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DEVELOPMENT AND REALISATION OF A FULLY AUTOMATIC TESTING FACILITY FOR DETERMINING THE VOLUME OF E1 WEIGHTS UP TO 50 kg BASED ON HYDROSTATIC WEIGHING.

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Abstract: The Federal Office of Metrology and Surveying (BEV, Austria) has developed and realised a new fully automatic test System for hydrostatic weighing and determining the density of solids up to 50 kg. This volume comparator allows a full automatically determination of the volume of E1 weights and plummets in the range from 1 kg up to 50 kg through direct comparison with one single volume reference (e.g. a Silicium sphere) with high accuracy. In this volume comparator, two hydrostatic weighing systems for density determination work simultaneously together so that it is possible to compare the density of a small, well-known standard sinker directly with the density of a submerged solid with masses up to 50 kg.

Keywords: Solid density; volume comparator; hydrostatic weighing

1. INTRODUCTION

In cooperation with the Institute of Production Engineering of the Vienna University of Technology and the Häfner Company in Oberrot, Germany the Austrian national metrology institute, the Federal Office of Metrology and Surveying (BEV) has developed and realised this new test system for hydrostatic weighing and determining the density of solids up to 50 kg

This cooperation has been supported by Sartorius AG in Goettingen, Germany.

This new 50 kg Volume comparator was realised as an obligatory complement to the 1 kg Volume comparator developed at the BEV in the year 2006 [1]. This Volume comparator can be applied for serial volume determination of masses from 1 g to 1 kg, also by direct comparison with a single volume reference (e.g., a 300 g silicon sphere). This principle has been implemented with a special, fully automatic insertion mechanism both for completely submersed weights and substitution weights.

2. CONCEPT

The concept was to build up a system, based on the hydrostatic weighing principle to compare a small Volume standard (e.g. a 1 kg Silicium sphere) and different substitution weights in air directly to an immersed solid of a mass between 1 kg and 50 kg. Clean water should be used as test liquid.

The measurement system consists completely of a special seawater resistant aluminium alloy to avoid any influence of magnetism and oxidation and has two different mass comparators on the top. The mass comparator specifications correspond to the range of the test objects to be measured. An automatic lift system can load the mass comparators alternately with weights and submerged plummets.

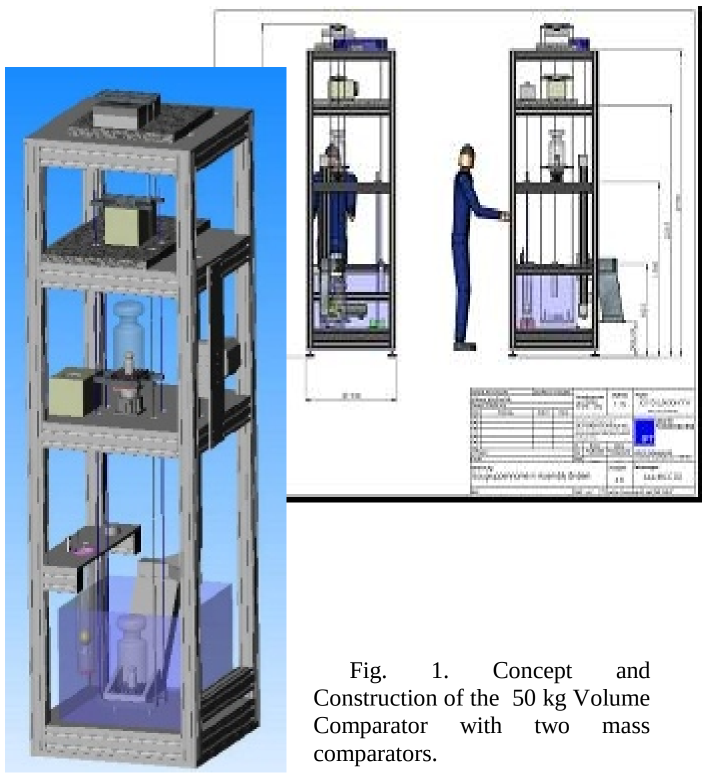

Fig. 1. Concept and Construction of the 50 kg Volume Comparator with two mass comparators.

3. CONSTRUCTION OF THE VOLUME COMPARATOR

Fig. 2. Realisation of the 50 kg Volume Comparator

This volume comparator allows determining consecutively the volume of E1 weights and plummets in the range from 1 kg up to 50 kg. It is a fully automatic handling system for a 60 kg mass comparator for the test weights and for a 1 kg mass comparator for the standard sinker.

In this volume comparator for big masses, two hydrostatic weighing systems for density determination work simultaneously together, in a way, that it is possible to compare directly the density of a small, well-known standard sinker (e.g. a 1kg Silicium sphere) with the density of a submerged solid with masses up to 50 kg. This means that with two load alternators for substitution weights and two load alternators for the plummets, the density of the transfer- liquid on one side and the density of a submerged solid on the other side can be determined hydrostatically, via direct comparison with a submerged standard plummet, a mass standard in air and an applied weight also in the liquid. The determination of the liquid density is carried out steadily before and after each volume measurement. This is implemented with a newly developed, fully automatic insertion mechanism both for completely submersed weights and the substitution weights in air.

The entire control system as well as all electronic components is housed in a control cabinet. The system is controlled by a computer, which is also used to evaluate the data. In order to determine environmental parameters the unit has sensors for air pressure, humidity and air temperature. A number of additional sensors are provided in order to exclude errors in the measuring process.

Fig. 3. Load alternator and suspension system for the test weight in the liquid tank; on the left the measurement chamber for the liquid density determination can be seen

So it is possible to determine the density and accordingly the volume of big masses with high precision.

The mass comparators used are the well-tried modified Sartorius CWZ1005 with a possible dead load of up to 400g and a maximum load is 1 kg with a resolution of 10 µg and a CCE60K3 balance and a maximum load is 60 kg with a resolution of 1g

For both, the substitution weights and the test weights a position below the mass comparator was chosen. This eliminates off-center loading problems on the weigh cell.

Due to these Comparators and the hydrostatic weighing principle the BEV is able to carry out serial volume determination of masses from 1 g to 50 kg through direct comparison with a single volume reference (e.g. a Silicium sphere).

4. FUNCTIONALITY AND PROCEDURE OF THE VOLUME COMPARATOR

During the measurements, the individual objects and the applied substitution weights can be raised and lowered using lifting rods that are moved pneumatically. This places and replaces the mass on the suspension system of the mass comparator. Except the test weight that is moved by an electrical axis; so it is possible to use it as a lift for bringing in the weights (especially the heavy ones) very easily (see Fig. 6).

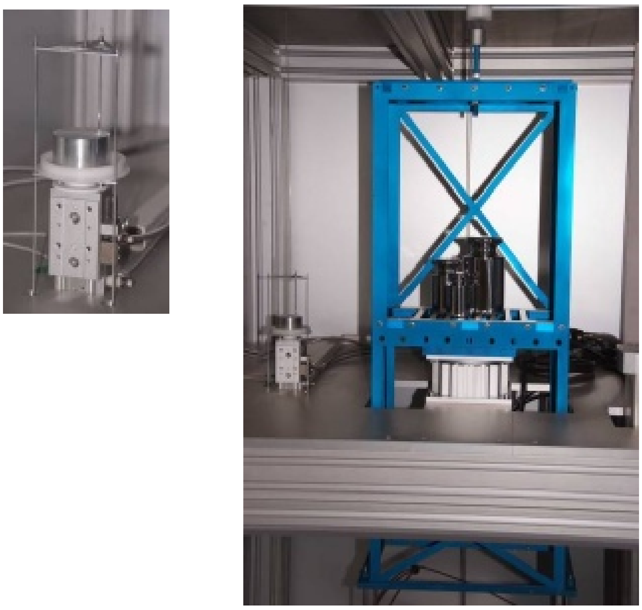

Fig. 4. Load alternators and suspension system for the substitution weights in air; on the left the substitution weight for the Standard sphere, in the middle (empty) suspension system and the Load alternator for the test weight

The temperature of the measuring liquid is monitored by up to nine high-precision sensors (25 Ω and 100 Ω standard platinum-resistant thermometers (SPRT) in compliance with ITS 90). Therefore it is possible to assess the thermal layering in the measuring vessel with a volume of approx. 200 litres. Between the measurements a stirrer guarantees a continuous rearrangement of the liquid and furthermore it is possible to connect a thermostat. The experience shows that under stabilised environment conditions (e.g. a good air conditioned laboratory) it is not necessary to use a thermostatic bath due to the big volume of the measuring vessel. The end of the disturbance of thermal balance and destabilisation of the bath after bringing in big masses can be monitored over the density stability.

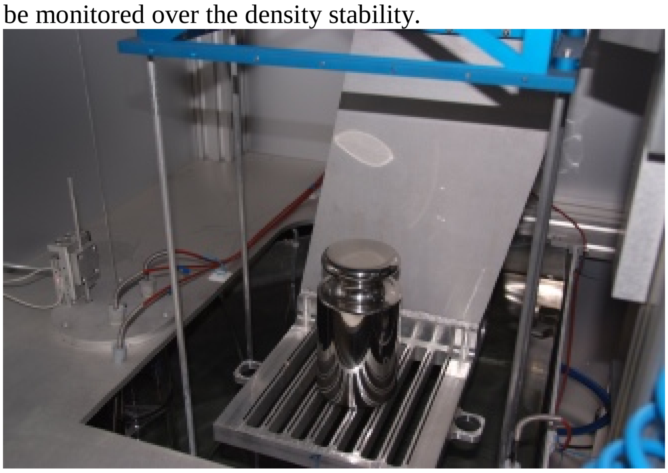

Fig. 5 and 6: Load alternator for bringing in a 10 kg test weight in the liquid tank; on the left there is the measurement chamber for the liquid density determination also with the load alternator; the red wires shows the platinum resistance sensors for the temperature measurement in the chamber of the liquid density measurement and these of the liquid tank

After bringing in the weights, it is necessary to pause over a specific period of time for an approximately acclimation. Following there is carried out automatically a series of liquid density determination combined with phases of stirring and stabilisation and the measurement starts automatically when the density of the liquid reaches a stable value. The range for this value is default. The experience shows if this changing in water density is better than $1 \cdot 10^{-5}$ kg/m^3 it gives a small standard deviations in the volume measurement. So it is guaranteed to have a stable liquid and an acclimatised weight for the volume determination.

To avoid a influence of the weighing value due to the changing of the meniscus and further a changing of buoyancy while lifting the test weights or plummets with these big lift system, a special sinker was implemented to compensate for the surface motion caused by form the lift movement.

Fig. 7.; the sinker to compensate the liquid surface motion caused by the movement of the lift in the foreground

The software assists the operator in the preparation and execution of the measurements. In addition to the fully automatic measurement program, operators have the option of performing individual steps separately (single-step mode). In addition, the program shows the operator all the measurement data from the sensors in real time as well as the current progress of the measurement.

To prepare the volume determination it is necessary to measure the weights in air. This is carried out separately (e.g. on the handling system for big masses of the BEV [2]). The software's user interface prompts the operator to prepare the measurement inserting the reference weights, the test weights and the appropriate substitution weights whereby a database can be used This entails use of the weight insertion mechanism; it is important at this point to make sure there are no air bubbles on the weights once they are immersed in the liquid. The result of each measurement is the volume, the density and the mass of each test weight and the standard deviation of the results, with complete documentation of the conditions of measurement and default values and also an appropriate estimation of uncertainty in measurement. Measurement values and all associated data can be provided as raw value output (for further calculation in e.g. Excel) or on printouts that contain a complete evaluation of the measurement data. The basis for the calculation procedure and the formulas are the same as at the 1 kg Volume comparator [1] and the fundamental apparatus of density [1]

Fig. 8. Load alternator (lift system) for the 50 kg test weight in the liquid tank; in the background there is the measurement chamber for the liquid density determination; on the right there is the additional sinker for liquid surface motion compensation.

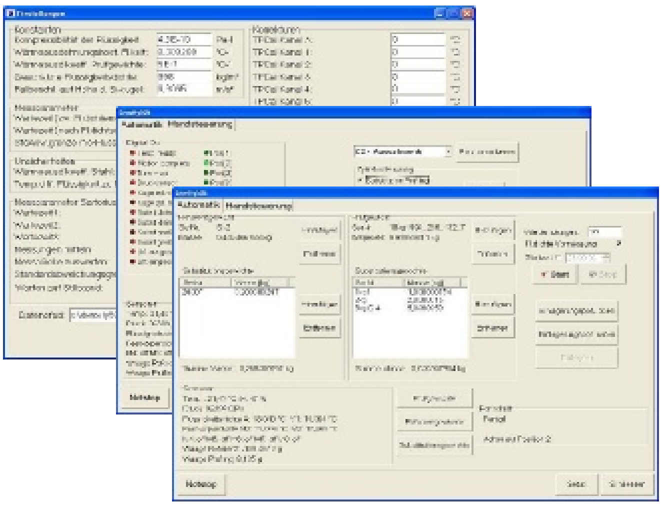

Fig. 9. Windows surface of the software

5. MEASUREMENT RESULTS WITH THE VOLUME COMPARATOR

Measurement series with already calibrated BEV test weights and plummets have been carried out to validate the system since Dec. 2008. Excellent results have been achieved in terms of reproducibility and standard deviation. At the moment there is the implementation of the system at the BEV. Beginning in summer 2009, international comparative measurements will be taking place on a bilateral basis with another institute for the final validation

The results and the Documentation will be finished at the end of 2009.

Comparisons with reference weights at BEV also showed excellent results. The prototype unit is already being used to measure the volume of weights with a mass of 1 kg to 20 kg in the scope of mass determination at BEV, for ongoing in-house and external calibrations and it has been implemented in the BEV quality system.

Further units have been built up for other accredited calibration laboratories whereas every unit is given an examination by the Physico- Technical Testing Service of the BEV ,

6. CONCLUSION

This 50 kg Volume comparator was realised as an obligatory complement to the 1 kg Volume comparator developed at the BEV in the year 2006. These Comparators based on hydrostatic weighing enable the BEV to carry out automatically serial volume determination of masses from 1 g to 50 kg through direct comparison with a single volume reference (e.g. a Silicium sphere) with a very high accuracy.

Both Volume comparators are used at the BEV and other institutes or calibration laboratories on one hand for the mass determination according to the OIML recommendation R111, and on the other hand for the determination of the density of solids up to 50 kg.

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