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The IMGC/CENAM-HG6 mercury manobarometer

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Abstract
The Centro Nacional de Metrología (CENAM, Mexico) has established a national primary standard for barometric pressure based on a mercury column and a laser interferometer, the first in this range in Latin America. The original design of the manobarometer, the HG5, was made at the Istituto di Metrologia 'Gustavo Colonnetti' (CNR-IMGC, Italy) and it served to develop this new version, the IMGC/CENAM-HG6 mercury manobarometer which was constructed and assembled at CENAM. The special features of this new version and its main design characteristics are presented here, together with the differences from its predecessor. To verify its performance, an internal comparison in absolute mode (gas, N_2) was carried out with a primary pressure balance, a piston-cylinder assembly with 50 mm diameter having direct traceability to SI base units and measuring range to 2.5 kPa to 175 kPa. The results of the comparison are presented and discussed.

1. Introduction

In general, there are two different types of mercury column barometers: some measure the height difference between mercury menisci by the ultrasonic interferometric technique while most others make use of optical laser interferometry [1]. These standards are used from 5 kPa to 120 kPa for absolute, relative and differential pressure [2].

A mercury column laser interferometer system was designed, constructed and started operation and has been established as a national primary standard for barometric pressure at the Centro Nacional de Metrología (CENAM, Mexico). The IMGC/CENAM-HG6 mercury manobarometer (IMGC/CENAM-HG6) is a new version of the prototype built and designed at the Istituto di Metrologia 'Gustavo Colonnetti' (CNR-IMGC, Italia) [3,4]. Table 1 shows its main specifications.

Table 1. IMGC/CENAM-HG6 mercury manobarometer specifications.

Measurement range	5 kPa up to 100 kPa
Measurement mode	Absolute, relative and differential
Measurement stability	0.01 Pa
Uncertainty ($k = 1$)	±(0.23 to 0.45) Pa absolute ±(2.0 to 4.0) Pa relative

2. The IMGC/CENAM-HG6

It is formed by two glass tubes with a height of 90 cm and an internal diameter of 60 mm, mounted 110 mm apart. These tubes are interconnected and partially filled with mercury. The large diameter of the tubes reduces the capillary effect and the hysteresis of the mercury meniscus. The mercury columns are immersed in a high stability thermostatic bath with water recirculation, to stabilize the mercury temperature at 20 °C (maximum deviation 0.012 °C and $u = \pm 0.01$ °C). The mercury temperature is measured with platinum resistance sensors (RTD Pt-100) placed in the bottom and inside the mercury columns. The mercury used was supplied by NIST (USA); its density was determined by two independent measurements (the first relative, the second absolute) performed by CSIRO (Australia) and PTB (Germany), respectively. The value adopted for mercury density at 20 °C and 100 000 Pa is $\rho = 13\,545.8507$ kg m^{-3} [3].

The height difference between the two columns is measured by means of a single-beam helium–neon laser interferometric system, with a resolution of 10 nm and a long term stability of 20 nm. An important characteristic of the

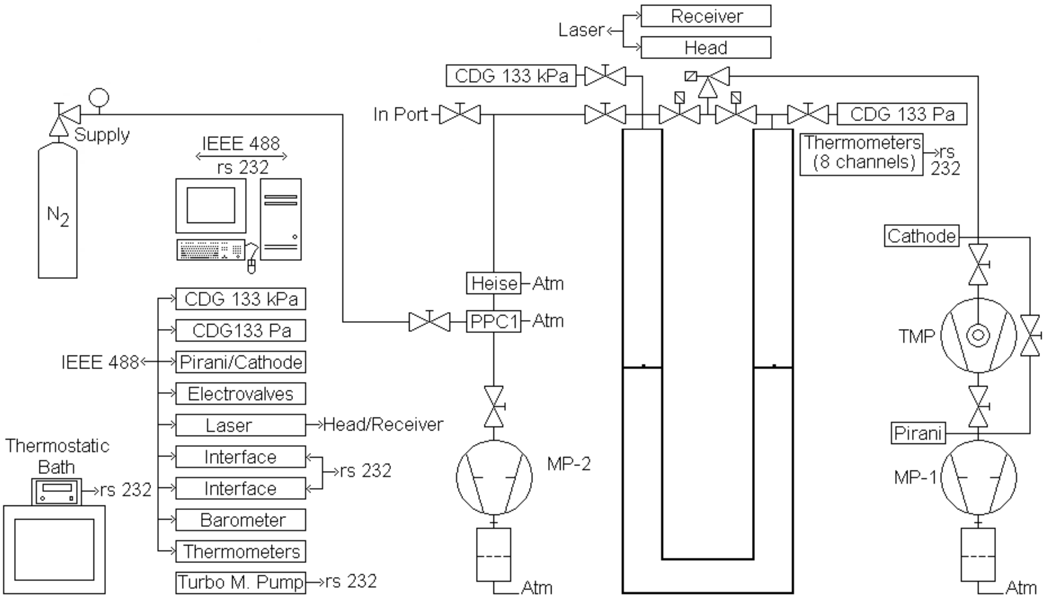

Figure 1. IMGC/CENAM-HG6 mercury manobarometer schematic.

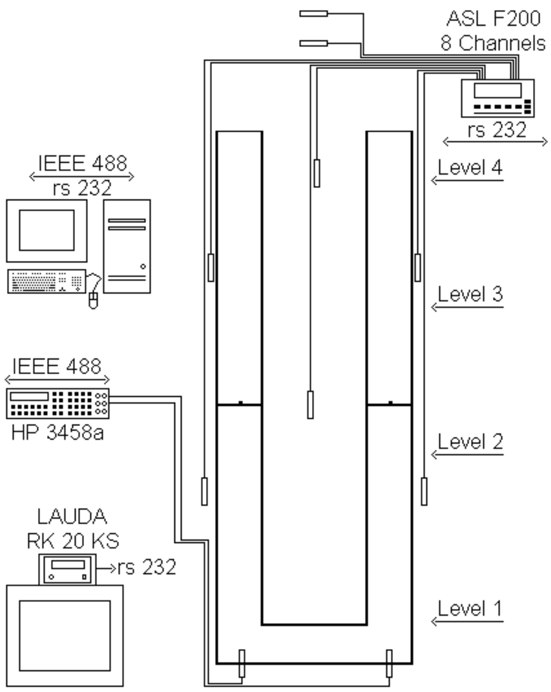

Figure 2. IMGC/CENAM-HG6 mercury manobarometer temperature measurement and control system schematic.

height difference measurement system is the use of Macor made devices (machinable glass ceramic), placed on the mercury surfaces and carrying the cube-corner retroreflectors. Figure 1 shows a schematic of the IMGC/CENAM-HG6.

2.1. Subsystems

The IMGC/CENAM-HG6 different subsystems are described below:

(a) Structure: the main structure is made of aluminium and is formed by three columns joined by two plates. The lower plate serves as a support for the whole manobarometer. The upper plate supports the interferometric system.

(b) Interferometric system: this system has a laser head, a beam splitter, a 45° mirror, retroreflectors (installed on the mercury column surfaces floats) and the beam receiver.

(c) Pressure application system: the pressure control is achieved by valves connected to one of the glass tubes. For changing the pressure a type PPC1 pressure controller is used, connected to an extra pure nitrogen tank and to a vacuum pump. For absolute measurements both tubes are connected to a turbo molecular vacuum pump.

(d) Temperature measurement and control apparatus: a water glass container surrounds the glass tubes and it is connected to a temperature control bath, which circulates the water. The temperature measurement is carried out through platinum resistance thermometers located in the glass tubes, the water container and the bath. Figure 2 is a schematic of this system.

(e) Data acquisition: all measurement instruments used in the IMGC/CENAM-HG6 for control, data acquisition and temperature measurement are interconnected in a transmission channel GPIB 488 (IEEE 488).

2.2. Main differences with HG5

The main differences between this system and the original HG5 [4] are

• Thicker plates for the laser head and the optical system (>stiffness)	• Stainless steel made support columns (instead of aluminium)
• Automatic valves control	• Thicker support plates (>stiffness)
• Automatic temperature data acquisition and control	• Stainless steel connection between glass tubes (instead of Teflon)
• Improved design of retroreflector floats	• Visual user-friendly program

3. Characterization of the IMGC/CENAM-HG6

A photograph, as it is in operation at CENAM, is shown in figure 3.

Several tests have been carried out to characterize the IMGC/CENAM-HG6. The main two tested were

- Mechanical vibrations. One of the first was to study the influence of mechanical vibrations on the measurements. As a result, a separate concrete platform was made and vibration absorption mats were installed on the operator's pathway, the vacuum pumps and thermostatic bath.
- Thermal stability. The thermostatic bath was characterized by measuring the temperature at more than 100 points at four different levels, shown in figure 2, along the height of the mercury columns. Several improvements were made including the use of ping-pong balls on the water surface, as temperature isolators and to reduce water evaporation. After the improvements, the maximum temperature difference within each level was 0.003 °C, while the maximum temperature difference among the different levels was 0.012 °C, with a standard deviation in these differences being 0.005 °C. The results are shown in figure 4.

Figure 3. IMGC/CENAM-HG6 mercury manobarometer photography.

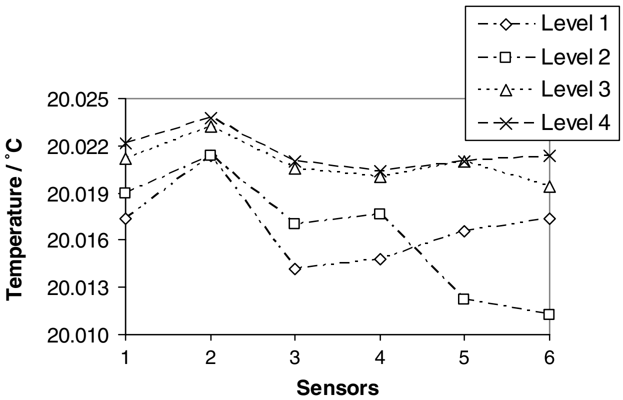

Figure 4. Bath characterization.

In order to validate the characterization of the IMGC/CENAM-HG6 a comparison in absolute mode (N_2 gas) with a primary pressure balance ($A_0 = 1.961\,0499 \times 10^{-3}\,\mathrm{m}^2$; $u_{A_0} = 14 \times 10^{-6}$) was carried out in the range of 2.5 kPa up to 80 kPa. The results (mean values from six cycles of measurements) are shown in table 2.

4. Results and conclusions

According to the results obtained from the internal comparison, the IMGC/CENAM-HG6 has a very good agreement within the declared uncertainty in the working measurement range. It is important to note that standard uncertainties are used for the normalized error equation.

The best metrological characteristics of the IMGC/CENAM-HG6 are obtained in the absolute pressure mode, where some influence quantities are eliminated, such as daily atmospheric pressure variations, mercury oxidation prevention (mercury is maintained in a nitrogen atmosphere avoiding mercury/air contact) and higher vacuum measurement accuracy in the reference column by use of a capacitance diaphragm gauge.

Improvements for the near future include the installation of GPIB-ENET/100 interfaces to control the measurement

Table 2. Deviations between the IMGC/CENAM-HG6 and the pressure balance.

Balance's pressure/kPa	Mercury column's pressure/kPa	Deviations between the instruments/Pa	*u* pressure balance/Pa	*u* mercury column/Pa	*u* deviation (combined uncertainty)/Pa	Standard normalized error
2.4935	2.4938	−0.27	0.23	0.22	0.314	0.9
4.9879	4.9877	0.19	0.24	0.22	0.330	0.6
9.9758	9.9761	−0.31	0.28	0.23	0.363	0.8
19.9511	19.9515	−0.41	0.35	0.25	0.432	0.9
29.9273	29.9275	−0.16	0.42	0.28	0.503	0.3
39.9027	39.9025	0.22	0.49	0.30	0.576	0.4
49.8797	49.8801	−0.37	0.56	0.33	0.650	0.6
59.8559	59.8565	−0.57	0.63	0.36	0.724	0.8
69.8327	69.8321	0.62	0.70	0.39	0.780	0.8
79.8094	79.8103	−0.92	0.77	0.42	0.876	1.0

processes via the CENAM internal network to increase temperature stability and diminish vibrations.

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References

[1] Torres Guzmán J C 2001 Manómetros de columna de líquido *CENAM Technical Publication* CNM-MMF-PT-001

[2] Tilford C R 1993/94 Three and a half centuries later—the modern art of liquid-column manometry *Metrologia* **30** 545–52

[3] Alasia F, Capelli A, Cignolo G and Sardi M 1993/94 A new generation of mercury manometers at the IMGC *Metrologia* **30** 571–7

[4] Alasia F, Birello G, Capelli A, Cignolo G and Sardi M 1999 The HG5 laser interferometer mercury manometer of the IMGC *Metrologia* **36** 499–503