DH·Budenberg

January 2006

METROLOGY RANGE

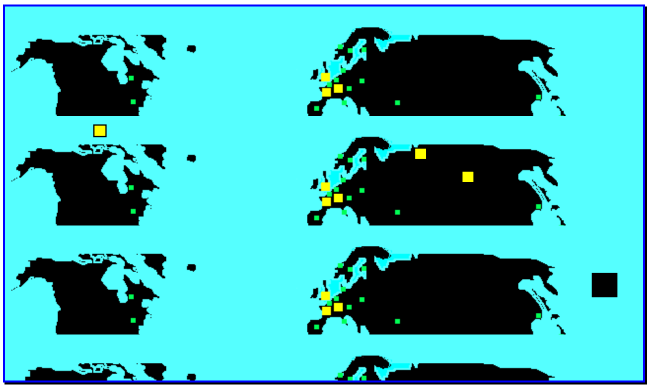
DPG10A

Digital Primary Standard

for Full Automatic Measurement & Calibration
of Gauge, Absolute and Differential Pressures from 0.2 Pa up to 5 MPa
1 ppm usable resolution

I. INTRODUCTION

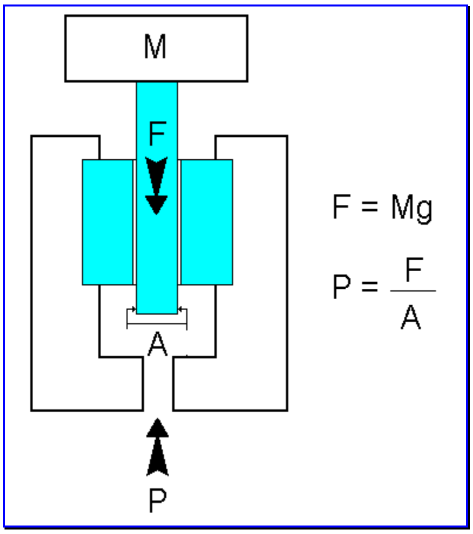
Established respectively more than 50 and 150 years ago, DESGRANGES & HUOT and BUDENBERG are specialised in the development and the manufacturing of pressure measuring and calibrating instruments and have gained a world wide reputation of excellence in this field. Today, the two companies have united under the name DH-BUDENBERG and gathered their know-how and resources to propose on the market the widest and most advanced range of pressure standards and calibration systems.
Through its subsidiaries, DH-BUDENBERG is directly established in France, the United Kingdom, Germany, United states, India and United Arabic Emirates. Its laboratories are COFRAC, DKD and UKAS accredited.
A wide international network of representatives and authorised services distributes their products all over the world.



The DPG10A pressure standard presented in this brochure is based on a unique technology innovated by DH-BUDENBERG. More than a thousand standards of this type have been produced.
It combines the metrological performances of primary pressure standards with the convenience of digital automatic transfer instruments.

II. ABSOLUTE DIGITAL PRIMARY STANDARD

The DPG10A's 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.
In a pressure balance, a vertical piston, which turns freely in a cylinder and whose effective area is perfectly known, receives a pressure on one of its ends. This pressure is balanced with the force which is generated by a mass loaded on the other end of the piston. This measuring principle enables the pressure measurement to be directly linked with the primary physical quantities of mass (kg), length (m) and time (s). It is used to establish the pressure References and to develop the high-performance Standards.
As far as the DPG10A is concerned, this principle is extrapolated and consists in the association of a similar piston-cylinder assembly, whose effective area A is perfectly known, with a high accuracy electronic measuring force cell which measures the force F and which is placed under a reference vacuum chamber:



- The vacuum realised on the measuring block and in the reference chamber is around 1 and 2 Pa.
- 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.
- This principle of 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.

As a result, the DPG10A's 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.

III. DPG10A'S SUBSETS

DPG10A's measurement quality and long-term performance are based on 5 main subsets.

III.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 DH-BUDENBERG'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 a sensitivity, a linearity and a repeatability no other manufacturer in the world can offer. The assemblies which equip the DPG10A 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.

DH-BUDENBERG manufactures for the DPG10A, 5 piston-cylinder assemblies of different effective areas, from 1/5 up to 5 cm², each of them offering a different measuring range.
In order to increase the ease of use, each of the 5 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.

III.2 THE MEASURING HEAD : AN ESSENTIAL ROLE

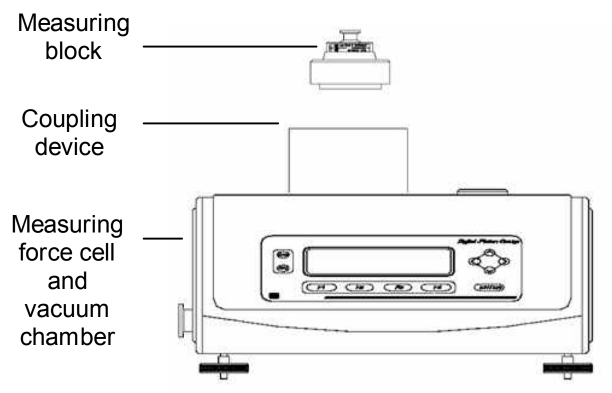
The measuring head is aimed at containing, operating and protecting the piston-cylinder assembly.

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.



III.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 electroerosion; 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 (Cf. III.4) 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.

III.4 THE AUTOCALIBRATING FUNCTION

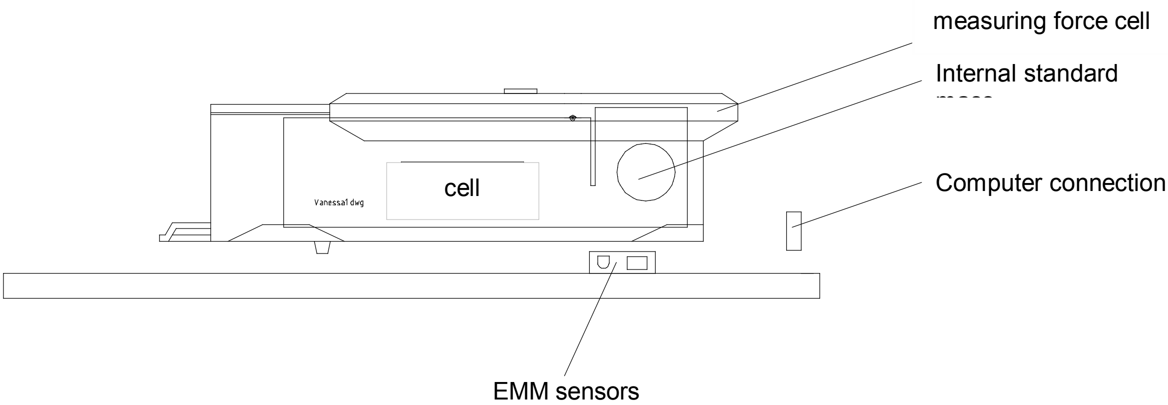
The DPG10A's measuring force cell response to the force which is applied to it may drift with time. In addition to this drift which is due to the ageing of the measuring force cell, a low short-term drift may appear: this is an evolution of the measuring force cell response according to the change of the environmental parameters, above all ambient temperature and relative humidity.

To curb these drifts, the DPG10A is fitted with an Auto-Calibrating Function (ACF) coupled with an Environment Monitoring Module (EMM) (Cf. III.5).

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 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.



III.5 THE ENVIRONMENT MONITORING MODULE

In order to determine whether it is worthy to use the ACF, the DPG10A is equipped with an Environment Monitoring Module which consists in 3 sensors for ambient temperature, relative humidity and barometric pressure, and their electronic components.

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.

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 DPG10A 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 DPG10A is operated from a remote computer.

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.

IV. DISPLAYED PRESSURE CALCULATION

The pressure displayed by the DPG10A is calculated according to the following formula

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

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 °C
- 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 DPG10A 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_{Vide} is the residual vacuum in the reference chamber.

The constant parameters entering in the computing of pressure are stored in the non-volatile memory of the DPG10A:

- 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 (Cf. XIII). You can easily modify them if necessary and the internal memory allow to save the parameter of three different piston-cylinder assemblies.

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.
- residual vacuum (P_{Vide})

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

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.

V. MEASURING RANGES

The DPG10A'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 DPG10A in order to adapt the standard to several applications.

They are interchangeable in a few seconds and the DPG10A'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
	In Gauge, Absolute or Differential			
DPG10-A02B	from 0.2 PaA to 200 kPa	0,2 Pa	0,2 bar/kg	Pure gas
DPG10- A05B	from 0.5 PaA up to 500 kPa	0,5 Pa	0,5 bar/kg	Pure gas
DPG10-A1B	from 1 PaA up to 1 MPaA	1 Pa	1 bar/kg	Pure gas
DPG10-A2B	from 2 PaA up to 2 MPaA	2 Pa	2 bar/kg	Pure gas
DPG10-A5B	from 5 PaA up to 5 MPaA	5 Pa	5 bar/kg	Pure gas

VI. METROLOGICAL SPECIFICATIONS

The manufacturing procedures, the quality of the materials we use, the technological choices of DH-BUDENBERG give the DPG10A standards metrological performances which are much better than those of the standard sensors and which can match up to these of the best pressure balances.

Researched metrological specifications
Linearity: 2E^{-6} FS
Hysteresis: 2E^{-6} FS
Bias: 7E^{-6} FS
Resolution: 1E^{-6} FS
Repeatability: $^{-6}$5ES
Long-term stability: 2E^{-6} FS
Temperature effect: full compensation
Precision* : 1^{6}1ES

- *Combination of repeatability, hysteresis, linearity and 3-year stability*

Typical uncertainty researched for a 200 kPa range (k=2)

$$U=0.8 \text{ Pa} + 1.E\text{-}5\ P$$

VII. TECHNICAL SPECIFICATIONS

VIII.1 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

VIII.2 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

VIII.3 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	-

VIII. OTHER TECHNICAL SPECIFICATIONS

Dimensions (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 measurement:	Pirani gauge 1Pa ±1E^{-4}	Power consumption:	20 VA
Weight	20 kg		

IX. SUMMARY OF THE FUNCTIONS

The DPG10A has a great variety of functions aimed at facilitating its use and assuring the quality of its long-term operation:

- ☑ Protection by password of the sensitive data
- ☑ Menus in English, French, German and Spanish
- ☑ Saving of the metrological characteristics for 3 pressure ranges
- ☑ Direct access to the main run screens by pressing function keys from the measurement mode
- ☑ Large LCD back-lighting graphic screen with contrast adjustment
- ☑ Membrane keypad with tactile effect and beeper
- ☑ Mechanical protection against overpressure up to 110%
- ☑ Overpressure visual and sound warning
- ☑ Under pressure visual warning
- ☑ Calibration visual warning when the calibration is necessary
- ☑ Visual indicator of the measuring range that has been used (bar graph)
- ☑ Visual indicators of the setting of the filters
- ☑ Pressure display in 12 pressure units, and a user unit
- ☑ User adjustable resolution
- ☑ User adjustable pressure stability criterion
- ☑ Clock
- ☑ Front panel taring key
- ☑ Front panel ACF running key
- ☑ Choice between internal/external calibration
- ☑ Environment vibrations filter with 4 adjusting levels
- ☑ Pressure fluctuations filter with 4 adjusting levels
- ☑ Measurement process filter with 4 adjusting levels

- ☑ Averaging filter with 3 adjusting levels
- ☑ EMM parameters display
- ☑ RS232C communication port for remote control
- ☑ Comprehensive programming language
- ☑ Piston-cylinder assembly temperature measuring circuit with auto-calibration by resistance of integrated reference
- ☑ Switching off of the motor and the display and maintaining the measuring force cell on power
- ☑ Permanent display of the residual vacuum.

X. REMOTE CONTROL

All the DPG10A's 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.

The DPG10A has therefore a comprehensive programming language with macro-commands. A programming example is given in the user's manual.

XI. MAINTENANCE

The DPG10A 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.

XII. CALIBRATION

All the DPG10A standards are delivered with a gauge calibration certificate issued as standard by the COFRAC accredited DH·BUDENBERG'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 DPG10A to the National French Standards and, through them, to the international standards.

The uncertainty calculation presented in the certificate respects the ISO TAG4 and EAL recommendations and shows the enlarged uncertainty of the DPG10A with a coefficient k = 2.
It takes into account the DPG10A's intrinsic measurement errors, the uncertainty of the reference means as well as the influence of the environment conditions

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 pressure control of the DPG10A's metrological performances and the calculation of its measurement uncertainty by comparison with a reference standard

XIII. CE COMPATIBILITY

The DPG10A 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)

XIV. CONCLUSION

Due to its design and its performances, the DPG10A primary digital standard is unique in the world. The operation with the balance do not necessitate a bell to make the vacuum and masses to load.
Associated to an automatic controler, the DPG10A allows to performed fast calibrations, without to have to break the vacuum between each pressure point and with a high metrological reliability.

This instruments are used by our more faithful customer who are National Laboratories, Meteorology, the R&D laboratories, sensor manufacturers, airway companies …

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