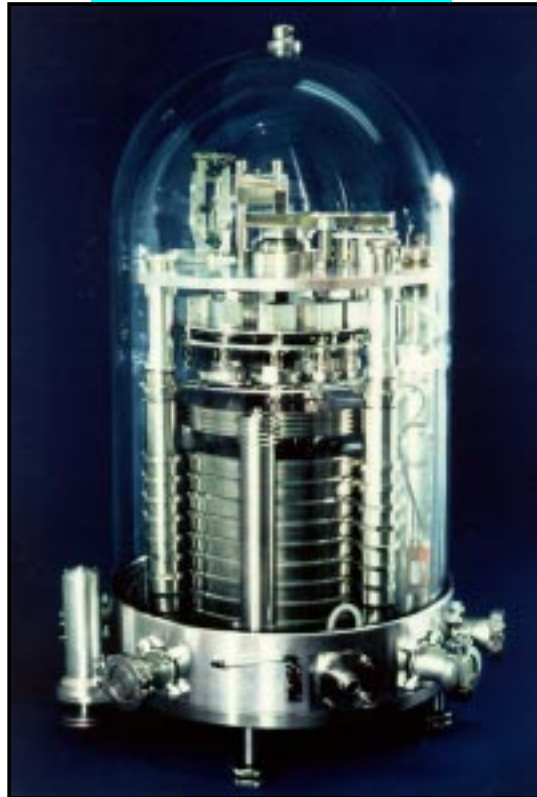


## METROLOGY RANGE



# APX50

## Automatic Absolute Pressure Balance

DH·BUDENBERG's latest development, combined with the BNM-LNE's metrological expertise, results in the leading APX50 absolute pressure balance.

The APX50 is very well suited for the calibration of absolute dead-weight testers, mano-barometers and quartz transducers.

This standard is now the new National absolute pressure Reference of the French calibration chain.

- HIGHEST LEVEL ACHIEVABLE UNCERTAINTY OF  $5 \cdot 10^{-6}$  WITH  $K=2$
- PRIMARY STANDARD
- ABSOLUTE/GAUGE PRESSURE MEASUREMENT
- AUTOMATIC MASS LOADING
- ALTERNATIVE TO HIGH ACCURACY MERCURY COLUMNS
- RANGES FROM 10 kPa TO 1 MPa



## INTRODUCTION

DH-BUDENBERG has always been dedicated to offering highest level accuracy pressure standards to its customers, hence it has reached its reputation in the pressure metrology field. French pioneer in this activity, DH-BUDENBERG is nowadays the world's number 1 supplier of primary pressure standards.

More than 50 countries on the 5 continents rely on DH standards for their pressure measurements. 47 national laboratories - including NIST in the USA, PTB in Germany, NRLM in Japan, LNE in France - have selected D&H to create their National Calibration Chain.

## UNIQUE APX50 CHARACTERISTICS

The APX50 pressure balance was chosen by the BNM-LNE over mercury manometer because its high-level technology brings the following advantages:

- achievable uncertainty on generated pressure is improved by a ratio of 2 to 3 over mercury manometer,
- primary fully automatic pressure standard,
- unique rotative system of the piston-cylinder assembly providing high sensitivity without any interference,
- sources of uncertainty are less important and more easily measured and monitored (no need for complex temperature regulation/monitoring, no meniscus and parallax problems, less external environment influences),
- no need for harmful fluid such as mercury,
- operation is faster thanks to quick pressure stabilization time (pressure setting and measurements take 1 to 2 minutes),
- measurements can be toggled between gauge and absolute pressures within minutes,
- measuring principle is fully coherent with pressure standards used for measuring higher pressures, and which are pressure balances as the APX50, therefore reducing uncertainties in crossfloating,
- extra large piston-cylinder assembly whose area can be determined from true dimensional measurement.

## MEASUREMENT PRINCIPLE

The APX50's measuring principle is based on the fundamental equation of pressure  $P = F/A$  with:

- $P$  as the measured pressure, expressed in Pa,
- $A$  as the perfectly well-known piston-cylinder assembly effective area expressed in  $m^2$ ,
- $F$  as the force (in N) created by masses (in kg) submitted to gravity (in  $m \cdot s^{-2}$ ) and applied to the piston.

As the masses  $M$  are determined through direct intercomparison with Standard Masses and the piston-cylinder assembly area  $A$  is directly measured with a laser interferometer, the measured pressure value then directly derives from the primary quantities of mass, length and time. Consequently, the APX50 pressure balance is recognised as a primary pressure standard.

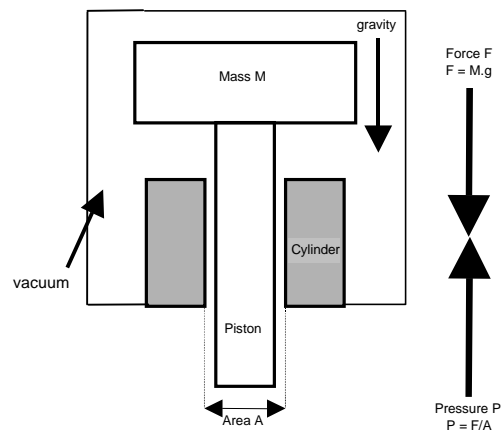
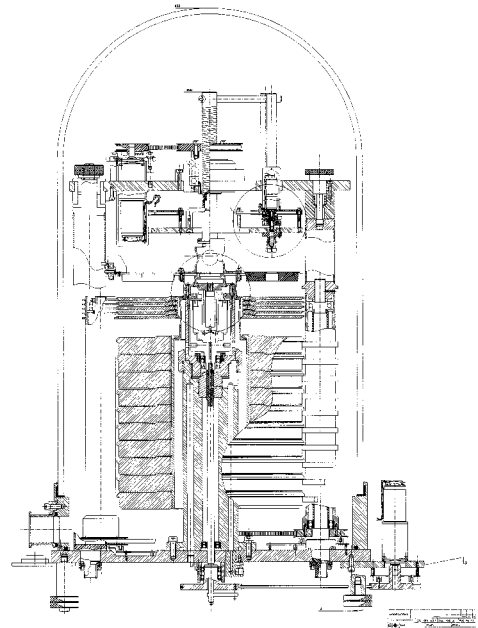
For the measurement of absolute pressure, the top of the piston and the masses are placed under vacuum. When the top of the piston and the masses are placed under ambient pressure, the APX50 allows gauge pressure measurements.

## PRESSURE CALCULATION

The French National Laboratory for pressure quantity BNM-LNE (Paris - France) consulted our company in 1993 in order to start the definition and study of a prototype for a new national absolute reference to be operated in a range from 10 kPa to 1 MPa.

The aim of the project was to reach uncertainty level of  $10^{-6}$  with the originality of using well-known large effective area piston/cylinder and having a fully automatic system with, for the first time with a pressure balance, automatic mass loading under vacuum.

The APX50 absolute pressure balance is the result of this joined cooperation between the BNM-LNE and DH-BUDENBERG.



The pressure measured by the APX50 is calculated according to the following formula:

$$P_A = P_{\text{vacuum}} + \frac{M_A g_l}{A(1 + (\alpha_p + \alpha_c)(t - 20))(1 + \lambda P)}$$

The APX50 pressure balance is designed in such a way that all the parameters of this equation are fully monitored so that maximum performance can easily be achieved.

#### *Masses*

They are made of austenitic, amagnetic type 304L stainless steel and their value is in kg, which is the SI quantity for masses.

They are hanged over the piston to curb side-effects and side forces.

The complete set consists of main masses (9 masses of 10 kg), divisional masses (5 masses of 2 kg and the mass loading bell), and fractional masses (masses from 1 to 2047 g with binary evolution) which can be combined in anyway to give a resolution as good as 10 ppm over the full range.

#### *Piston-cylinder assembly*

It is made of tungsten carbide which is the material that offers the best machining possibilities, and the best metrological specifications among which are:

- roundness, straightness and parallelism within 0.1  $\mu\text{m}$
- clearance between piston and cylinder of 0.4  $\mu\text{m}$
- sensitivity better than 0.1 ppm
- thermal expansion coefficient of 9 ppm / $^{\circ}\text{C}$
- pressure distortion coefficient of  $4.10^{-9}$  kPa $^{-1}$
- Young's modulus of  $6 \cdot 10^{11}$  N/m $^2$

## **SYSTEM CONFIGURATION AND ACCESSORIES**

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The standard configuration of the APX50 automatic primary pressure standard is composed of:

- 1 APX50 pressure balance with automatic mass loading system under bell.
- 1 tungsten carbide piston-cylinder assembly with a nominal diameter of 35 mm, and a nominal effective area of 10 cm $^2$ .
- 1 mass set of total value 100 kg with smallest incremental mass of 1 g, with full automatic changeover under vacuum, from 0.95 kg to 100 kg, by steps of 1 g within seconds.
- 1 bell jar.
- 1 command interface to execute remote mass loading.
- 1 optical piston position sensor.
- 1 MS-Windows-based command software package to command mass loading through the command interface.
- 1 IBM compatible computer P200 to host supplied software (optional).
- 1 capacitive vacuum sensor to measure residual pressure in the vacuum chamber.
- 1 molecular vacuum pump to establish reference vacuum.
- 1 pressure control automatic or manual rack (as requested) to apply pressure points to the pressure balance and to the instrument under test.
- 1 platinum resistance thermometer.
- 1 double stage vacuum pump to establish test pressure points below atmospheric pressure.

## CALIBRATION

Calibration will be performed by the BNM-LNE French National Laboratory.

### Area calibration

The piston-cylinder assembly area will be determined by direct measurement with a laser interferometer dimensional measurement bench. Measurements of diameters, straightness and roundness will be made both on the piston and cylinder, in various plans and sections.

The uncertainty that can be achieved depends on the geometry of the piston and cylinder and will range from  $2 \cdot 10^{-6}$  to  $4 \cdot 10^{-6}$  of value with  $k=2$ .

### Mass calibration

The value of the masses will be determined by direct intercomparison with the French National Standards. The uncertainty will be  $1,5 \cdot 10^{-6}$  with  $k=2$ .

### Uncertainty on pressure measurement

The achievable uncertainty on pressure measurement is the sum of the uncertainties on mass value and piston-cylinder area value. It will range from  $\pm(0,1 \text{ Pa} + 3 \cdot 10^{-6} p)$  to  $\pm(0,1 \text{ Pa} + 5 \cdot 10^{-6} p)$  with  $k=2$ .

Additional sources of uncertainty will come from the monitoring and correction of environmental influences. Under normal laboratory conditions and using the built-in environmental monitoring facilities, environment influence may bring an additional 1 to 2 ppm of reading to the uncertainty on pressure.

## METROLOGICAL SPECIFICATIONS

The APX50 automatic primary pressure balance has the following metrological specifications:

Pressure range:	10 kPa to 1 MPa absolute and gauge 2.95 inHg to 295 inHg absolute and gauge
Minimum pressure step:	10 Pa
Sensitivity:	better than 0.1 ppm
Stability:	better than 1 ppm/year
Repeatability:	better than $3 \cdot 10^{-6}$ of reading from 100 kPa
Readout resolution:	10 Pa 0.002953 InHg
Resolution of capacitive sensor:	0.01 Pa
Pressure units:	inHg, psi, kPa, Torr, inH <sub>2</sub> O, mbar, altitude, mmH <sub>2</sub> O, bar, MPa, kg/cm <sup>2</sup> and one user defined unit
Operating pressure medium:	clean and dry gas, e.g. nitrogen

## OTHER TECHNICAL SPECIFICATIONS

Dimensions:	height < 100 cm width < 70 cm depth < 70 cm weight $\approx$ 200 kg
Power requirements:	220 V AC
Other requirement:	a nitrogen supply at 1.1 MPa, a bench, a hanging system to lift the bell

If you require more details about the APX50, or a demonstration, please consult us. D&H is also providing full assistance for on-site installation and complete training on the APX50.

### REFERENCES

J.C. LEGRAS and J. LE GUINIO, BNM-LNE, "La balance de pression absolue du BNM-LNE dans le domaine de 15 kPa à 1 MPa", 7ème Congrès International de Métrologie, Nîmes, France, Oct 95.

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