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NEW PRIMARY BALANCE OF BEV FOR HIGH-PRECISION MASS DETERMINATION AND REALIZATION OF THE MASS SCALE IN THE RANGE FROM 10 G UP TO 1 KG

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Abstract: The Austrian Federal Office of Metrology and Surveying (BEV) has developed and realized in cooperation with Sartorius AG (Göttingen) and the Vienna University of Technology a new 1 kg high-precision mass comparator. The new balance is intended to be used for automatic calibration of weights with high precision, for the realization of the mass scale in the range from 10 g up to 1 kg and for mass calibration of density standards.

Keywords: mass, prototype, balance design.

1. INTRODUCTION

Electromagnetically compensated mass comparators [5] are generally used in mass metrology. The factory made designs are usually good for standard calibrations of weights, but they are not versatile enough for special purposes.

Fig. 1. The new prototype balance

To override this problem BEV developed and realized a primary balance for high precision calibration, especially for dissemination of mass unit using the national copy of the prototype, determination of mass of density spheres and dissemination of the unit of mass using subdivision method in the mass range 10 g -1 kg.

1. EVALUATION OF THE CURRENT SITUATION

The current balance in use is a Sartorius CC 1000 S-L factory made mass comparator under an isolated extra house (fig.2.). Inside the weighing chamber the stability is very good due to the introduction of the isolated house with its double glass front installed in the brand new laboratory of BEV opened in 2011.

Fig. 2. The factory made mass comparator with the extra house

The typical standard deviation of a comparison of two stainless steel standards is 0,6 μg and 2,8 μg for the comparison of a stainless steel standard and the copy of the prototype.

The balance is limited to 4 positions. The weighing pan cannot hold weigh combinations therefore the introduction of special technics are necessary [6].

The place of the determination of the carbon dioxide content is under the isolated house, but outside the weighing chamber, which could lead to an increased measurement uncertainty.

Finally, the weighing chamber is too small for density standards to fit in.

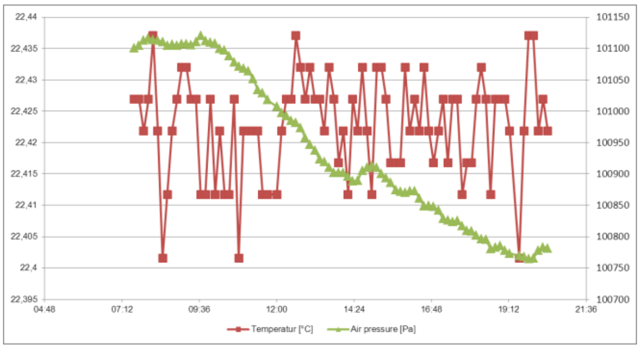

Fig. 3. Temperature and air pressure changes during a measurement

As it is shown in Fig. 3, the temperature is stable in the weighing chamber while there is a usual change of air pressure due to the weather change causing and increased uncertainty.

2. DESIGN AND CONSTRUCTION

At the start of this project BEV established some important requirements for the new system. The summary of these requirements are the following:

- Provide a minimum of 8 weight holders.
- The measuring range shall cover the nominal weights from 10 g to 1 kg in order to realise the mass scale by using only this comparator and the 10 g robotic system of BEV.
- Provide the possibility to measure any usual combination of weights used in subdivision method [4].
- The weighing chamber shall be spacious enough for the measurement of 1 kg silicon sphere density standards (diameter about 100 mm).
- Minimalize the air pressure change in the weighing chamber.
- Provide means for setting the air pressure inside the weighing chamber for the usage of buoyancy artefacts.
- The whole system shall be made of non-magnetic, non-static materials.

Main elements of the construction are shown in the CAD design (Fig 4):

- Upper part:
  - Modified Sartorius CC 1000 S-L, mass comparator with 1 kg maximum load and 1 µg resolution;
- Middle part
  - Mechanism and servo systems;
  - Dead weighs for maintaining constant load.
- Weighing chamber (lower part):
  - Two pressure sensors to cover the range from normal air pressure to vacuum with 1 Pa resolution;
  - Two temperature and humidity sensors, with 0,01 °C and 0,01 % resolution;
  - Carbon dioxide sensor with 1 ppm resolution;
  - Turntable with 8 positions.

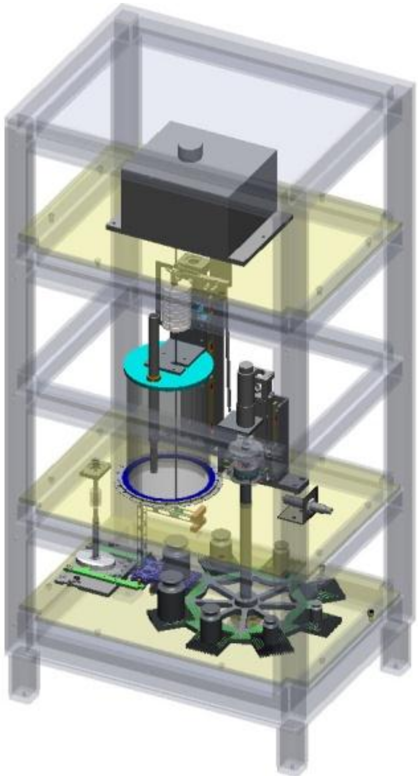
Fig. 4. CAD design of the new prototype balance

The weights are positioned below the mass comparator to eliminate the off-centre loading on the weigh cell. A constant load mechanism was designed to reduce the temperature differences in the monocell coil of the comparator.

The original top-load comparator was specially modified by Sartorius for this system by providing connectivity for a suspension system. The main parts of the suspension system are the dead weights and the weighing pan. The specially developed comb-type grabber system makes it possible to insert the 10 g to 1 kg weights and to position them precisely on the weighing pan of the mass comparator.

Before loading the actual weight to the weighing pan by moving the magazine the whole suspension system is moved and fixed to a defined position. This allows using very small gaps between the fingers of the comb-type grabber and the weight holder of the comparator. Before the measurement starts the fixation of the suspension system is unfastened.

Based on the previous experiences [1], this system was also designed on the basis of linear movement. It is rather simple, universal and well manageable. The only exception is the rotation of the magazine (turntable), which does not follow this concept. The 8 weight holders of the magazine can be loaded with reference weights and test weights, air density artefacts or density standards (such as silicon spheres) as desired.

Fig. 5. Inside the new prototype balance

To reduce the uncertainty caused by unstable environment the whole balance placed in a protective, airtight closure and the weighing chamber itself has a glass cylinder, functioning as a “draft shield”, which can be lowered and closed before the actual balance reading. The protective enclosure is made of thick aluminium plates while the front is made of thick glass plates. All cables are sealed to prevent the change of the air pressure in the weighing chamber. The carbon dioxide is measured inside the enclosure.

Attaching a pump to the system the air pressure can be adjusted inside the enclosure. Primarily BEV does not plan to reduce the pressure below 800 mbar. It is more important to keep the air pressure constant to avoid the influence of the air buoyance change due to the air density change. This system is constructed to provide measurements in vacuum.

To reduce the standard deviation of the balance indication and therefore to increase the reproducibility a special mechanism guarantees the constant load of the comparator. The dead weights are put on the suspension system below the balance exactly the moment when the weight is lifted off the weighing pan. The dead weights have to been chosen and stacked on the suspension manually.

Fig. 6. View of glass cylinder, the dead weights and the mechanisms (plate separating the weighing chamber and the middle part is removed for the photo).

3. METHOD OF THE OPERATION

All test and reference weights from 10 g to 1 kg or groups (combinations) of weights are introduced by hand onto the magazine. To ease the pre-centring of the weights there are concentric ring-marks on the magazines see Fig 5. The measurement procedure and the evaluation of the data is the same used by the other weighing system in BEV.

To meet the design requirement that the weights should always be picked up without the aid of an extra transportation unit a comb-type grabber system was manufactured. In the middle of each slot there is a small deepening to hold the density standards (spheres) safely.

The weighing system is controlled by a personal computer, which communicates with the DC-servo controller via Profibus-DP.

The whole system is placed on a 4 m long granite plate supported by a concrete table with a mass of approximately 15 t. The concrete table is mounted on passive air springs.

4. THE PERFORMANCE OF THE SYSTEM

Using the previously proven solution, the same evaluation logic and calculation procedure is used as in the other handling systems of the BEV.

The ambient parameters for the determination of air density are automatically recorded for each balance reading. Air temperature and humidity are measured in two places. One sensor is installed in the weighing chamber of the system near the weighing pan while the second is situated near the magazine to monitor the thermal distribution. For more accurate air density determination, especially during calibration of steel weights against the copy of prototype or during comparison of silicon and steel objects, air density artefacts will be used.

The measured temperature and humidity stability are in the same range as in the current comparator. The expected standard deviation for Prototype and stainless steel as well as for two stainless steel standards shall not be larger than those being used the current comparator.

In order to validate the system, measurement sequences are carried out using calibrated weights. The BEV also takes part in inter-laboratory comparisons to finalise the evaluation of the performance of the new primary balance.

5. CONCLUSION

Besides the better air pressure stability and the improved mass determination in BEV the new balance opens new possibilities in mass metrology for Austria. It also gives the opportunity to take part in certain research projects.

ACKNOWLEDGMENTS

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