Digital Pressure Standard
Model CPD8000

Desgranges & Huot

Applications

- High level Digital Primary standard.
- Reference instrument for testing, adjusting and calibrating pressure measuring instruments in factories and calibration laboratories.
- Unique working principle.
- Self-contained, complete system also suitable for on-site measurements/calibrations

Special Features

- Absolute & gauge
- Resolution down to 1 ppm
- Several ranges up to 5 MPa
- Accuracy down to 20 ppm of reading
- Perfect for automatic calibration system.

CPD8000-A fitted with low pressure head

Description

A unique concept

The CPD8000 measuring principle lies on the principle of the pressure balances and is based on the fundamental equation which defines pressure: P = F/A with P as a pressure, F a force and A an effective area.

CPD8000 is a worldwide exclusivity combining two high level technologies:

- **Best available piston cylinder assemblies**; whose effective area A is perfectly known
- **High accuracy force cell** which measure the force F.

CPD8000 is defined as a digital pressure balance and is a high accuracy pressure measurer.

Primary principle

As a result, the CPD8000 measuring principle is a primary principle; it associates the measurement accuracy and reliability of fundamental pressure standards with the ease of use of automatic digital instruments.

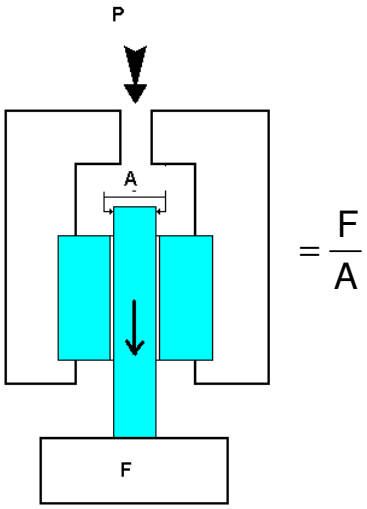
Easy of use

Model CPD8000 offers same high accuracy as a high end pressure primary standard with the benefits of:

- No weights manipulation
- Built-in reference mass for auto-calibration
- Displaying of full corrected pressure

The working principle

- The pressure is applied on the piston, and turns it linearly into a perfectly proportional force that is transferred to the measuring force cell.
- A microprocessor calculates the force corresponding to the pressure, corrects it for all the environmental influences and finally transfers the pressure value to the display and to the communication interface.
- The measuring force cell permanently measures and interpolates the pressure-generated force.



CPD8000 basic principle

Absolute and gauge mode

Two models of CPD8000 are available according to your needs :

CPD8000-G: Gauge mode only

Dedicated to gauge measurements, the force cell is let at the atmospheric pressure.

CPD8000-G

CPD8000-A: Absolute and gauge mode

Versatile measurer, the force cell is placed in reference chamber which can be at the atmospheric pressure for gauge measurement or vacuum for absolute measurement.

The measurer is placed under a **reference vacuum chamber**:

- Absolute pressure measurement is a simple and fast solution, it allows to **measure in continue an absolute pressure without to have to break the vacuum** between each pressure point as it is necessary with the classical pressure balances.
- The vacuum realised on the measuring block and in the reference chamber is around 2 Pa.

CPD8000-A

General Assembly

CPD8000's measurement quality and long-term performance are based on 5 main subsets.

1 – The Piston-Cylinder Assembly: The Corner Stone

The role of the piston-cylinder assembly consists in turning perfectly the pressure into force. The quality of this transformation mainly depends on an **excellent geometry**, but also on a **very low sensitivity** to external influences.

The Desgranges & Huot's piston-cylinder assemblies are manufactured in a special grade of **tungsten carbide**, according to techniques which have been permanently refined for more than 50 years. The manufacturing tolerances are typically below 0.1 micrometer as far as straightness, roundness and parallelism are concerned, which gives them sensitivity, linearity and a repeatability no other manufacturer in the world can offer. The assemblies which equip the CPD8000 are absolutely identical to those used to develop the highest-performance pressure standards.

Tungsten carbide has the advantage of not being very easily distorted under temperature and pressure. Therefore, the piston keeps its metrological qualities regardless the operating conditions.

A large choice of pressure ranges
DH manufactures 21 piston-cylinder assemblies of different area (6 for the CPD8000-A, 15 for the CPD8000-G) , each of them offering a different measuring range.

In order to increase the ease of use, each nominal areas has been designed in order that the piston-cylinder assembly has a simple conversion coefficient of pressure into mass called Kn, so that a Kn bar pressure is converted in 1 kg.

2 – The Measuring Head: An Essential Role

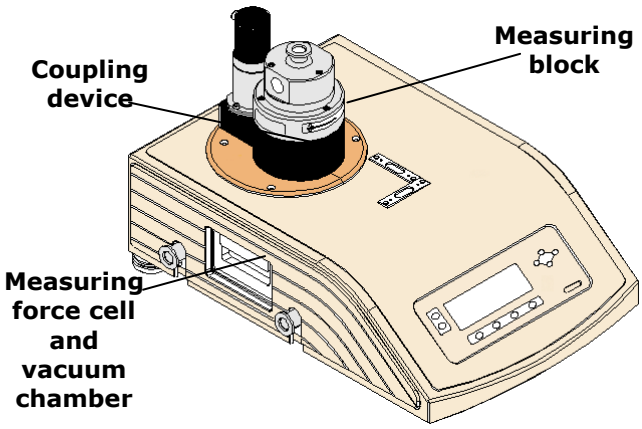
The measuring head is aimed at containing, operating and protecting the piston-cylinder assembly.

It is fitted with the new motorised rotating system which ensures the centring by rotation of the piston in its cylinder so that the force transmitted to the measuring force cell by the pressure is perfectly and fully vertical then without alteration. It has been created to make sure that the rotating noises be less important than the sensitivity of both the piston and measuring cell.

It is equipped with a 4-wire platinum resistance thermometer allowing the most accurate measurement of the piston-cylinder assembly temperature.

The measuring head is coupled with the measuring force cell by 3 screws and can be dismantled in a few seconds.

It is possible to combine a measuring force cell with several measuring heads, each of which being fitted with a piston-cylinder assembly of different Kn to meet various application fields.



3 – The Measuring Cell: A Force Transferring Function

The electronic measuring force cell has been developed for the high accurate manufacturing of mass comparators.

It uses the MONOBLOC technology manufactured by electro erosion; this technology reflects latest innovations realised in mechanics, electronic, computer science and opto-electronic.

The concept of MONOBLOC eliminates all the complicated mechanical links fit in a force sensor, due to the substitution of the 90 assembly spares found in a traditional load cell by only one part.

The measuring force cell is associated with an Auto Calibrating Function (see further) which enables to apply to it, easily and whenever it is necessary, a reference force that is equivalent to the product of the mass multiplied by the local acceleration of the gravity *(F = M* x g) in order to recalibrate it.

Consequently, the measuring cell is not used as a force measuring instrument but as a comparator between the reference force created by the mass when the calibration takes place and the force which is exerted by the piston during the pressure measurements. The measuring force cell is thus exclusively used for its short-term repeatability.

4 – The Autocalibrating Function (ACF)

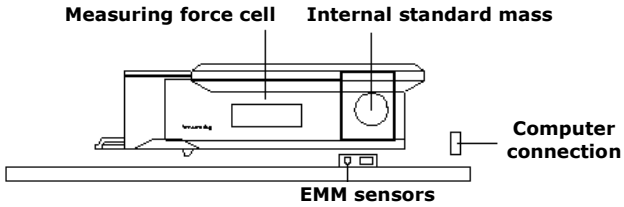
The CPD8000 measuring force cell response to the force, which is applied to it, may drift with time. In addition to this drift which is due to the ageing of the measuring force cell, a low short-term drift may appear: this is an evolution of the measuring force cell response according to the change of the environmental parameters, above all ambient temperature and relative humidity.

To curb these drifts, **the CPD8000 is fitted with an Auto Calibrating Function (ACF) coupled with an Environment Monitoring Module (EMM)**.

The use of the ACF enables the measuring force cell to easily free from this drift by readjusting its deviation according to the new environmental conditions, even when the measuring head is fitted.

The ACF consists in an **automatic loading of an internal standard mass** which can be easily loaded by pressing a key located on the front panel, or from a remote computer. By applying the standard mass, you readjust the deviation of the measuring force cell according to two points: zero and the mass generated force value (i.e. the full scale value).

You can optionally use a set of external standard masses in order to check the measuring force cell linearity over 5 points. These masses can also be used to run an external calibration.



5 – The Environment Monitoring Module (EMM)

In order to determine whether it is worthy to use the ACF, the CPD8000 is equipped with an Environment Monitoring Module which **consists in 3 sensors for ambient temperature, relative humidity and barometric pressure**, and their electronic components.

After the calibration, the EMM keeps on monitoring the evolution of the ambient conditions in real time.

If these conditions vary in proportions that might noticeably alter the measuring performance, the CPD8000 displays a warning flag to advise the user to command the ACF in order to readjust the dynamometer to the new operating conditions. The warning flag is also sent to the command software if the CPD8000 is operated from a remote computer.

When the ACF is in use, the environment conditions, for which the measurements carried out by the measuring force cell are valid, are measured by the EMM and stored in the internal memory

Therefore, the EMM monitors the difference between the conditions stored during the calibration, at t0, and the conditions measured when the operation took place, at t+1. The sensors with which the EMM is fitted are not used for their accuracy and long-term stability, but for their short term repeatability.

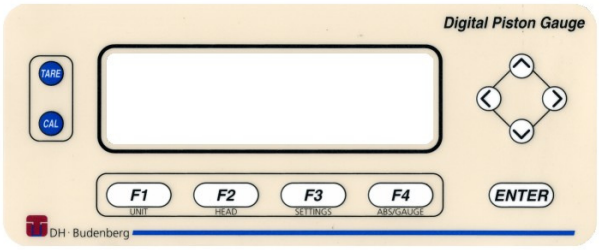
Displayed Pressure Calculation

The pressure displayed by the CPD8000 is calculated according to the following formula

$$P = Kn \times \frac{N}{N_k} \times \frac{g_l}{g_n} \times (1 - (\lambda_{PC} \times P)) \times (1 - \alpha_{PC} \times (t - 20)) \times \left(\frac{\rho_{ac} - \rho_m}{\rho_{an} - \rho_m} \right) + Pvac$$

where:

- **Kn** is the specific coefficient of the piston-cylinder assembly
- **N** is the indication of the measuring force cell in count
- **N_k** is the sensitivity of the measuring force cell
- **g_l** is the local gravity in $m.s^{-2}$
- **g_n** is the normal gravity in $m.s^{-2}$
- **λ_{PC}** is the pressure distortion coefficient of the piston-cylinder assembly
- **α_{PC}** is the thermal dilation coefficient of the piston-cylinder assembly
- **t** is the temperature of the piston-cylinder assembly in ℃
- **ρ_{ac}** is the air density during the adjustment of the measuring force cell in en $kg.m^{-3}$. This parameter is null when the CPD8000-A operates in absolute mode.
- ρ_m is the density of the adjustment mass in $kg.m^{-3}$
- ρ_{an} is the normal air density in $kg.m^{-3}$
- **P_{Vac}** is the residual vacuum in the reference chamber.



Constant Parameters

The constant parameters entering in the computing of pressure are stored in the non-volatile memory of the CPD8000:

- Kn of the piston-cylinder assembly,
- Sensitivity of the measuring force cell (N_k),
- Normal gravity (g_n),
- Local gravity (g_l),
- Pressure distortion coefficient of the piston-cylinder assembly (λ_{PC}),
- Thermal dilation coefficient of the piston-cylinder assembly (α_{PC}),
- Density of the calibration mass (ρ_m),
- Normal air density (ρ_{an}).

Some of these parameters are specific to each piston-cylinder assembly and are determined during the calibration. You can easily modify them if necessary and the internal memory allow to save the parameter of three different piston-cylinder assemblies

Variable Parameters

The variable parameters affecting the calculation of the pressure are automatically measured and integrated in the expression of the pressure :

- temperature of the piston-cylinder assembly (t),
- ambient temperature ,
- humidity,
- atmospheric pressure.

Defining the air density during the calibration (ρ_{ac})

- residual vacuum (P_{Vide})

The pressure is automatically converted into any of the common pressure units and the user has the possibility to configure the system to special units.

This rigorous metrology enables an ease of use as well as a speed of measurement operation.

Technical Specifications

Measuring Ranges

The CPD8000's pressure measuring ranges depend on the specific Kn coefficient of the piston-cylinder assembly with which the measuring head is equipped.

Various measuring heads can be used with a same CPD8000 in order to adapt the standard to several applications.

They are interchangeable in a few seconds and the CPD8000's internal memory has the ability to save the metrological coefficients for 3 different piston cylinder assemblies.

Designation	Pressure Ranges	Resolution	PCA Kn	Operating fluid
A01	0.1 Pa ... 100 kPa	0,1 Pa	0,1 bar/kg	Pure gas
A02	0.2 Pa ... 200 kPa	0,2 Pa	0,2 bar/kg	Pure gas
A03	0.5 Pa ... 500 kPa	0,5 Pa	0,5 bar/kg	Pure gas
A04	1 Pa ... 1 MPa	1 Pa	1 bar/kg	Pure gas
A05	2 Pa ... 2 MPa	2 Pa	2 bar/kg	Pure gas
A06	5 Pa ... 5 MPa	5 Pa	5 bar/kg	Pure gas
G01	0.1 Pa ... 100 kPa	0,1 Pa	0,1 bar/kg	Pure gas
G02	0.2 Pa ... 200 kPa	0,2 Pa	0,2 bar/kg	Pure gas
G03	0.5 Pa ... 500 kPa	0,5 Pa	0,5 bar/kg	Pure gas
G04	1 Pa ... 1 MPa	1 Pa	1 bar/kg	Lubricated gas
G05	2 Pa ... 2 MPa	2 Pa	2 bar/kg	Lubricated gas
G06	5 Pa ... 5 MPa	5 Pa	5 bar/kg	Lubricated gas
G07	10 Pa ... 10 MPa	10 Pa	10 bar/kg	Lubricated gas
G08	20 Pa ... 20 MPa	20 Pa	20 bar/kg	Lubricated gas
G09	50 Pa ... 50 MPa	50 Pa	50 bar/kg	Lubricated gas
G20	$2E^{-4}$ ... 200 Psi	$2E^{-4}$ Psi	20 Psi/kg	Lubricated gas
G21	$5E^{-4}$ ... 500 Psi	$5E^{-4}$ Psi	50 Psi/kg	Lubricated gas
G22	$1E^{-3}$ ... 1000 Psi	$1E^{-3}$ Psi	100 Psi/kg	Lubricated gas
G23	$2.5E^{-3}$ ... 2500 Psi	$2.5E^{-3}$ Psi	250 Psi/kg	Lubricated gas
G24	$3E^{-3}$ ... 3000 Psi	$2E^{-3}$ Psi	200 Psi/kg	Lubricated gas
G25	$5E^{-3}$ ... 5000 Psi	$5E^{-3}$ Psi	500 Psi/kg	Lubricated gas

The measuring blocks highlighted in green are "standard products", available in shorter delivery time.

Technical Specifications (Continuation)

Piston-Cylinder Assemblies

- Material: tungsten carbide
- Poisson's ratio: 0,218
- Young's modulus: 6 10^{11} N/m

Typical geometry researched:

- Straightness (typical manufacturing tolerance): 0,1 µm
- Roundness (typical manufacturing tolerance): 0,1 µm
- Parallelism (typical manufacturing tolerance) : 0,1 µm
- Clearance between the piston and the cylinder: 0,2 to 0,4 µm according to the model
- Stability of the effective area: ≤ 1 ppm / an

Standard Masses

Internal mass

- Material: nickel chromium steel
- Mass density: 7900 kg/m^3 ± 10%

External optional calibration masses

- Material: 304L steel
- Mass density: 7920 kg/m^3 ± 10%
- Composition of the set: 5 x 2 kg
- Adjusting tolerance to the nominal value: ±1E^{-6} M
- Calibration Uncertainty: ± 2,4E^{-6} M

EMM Environmental Measuring Module

Sensors	Type	Accuracy	Alarm setting
Ambient temperature:	4-wire PT100	± 0,2°C	± 2°C
Relative humidity:	Capacitive sensor	± 5 %	± 20%
Atmospheric pressure:	Strain gauge	± 2 mbar	± 10 mbar
PCA temperature:	A DIN 43760 4-wire PT100	± 0,1 °C	N/A

Metrological Specifications

Researched metrological specifications

Linearity: 2E^{-6} FS

Hysteresis: 2E^{-6} FS

Bias: 7E^{-6} FS

Repeatability: ≤ 5E^{-6} FS

Temperature effect: full compensation

Precision* : ≤ 11E^{-6} FS (*Combination of repeatability, hysteresis, linearity and 3-year stability)*

Typical uncertainty researched for a 200 kPa range (k=2) : U=0.8 Pa + 1.E-5 P

Dimension (L x W x H):	530 x 400 x 320 mm	Measurement fluid:	Dry and non corrosive clean gas
Maximum overpressure:	110 % FS	Operating temperature:	10 to 30 ° C
Sampling rate:	250 ms	Operating humidity:	15 to 85 % HR
Computer interface:	RS232C	Power supply:	110 - 240 VAC, 50-60 Hz
Residual vacuum :	Pirani gauge ≥ 1Pa ±1E^{-4}	Power consumption:	20 VA
Weight	20 kg		

Summary of the Functions

The CPD8000 has a great variety of functions aimed at facilitating its use and assuring the quality of its long-term operation:

Menus in English, French, German and Spanish	Saving of the metrological characteristics for 3 pressure ranges
Large LCD back-lighting graphic screen with contrast adjustment	Mechanical protection against overpressure up to 110%
Overpressure visual and sound warning	Calibration visual warning when the calibration is necessary
Pressure display in 12 pressure units, and a user unit	User adjustable pressure stability criterion
Front panel tarring key	Front panel ACF running key
Choice between internal/external calibration	EMM parameters display
Piston-cylinder assembly temperature measuring circuit with auto-calibration by resistance of integrated reference	Permanent display of the residual vacuum

Remote Control

All the CPD8000 functions, even the ACF running command, **can be executed from an external computer** through serial communication (RS232C), which enables it to be integrated in an automatic calibrating system.
A programming example is given in the user's manual.

Calibration

All the CPD8000 standards are delivered with a gauge calibration certificate issued as standard by the COFRAC accredited Degranges & Huot's laboratory (accreditations 2-1033 and 2-1129), which assures the user that the presented calibration results are unbiased.
The COFRAC calibration guarantees the traceability of the measurements done by the CPD8000 to the National and International Standards.

The calibration is operated in accordance with the RM aero 802.22 recommendation and takes into account:
- The Kn specific coefficient determination
- The ACF calibration control

The uncertainty calculation presented in the certificate respects the ISO TAG4 and EAL recommendations and shows the enlarged uncertainty of the CPD8000 with a coefficient k = 2.

It takes into account the CPD8000's intrinsic measurement errors, the uncertainty of the reference means as well as the influence of the environment conditions, the pressure control of the CPD8000's metrological performances and the calculation of its measurement uncertainty by comparison with a reference standard.

Conclusion

Due to its design and its performances, the CPD8000 primary digital standard is unique in the world. The operations with the balance do not necessitate a bell to make the vacuum and masses to load.
Associated to an automatic controller, the CPD8000 allows performing fast calibrations, without having to break the vacuum between each pressure point, with a high metrological reliability.
This instruments is used by our more faithful customer who are National Laboratories, Meteorology, the R&D laboratories, sensor manufacturers, airway companies …

Maintenance

The CPD8000 is delivered with all the operating instructions, consumables and tools allowing its general maintenance. No other maintenance is necessary if the standard is used in accordance with the routine instructions described in the manual. Usual recalibrations need only take place every 3 years.

CE Compatibility

The CPD8000 complies with the following European directives and norms:
- n° 89/336/CEE Electromagnetic Compatibility Directive dated May 3th, 1989 modified by the n° 92/31/CEE directive dated May 12th, 1992 and the n° 93/68/CEE directive dated July 22th, 1993
- n° 73/23/CEE Low Tension Directive dated February 19th, 1973 modified by the n° 93/68/CEE directive dated July 22 th, 1993
- EN 50082-1 Ed.92 norm (Emission with the 89/336/CEE directive)
- EN 55022 B Class Ed. 87 norm (Immunity with the 89/336/CEE directive), EN 61010 norm (Safety rules for the use of measuring, regulating and laboratory electric instruments with the 73/23/CEE directive)

Option

By using a special adaptation kit, it is possible to use the gauge head model of the CPD8000-G(Head model 110, 111, 410 and 710) with the CPD8000-A. Those heads can be used to works only in gauge mode but allows extending the range capability of the CPD8000-A up to 50 MPa.

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