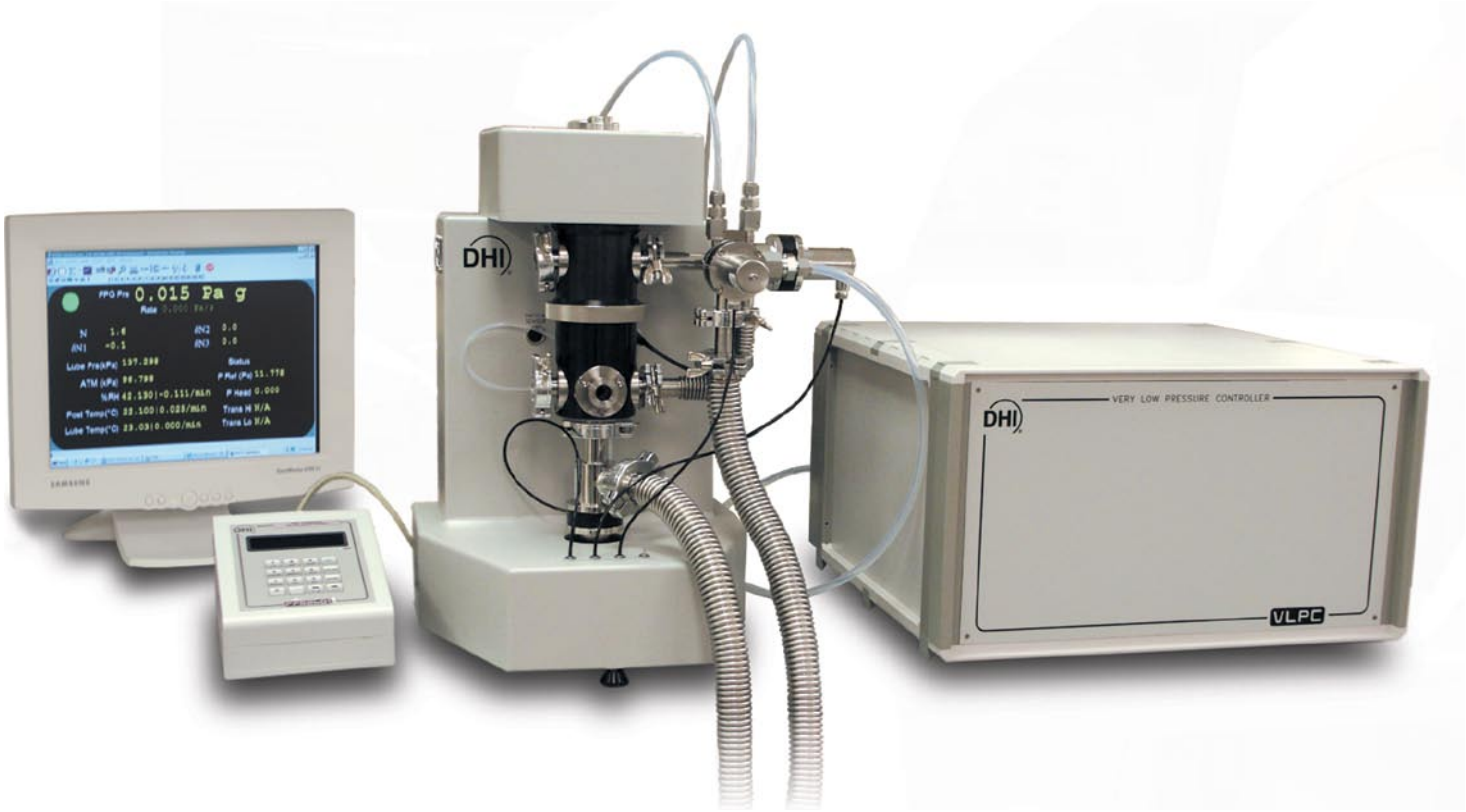
FPG8601™

Force Balanced Piston Gauge



Reference Level Calibration System
for Very Low Pressure

DHI® DH Instruments
A Fluke Company

FPG8601™ Force Balanced Piston Gauge

THE SOLUTION TO VERY LOW PRESSURE TRACEABILTY

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 ± 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. H2O), and even 13 Pa (100 mTorr, 0.05 in. H2O).

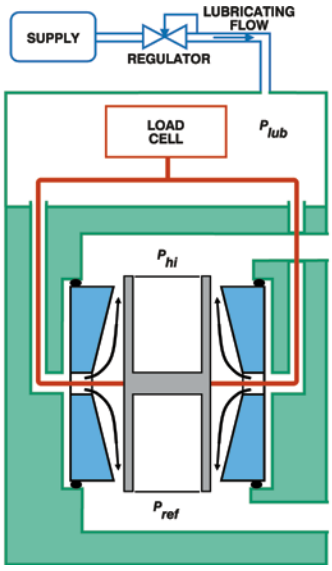
FPG8601's measurement uncertainty is documented in a complete uncertainty analysis (see **DHI** TechNote 2090TN05). The instrument's stability over time is dependent on the stability of a tungsten carbide piston-cylinder and stainless steel mass, allowing FPG8601's calibration interval to be the same 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 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.



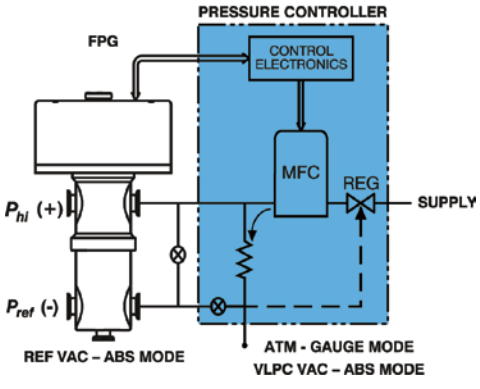
Non-Rotating Piston Principle

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 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.



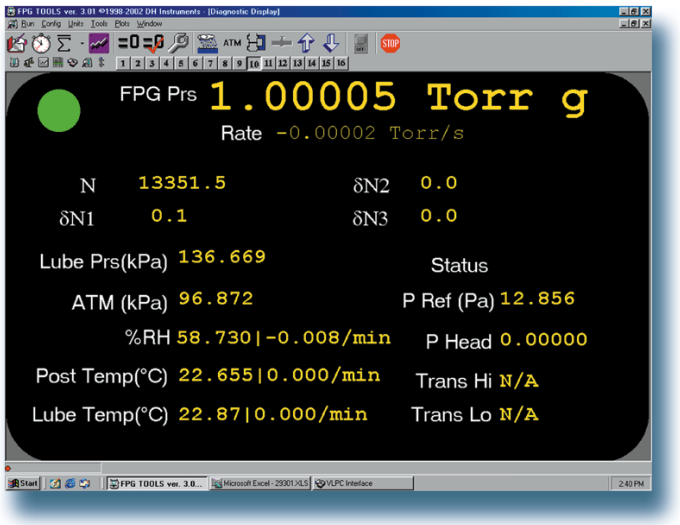
Pressure Controller Principle

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 acquistion. All FPG and device under test data 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 m (6 ft.) 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 set up 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 **DHI**'s Phoenix, Arizona facility prior to delivery and/or at the installation location following delivery.

ORDERING INFORMATION

FPG8601-SYS, CALIBRATION SYSTEM, P/N 401660 OR 401660-CE

Complete FPG8601 Calibration System with standard resolution:

- 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
- Interconnections between VLPC and FPG8601 platform
- System controller with system software, (2) RS232 ports and IEEE-488
- Piston insertion tool
- Operation and maintenance manual
- A2LA accredited calibration report

ADD OPTIONS AND ACCESSORIES TO YOUR FPG8601 SYSTEM AS NEEDED...

OPTIONS

DESIGNATOR	PART NO.
FPG8601-SYS-OPT, vacuum ref mode	401861
FPG8601-SYS-OPT, high resolution (1 mPa)	401860

ACCESSORIES

DESIGNATOR	PART NO.
MS-8601-2, 2.0 kg mass set w/hanger	401672
BENCH-8601-ABS	402010

Various vacuum pump choices for the FPG reference and the VLPC controller in absolute modes (consult **DHI**)

FPG8601™ Force Balanced Piston Gauge

SPECIFICATIONS

GENERAL

Power Requirements	
FPG8601	85 to 264 VAC, 50/60 Hz, 60 VA max
VLPC	85 to 264 VAC, 50/60 Hz, 70 VA max
Normal Operating Temperature Range	20 to 26 °C
AmbientTemperature Stability	0.1 °C/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	
FPG8601 Platform	53 cm H x 36 cm W x 35 cm D (21 in. x 14 in. x 14 in.)
FPG8601 Terminal	12 cm H x 15 cm W x 20 cm D (4.7 in. x 6 in. x 8 in.)
VLPC Pressure Controller	31 cm H x 51 cm W x 53 cm D (12.2 in. x 20 in. x 21 in.)
System Controller	Runs FPG Tools™, Windows® operating system, RS232 and IEEE-488 interfaces to FPG and DUT data acquisition
Overall Pressure Range	0 to 15 kPa gauge, absolute, absolute differential
Test Medium	N_2 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 to 800 kPa, clean, dry N_2 or Air
FPG Reference Vacuum (for absolute modes)	Turbo pump: 378 m^3/hr typical, 8.10^{-6} Pa ultimate pressure
	Rotary vane pump: 16.5 m^3/hr, 0.2 Pa ultimate pressure
VLPC Supply	700 to 800 kPa, clean, dry N_2
VLPC Vacuum	10 m^3/hr @ 0.5 Pa
Drive Air (FPG8601 and VLPC)	400 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 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

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:	± (0.020 Pa + 100 ppm of range)
	Absolute modes:	± (0.020 Pa + 30 ppm of range)
High Resolution Option	Gauge mode:	± (0.005 Pa + 60 ppm of range)
	Absolute modes:	± (0.020 Pa + 30 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)	
TypicalPressure Setting Time	1 to 2 minutes, dependent on test volume	

PISTON-CYLINDER

Nominal Size	
Diameter	35 mm
Area	10 cm^2
Piston Material	Tungsten carbide
Cylinder Material	Tungsten carbide
Mounting System	Non-rotating, self-centering by independently, centrally supplied, lubricating pressure
Piston-Cylinder Gap	Symetrical conical gap with dual taper from 6 microns at central lubrication point to 1 micron at cylinder ends
Lubricating Gas Quality	Clean, dry N_2 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 (°C)	
Range	0 to 40
Resolution	0.01
Uncertainty	± 0.1
Residual Vacuum (Pa)	
Range	0 to 13
Resolution	0.001
Uncertainty	± (0.5 % rdg + 5 mPa)

MONITORING MEASUREMENT

Lubrication Gas Temperature (°C)	
Range	0 to 40
Resolution	0.1
Uncertainty	± 0.2
LubricationGas Pressure (kPa)	
Range	0 to 200 absolute
Resolution	0.001
Uncertainty	± 0.1
Lubrication Gas Humidity (%RH)	
Range	5 to 95
Resolution	1
Uncertainty	± 10

Due to a policy of continuous improvement, all specifications contained in this document are subject to change without notice.

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Products described in this brochure are protected by US and international patents and patents pending.

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