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DENSITY MEASUREMENT SYSTEM OF 50 KG WEIGHTS BY METHOD A IN OIML R111 (2004) AT CMS

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Abstract − In OIML R111 (2004), six accepted methods for the determination of the density of weights are given. Method A is most accurate method and method D is an alternative way to determine the volume of large weights which are difficult to handle in hydrostatic weighing in an indirect way. In this paper, a hydrostatic weighing system by method A for large weights built up at CMS are described.

Keywords: OIML R111 (2004), density measurement, hydrostatic weighing

1. INTRODUCTION

Six accepted methods for the determination of the density of weights are given in OIML R111 (2004). As mentioned in this recommendation, the method A using a hydrostatic technique is the most accurate method than the other five methods.

However, it is not considered to be suitable for all the weights to use the method A because of liquid immersion, weight handling, complex procedures and etc....

Although an alternative way method D is provided in R111 to indirectly determine the volume of large weights which are difficult to handle, a hydrostatic weighing system by method A for large weights is built up at CMS in order to process the semiautomatic comparison.

With load alternator and controller, it is easier to handle the weights from 2 to 50 kg during the density measurement by using hydrostatic weighing.

2. PRINCIPLE

2.1. Definition of symbol

Symbol	Definition
ρ	Density
m	Mass
V	Volume
F_b	Buoyancy force
fl	Subscript for static fluid
g	Gravitational acceleration
F_g	Gravitational force
f_k	Correction factor for mass comparator
I	Indication of the mass comparator (scale division)
l	Subscript for liquid
a	Subscript for air
r	Subscript for reference weight
t	Subscript for unknown weight
s	Subscript for sensitivity weight
w	Subscript for weighing process
Δm	Mass difference
C	Buoyancy correction factors

2.2. Principle

As mentioned in this recommendation, the hydrostatic technique in method A is based on the well-known Archimedes' principle. Object in the static fluid is subjected to the buoyancy force F_b as seen in (1).

$$F_b = \rho_{fl} g V \quad (1)$$

From the well-known Newton's law of gravitation, the gravitational force for an object is F_g as seen in (2).

$$F_g = mg \quad (2)$$

Then, the weighing equation in the static fluid (air or liquid) is seen in (3).

$$mg\left(1-\rho_{fl}/\rho\right) = kI \quad (3)$$

According to the method A2 recommended in OIML R111 (2004) [1], compare between unknown weight and reference weight both in air and in liquid, then the equations are seen in (4) ~ (7) (gravitational acceleration g is assumed to be the same).

Reference weight in liquid: $$m_r g\left(1-\frac{\rho_l}{\rho_r}\right) = f_k I_{rl} \quad (4)$$

Reference weight in air: $$m_r g\left(1-\frac{\rho_a}{\rho_r}\right) = f_k I_{ra} \quad (5)$$

Unknown weight in liquid: $$m_t g\left(1-\frac{\rho_l}{\rho_t}\right) = f_k I_{tl} \quad (6)$$

Unknown weight in air: $$m_t g\left(1-\frac{\rho_a}{\rho_t}\right) = f_k I_{ta} \quad (7)$$

The density of the unknown weight ρ_t is then calculated in (8).

$$\rho_t = \frac{\rho_l(C_a m_t + \Delta m_{wa}) - \rho_a(C_l m_r + \Delta m_{wl})}{m_r(\rho_l - \rho_a)/\rho_r + \Delta m_{wa} - \Delta m_{wl}} \quad (8)$$

Where C_a , C_l , Δm_{wa} and Δm_{wl} represent in (9) ~ (12) respectly.

$$C_a = 1 - \rho_a / \rho_r \quad (9)$$

$$C_l = 1 - \rho_l / \rho_r \quad (10)$$

$$\Delta m_{wa} = (I_{ta} - I_{ra}) C_s \quad (11)$$

$$\Delta m_{wl} = (I_{tl} - I_{rl}) C_s \quad (12)$$

$$C_s = 1 - \rho_{as} / \rho_s \quad (13)$$

3. BRIEF OVERVIEW OF THE MEASUREMENT SYSTEM

As the load alternator used in common mass comparator, we built up a measurement system with load alternator. The system diagram is shown in Fig. 1 and the system photo is shown in Fig. 2.

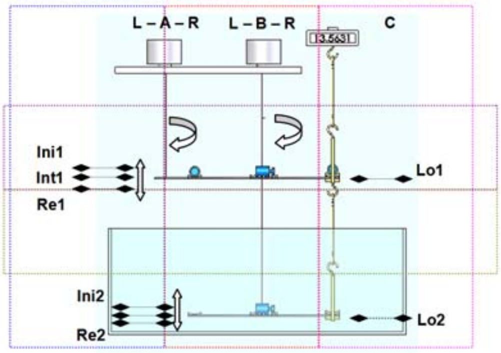

Fig. 1. The system diagram.

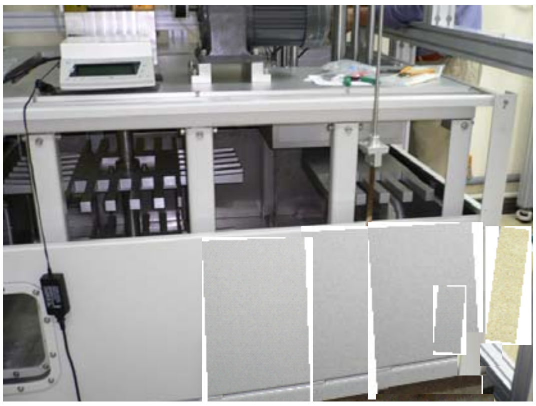

Fig. 2. The system photo.

There are three motion areas and two weighing areas in the system. These three motion areas are area A loading area in Fig. 3, area B exchanging area in Fig. 4 and area C weighing area in Fig. 5. These two weighing areas are area D air-weighing area and area E liquid-weighing area.

Fig. 3. The area A loading area.

Fig. 4. The area B exchanging area.

Fig. 5. The area C weighing area.

The area A loading area is composed of a driving motor in Fig. 6, a loading axis and a platform in Fig. 7. The area B exchanging area is composed of a driving motor in Fig. 8, a exchanging axis and a set of turntable in Fig. 9. The area C weighing area is composed of a hanger in Fig. 10, a suspension strip and a weight holder in Fig. 11. The hanger is connected directly to the bottom of the comparator.

The motions of loading weight from the loading platform to the exchanging turntable can be seen in Fig. 12. The motions of loading weight from the exchanging turntable to the weight holder can be seen in Fig. 13. All of the motions can be operated from the control panel in Fig. 14 with a programmable logic controller (PLC) inside which can also provided computer control after connection.

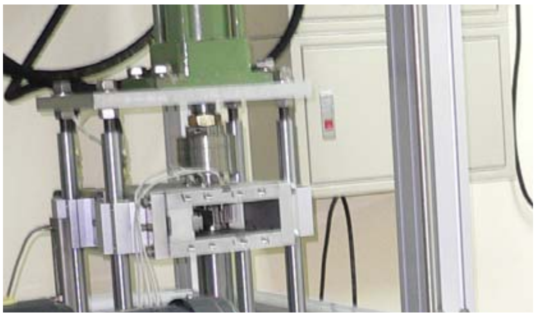

Fig. 6. The driving motor in area A loading area.

Fig. 7. The loading axis and platform in area A loading area.

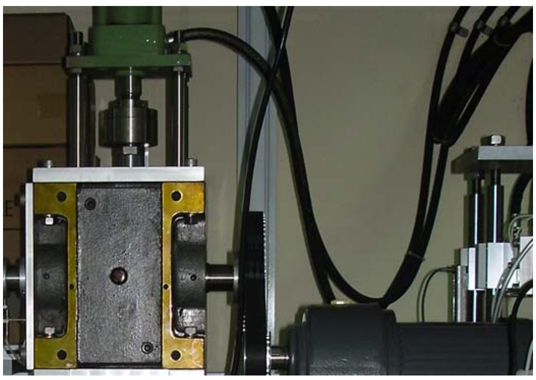

Fig. 8. The loading axis and platform in area B exchanging area.

The most importance thing in designing the system is to find out a suspension wire which is thin but strong enough to withstand the 50-kg loading and can pass the air-liquid interface at a right angle. We use beryllium-copper alloy here as seen in Fig. 15 and Fig. 16. The Be-Cu strip plays a good role here but is easy to break down after torsion.

Fig. 9. The loading axis and turntable in area B exchanging area.

Fig. 10. The hanger in area C weighing area.

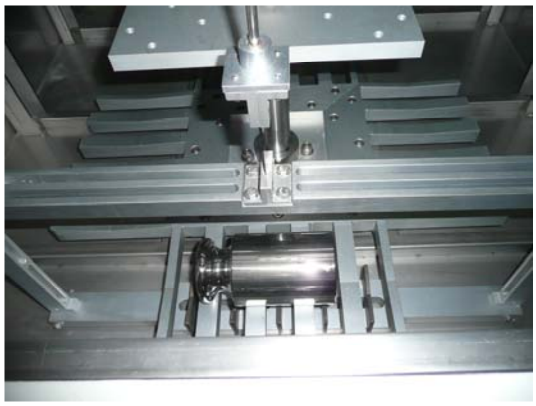

Fig. 11. The suspension strip and weight holder in area C weighing area.

4. CONCLUSIONS

With load alternator and controller, it is easier to handle the weights from 2 to 50 kg during the density measurement by using hydrostatic weighing. With the same design except a vacuum system used in the 1 kg system to drive away the air bubbles, another two measurement system for 1 to 200 g and 200 g to 1 kg are built at the same time to fulfil the density requirement of R111.

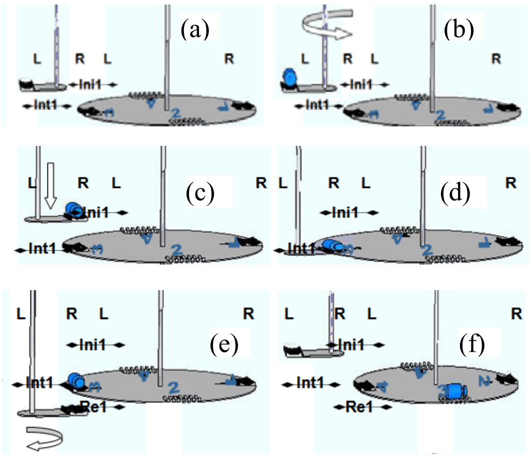

Fig. 12. The motion of loading weight from loading platform to exchanging turntable.

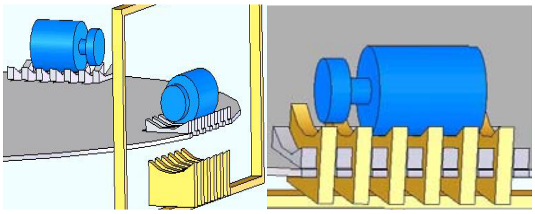

Fig. 13. The motion of loading weight from the exchanging turntable to the weight holder.

Fig. 14. The control panel.

ACKNOWLEDGMENTS

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Fig. 15. The beryllium-copper alloy.

Fig. 16. Loading test for the Be-Cu strip.