8601 offers fully automated operation; reasonable size and weight and has no environmental requirements beyond those typically found in a high end metrology laboratory.

#### Operating principles Measurement

FPG8601 operates on the well known piston gauge principle in which pressure applied to the effective area of a piston-cylinder is transformed into a proportional force. However, rather than being balanced against masses accelerated by gravity, the force resulting from pressure is measured by a force balanced load cell to which the piston is attached. As the piston-cylinder is fitted with pressure chambers at both its top and bottom, the reference pressure against which pressure is defined can be changed (atmosphere for gauge, vacuum for absolute). Zeroing the load



Non-rotating piston principle.

cell with the high and low chambers at a common pressure, tares out the mass of the piston and any other forces not due to measured pressure, allowing pressure measurement to start from zero. The value of the differential pressure applied is calculated from the effective area of the piston-cylinder and the net force value measured by the load cell.

To avoid the instability and mechanical complexity of centering the piston by rotating it in the cylinder, the FPG piston is centered by the flow of an independent lubricating gas pressure in the piston-cylinder gap. The gap is conical, narrowing symmetrically toward the piston's extremities. The piston-cylinder gap is 1 μm to 6 μm and the lubricating pressure is 40 kPa greater than the reference pressure, keeping flow into the measurement chambers very low (less than 1 sccm total).

The force across the piston is transmitted to the load cell through a gimbal coupling system that holds the piston at its center of gravity. The connecting system passage is also used to supply the piston-cylinder lubricating gas. The

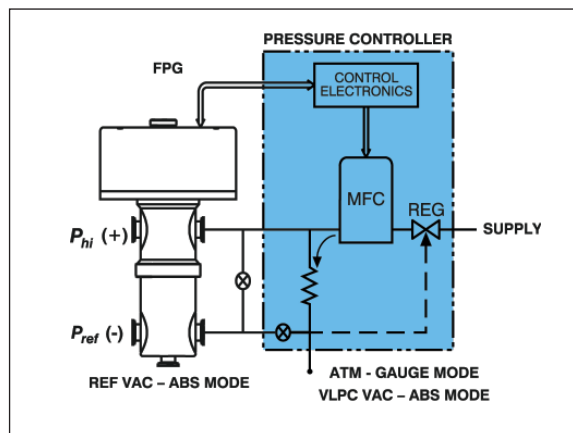
load cell is enclosed in a hermetic chamber through which the lubricating gas flows. The design of the load cell chamber contributes to maintaining its temperature constant and the lubricating gas is conditioned to assure relative humidity of 40% to 70% for optimum load cell performance.

### Control

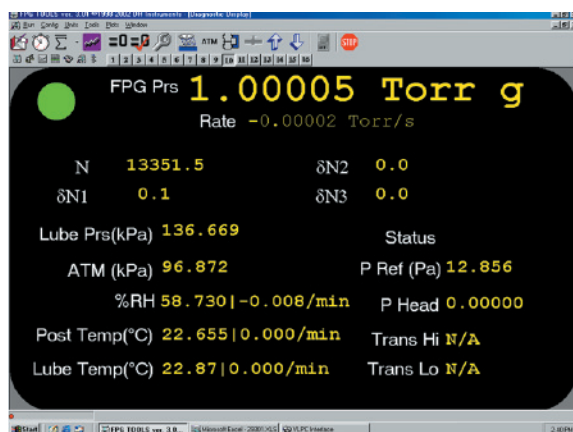
The FPG8601 pressure controller operates by the adjustment of flow across a flow restriction. The upstream side of the restriction is connected to the upper FPG pressure chamber and the downstream side is connected to the lower FPG pressure chamber and to atmosphere or to an independent vacuum source for absolute mode operation. Several flow restrictions of different conductance are included in the controller and the one appropriate for the pressure range is selected automatically. Two mass flow controllers (MFC), one for coarse pressure control and the other, lower range, for fine pressure control, are used in parallel to adjust the flow in a feedback loop. Control is based on the difference between the pressure set point and the FPG pressure measurement. A two stage pressure regulator whose second stage is referenced to the downstream side of the flow restrictions supplies a stable input pressure to the mass flow controllers.

### Automated operation

The FPG8601 includes a Windows® based system controller. The system controller communicates with the FPG8601 hardware and devices under test. FPG Tools™ software monitors and controls FPG operation and supports a wide variety of high level functions, including running fully automated, unattended test sequences with device under test data acquisition. All FPG and device under test data



Pressure controller principle.



FPG Tools software monitors and controls FPG operation.

are recorded in delimited data files that are easily downloaded to other applications for analysis.

Some of the functions of FPG Tools software include:

- Measurement mode (gauge/absolute) changes
- Auto zero and auto span the load cell
- Data point averaging time adjust
- Excessive change in operating conditions alarms
- Thermal transpiration corrections in low absolute
- Device under test setup
- Test procedure definition and storage
- Fully automated test execution
- Real time test result plotting

## Gauge, absolute and absolute differential measurement modes

FPG8601 supports three different measurement modes:

- Gauge mode: The lower chamber of the FPG and the “low” side of the test are connected together and left open to atmosphere.
- Absolute mode: The lower chamber of the FPG is evacuated and the residual vacuum is measured by a vacuum gauge. This mode is used to calibrate sealed absolute DUTs.
- Absolute differential mode: The lower chamber of the FPG and the “low” side of the test are connected together and evacuated. This mode is used to calibrate differential DUTs relative to vacuum.

## Bench top system without special environmental requirements

FPG8601 can be installed on a high quality, 2 meters (6 feet) laboratory bench. The pressure controller is often mounted under the bench. Location of the vacuum pumps needs to be considered when absolute pressure capability is included. A custom mounting bench can be supplied with the system if desired.

The environmental requirements for FPG8601 operation are those typically found in a high end metrology laboratory.

## Installation and training service

Three to five days of installation and training service is recommended with a new FPG8601 installation. This service includes setup and check out of the FPG8601 system as well as training of users on operation and maintenance, including running typical tests.

Training can be supplied at the Fluke Calibration facility in Phoenix, Arizona prior to delivery and/or at the installation location following delivery.

## Specifications

General	
Power requirements	FPG8601: 85 V ac to 264 V ac, 50/60 Hz, 60 VA max VLPC: 85 V ac to 264 V ac, 50/60 Hz, 70 VA max
Normal operating temperature range	20 °C to 26 °C (68 °F to 79 °F)
Ambient temperature stability	0.1 °C (32.2 °F)/minute max rate
Weight	FPG8601 Platform: 30 kg (66 lb) FPG8601 Terminal: 2 kg (4.4 lb) VLPC Pressure Controller: 41 kg (90.4 lb)
Dimensions (H x W x D)	FPG8601 Platform: 53 cm x 36 cm x 35 cm (21 in x 14 in x 14 in) FPG8601 Terminal: 12 cm x 15 cm x 20 cm (4.7 in x 6 in x 8 in) VLPC Pressure Controller: 31 cm x 51 cm x 53 cm (12.2 in x 20 in x 21 in)
System controller	Runs FPG Tools®, Windows® operating system, RS-232 and IEEE-488 interfaces to FPG and DUT data acquisition
Overall pressure range	0 kPa to 15 kPa gauge, absolute, absolute differential
Test medium	N <sub>2</sub> or Air
Mode change time	Absolute to gauge: 30 minutes Gauge to absolute: 1 hour
Vibration	Same as conventional piston gauge, vacuum pumps must be connected by flexible tubing
Pressure supplies	
Piston-cylinder lubrication gas (FPG8601)	700 kPa to 800 kPa, clean, dry N <sub>2</sub> or Air
FPG reference vacuum (for absolute modes)	Turbo pump: 378 m <sup>3</sup> (13,348 ft <sup>3</sup> )/hr typical, 8.10 <sup>-6</sup> Pa ultimate pressure Rotary vane pump: 16.5 m <sup>3</sup> (583 ft <sup>3</sup> )/hr, 0.2 Pa ultimate pressure
VLPC supply	700 kPa to 800 kPa, clean, dry N <sub>2</sub>
VLPC vacuum	10 m <sup>3</sup> (353 ft <sup>3</sup> )/hr @ 0.5 Pa
Drive air (FPG8601 and VLPC)	400 kPa to 700 kPa shop air
Pressure Connections	
Test high (FPG8601)	KF16
Test low (FPG8601)	KF16
Vacuum Ref (FPG8601)	KF25
Vacuum (FPG8601)	1/8 in. NPT F
Drive/lubrication (FPG8601)	1/8 in. NPT F
Supply (VLPC)	1/8 in. NPT F
Drive (VLPC)	1/8 in. NPT F
Vacuum (VLPC)	KF25
Pressure measurement	
Overall range	0 kPa to 15 kPa gauge, absolute, absolute differential
Temperature effect	Instrument temperature monitored and alert provided when rate and/or magnitude of temperature change is significant to performance.
Resolution	Standard: 0.010 Pa High resolution option: 0.001 Pa
Typical pressure measurement uncertainty	Standard: Gauge, absolute differential modes: ± (0.020 Pa + 30 ppm rdg) Absolute mode: ± (0.025 Pa + 30 ppm rdg)
	High Resolution Option: Gauge, absolute differential modes: ± (0.005 Pa + 30 ppm rdg) Absolute mode: ± (0.008 Pa + 30 ppm rdg)
Typical residual vacuum in absolute mode	With Turbo Molecular Pump: 0.04 to 0.1 Pa With Rotary Vane Pump: 0.3 Pa to 0.4 Pa

## Specifications

Pressure control	
Control ranges (Pa)	Gauge mode: 5 overlapping control ranges Minimum pressure: 0 Minimum controlled pressure: 0.1 Pa
	Absolute mode: 5 overlapping control ranges Minimum pressure: 0.4 to 1 Pa Minimum controlled pressure: 2 Pa
Control Precision	Standard: Gauge mode: $\pm (0.020 \text{ Pa} + 100 \text{ ppm of range})$ Absolute modes: $\pm (0.020 \text{ Pa} + 30 \text{ ppm of range})$
	High Resolution Option: Gauge mode: $\pm (0.005 \text{ Pa} + 60 \text{ ppm of range})$ Absolute modes: $\pm (0.020 \text{ Pa} + 30 \text{ ppm of range})$
	Note: Control precision is worst case. Absolute mode constant is smaller in lower ranges.
Nominal test volume	Gauge Mode: Up to 20 cc/side (high and low) Absolute Mode: Up to 500 cc/side (high and low)
Typical pressure setting time	1 to 2 minutes, dependent on test volume
Piston-cylinder	
Nominal size	Diameter: 35 mm (1.4 in) Area: 10 cm <sup>2</sup> (1.6 in <sup>2</sup> )
Piston material	Tungsten carbide
Cylinder material	Tungsten carbide
Mounting system	Non-rotating, self-centering by independently, centrally supplied, lubricating pressure
Piston-cylinder gap	Symmetrical conical gap with dual taper from 6 microns at central lubrication point to 1 micron at cylinder ends
Lubricating gas quality	Clean, dry N <sub>2</sub> or air, on-board conditioning to 40 % to 70 % R.H.
Lubricating gas pressure	Gauge mode: 40 kPa gauge Absolute modes: 40 kPa absolute Lubricating gas flow: < 1 sccm total to the high and low chambers
Secondary Measurement	
Piston-cylinder temperature	Range: 0 °C to 40 °C (32 °F to 104 °F) Resolution: 0.01 °C (32.018 °F) Uncertainty: $\pm 0.1 \text{ °C}$ (32.18 °F)
Residual vacuum	Range: 0 Pa to 13 Pa Resolution: 0.001 Pa Uncertainty: $\pm (0.5 \% \text{ rdg} + 5 \text{ mPa})$
Monitoring measurement	
Lubrication gas temperature	Range: 0 °C to 40 °C (32 °F to 104 °F) Resolution: 0.1 °C (32.18 °F) Uncertainty: $\pm 0.2 \text{ °C}$ (32.36 °F)
Lubrication gas pressure	Range: 0 kPa to 200 kPa absolute Resolution: 0.001 kPa Uncertainty: $\pm 0.1 \text{ kPa}$
Lubrication gas humidity	Range: 5 % RH to 95 % RH Resolution: 1 % RH Uncertainty: $\pm 10 \% \text{ RH}$

**Fluke Calibration.** Precision, performance, confidence.™

Electrical	RF	Temperature	Pressure	Flow	Software
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2675 200 or Fax +31 (0) 40 2675 222  
In Canada (800)-36-FLUKE or  
Fax (905) 890-6866

## Ordering information

### Model

**FPG8601-SYS** Calibration System

### Includes

FPG8601 platform  
FPG8000 terminal  
FPG8601 10 kPa/kg piston-cylinder  
Gauge mode operation capability  
Standard resolution (10 mPa), for  
high resolution (1 mPa) order  
FPG-8601-SYS-HR  
VLPC pressure controller, intercon-  
nections between VLPC and  
FPG8601 platform  
System controller with system  
software, (2) RS-232 ports and  
IEEE-488  
Piston insertion tool  
Operation and maintenance manual  
A2LA accredited calibration report

### Options

**FPG8601-SYS-OPT** Vacuum ref mode  
**FPG8601-SYS-OPT** High resolution  
(1 mPa)

### Accessories

**MS-8601-2** 2.0 kg mass set  
w/hanger  
**BENCH-8601-ABS** Various vacuum  
pump choices for the FPG reference  
and the VLPC controller in absolute  
modes (consult Fluke Calibration)

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