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Conventional Value of the Result of Weighing in Air

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INTERNATIONAL RECOMMENDATION

OIML R 33

Edition 1979 (E)

Conventional value of the result of weighing in air

Valeur conventionnelle du résultat des pesées dans l'air

OIML R 33 Edition 1979 (E)

ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE

INTERNATIONAL ORGANIZATION OF LEGAL METROLOGY

Foreword

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This publication – reference OIML R 33 (E), edition 1979 – which is under the responsibility of TC 9/SC 3 *Weights*, was sanctionned by the International Conference of Legal Metrology in 1972.

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CONVENTIONAL VALUE

OF THE RESULT OF WEIGHING IN AIR

0 OBJECT OF THE RECOMMENDATION

The aim of this Recommendation is to define the "conventional value of the result of weighing in air" and to fix the values of the physical constants which play a part in this definition.

Furthermore it lays down:

— the provisions relating to the density of weights (*) used with weighing machines and weights incorporated in these machines,

— the requirements for the adjustment of weights used with weighing machines and the requirements for the setting of these machines,

and specifies,

— the way to use the weights and weighing machines for the weighing of bodies.

The justification for the rules adopted may be found in the Annex.

CHAPTER I

1 DEFINITION

The conventional value of the result of weighing a body in air is equal to the mass of a standard, of conventionally chosen density, at a conventionally chosen temperature, which balances this body at this reference temperature in air of conventionally chosen density.

2 VALUES OF THE PHYSICAL CONSTANTS

The conventionally chosen values of the physical constants playing a part in the preceding definition are:

reference temperature:	20 °C
density of the standard of mass at 20 ° C:	8000 kg/m^3
density of the air:	1.2 kg/m^3

(*) The weights referred to are, particularly, prescribed weights:
Weights whose metrological properties (nominal value, maximum permissible error ......) and technical properties (shape, material, manufacture .....) are fixed by regulations.

CHAPTER II

3 DENSITY OF WEIGHTS

The density [(*)] of weights, as well as that of counterpoises, sliding poises, and incorporated weights of weighing machines must be chosen in such a way that when these weights are compared with a standard of 8000 kg/m^3 density, variation in the air density of 10 % above or below the value of 1.2 kg/m^3 does not lead to variations in the result of the comparison exceeding one quarter of the maximum permissible error on the weight or on the indication of the instrument (see Annex paragraph A.2).

4 ADJUSTMENT OF WEIGHTS

A weight of given nominal value must be adjusted in such a way that the conventional value of the result of weighing this weight in air is equal to the given nominal value, within the limits of the errors fixed for the accuracy class to which the weight belongs (see Annex paragraph A.3).

Note: This requirement does not apply to mass standards which must be adjusted in such a way that their mass is equal to the given nominal value, within the limits of the errors fixed for the accuracy class to which the standard belongs.

5 SETTING OF WEIGHING MACHINES

Whatever the method of operation of the weighing machines, (counterpoises, or sliding poises, or with or without incorporated weights) and accuracy class, they are set, without correction for displaced air by placing on their load receptors weights adjusted in accordance with the provisions of paragraph 4 above, tht ambient air density not differing by more than 10% from the conventional value of 1.2 kg/m^3.

CHAPTER III

6 WEIGHING OF BODIES

6.1 The weighing of a body is generally carried out:

either by comparison with weights adjusted in accordance with paragraph 4, or by using a weighing machine set in accordance with paragraph 5, without correcting for displaced air.

6.2 If it is necessary to determine the mass of the body (for example in the case of scientific or technical work) it is advisable to carry out a correction so as to take into account the difference between the displaced air on the body and the displaced air on the weights (this correction is calculated by giving the weights a nominal density of 8000 kg/m^3, whatever their real density).

(*) It is understood that this refers to the mean density of the weight as an object in its entirety and not just the density of the constituent materials.

There are for instance weights made of several materials of different densities and weights with a closed cavity not open to the atmosphere.

ANNEX A

The units used are:

for the masses, the kilogram (kg),

for the densities, the kilogram per cubic metre (kg/m^3).

A. 1 Relationship between the mass *m* of a body and the conventional value $\mathfrak{M}$ of the result of weighing this body in air.

The condition of equilibrium between the body and the standard, of mass *m'*, of density 8000 kg/m , in air of density 1.2 kg/m^3, is written:

$$m\left(1-1.2/\rho\right)=m'\left(1-1.2/8000\right)^{(*)}$$

ρ being the density of the body at 20 °C.

By definition the conventional value of the result of weighing the body in air is

$$\mathfrak{M} = m' \text{ or}$$
$$\mathfrak{M} = m\,[1-1.2\,(1/\rho-1/8000)]$$

A.2 Rule relating to the density of weights

(applying paragraph 3 of the Recommendation)

Let ε be the absolute value of the maximum permissible relative error on the weights (or on the indication of the weighing machine).

The density ρ of the weight must satisfy the following conditions:

$$8\,000\ \text{kg/m}^3 \times \frac{1}{1+10^5\frac{\varepsilon}{6}} \le \rho \le 8\,000\ \text{kg/m}^3 \times \frac{1}{1-10^5\frac{\varepsilon}{6}} \quad \text{if} \quad \varepsilon < 6\cdot 10^{-5}$$

$$8\,000\ \text{kg/m}^3 \times \frac{1}{1+10^5\frac{\varepsilon}{6}} \le \rho \qquad \text{if} \quad \varepsilon \ge 6\cdot 10^{-5}$$

A.3 Adjustment of a weight to a nominal value $\mathfrak{M}$

A.3.1 By reference to standards of mass

The weight is adjusted in such a way that it balances, in ambient air density *a*, the standard of mass of density ρ’ and of a mass

$$m' = \mathfrak{M}\ [1-a\,(1/8000-1/\rho')]$$

Note: This adjustment, which makes it possible to move from the standard of mass (primary standard) to the highest accuracy weights, is exceptional.

(*) In order to simplify the representation of the relationship, 1.2 and 8000 are used instead of 1.2 kg/m^3 and 8000 kg/m^3.

A.3.2 By reference to weights of higher accuracy whose adjustment meets the requirements of paragraph 4.

The weight is adjusted in such a way that it balances, in ambient air, a higher accuracy weight (or weights) of a nominal value equal tojicin ambient air whose density does not differ by more than 10 % from the conventiona l value of 1.2 kg/m^3.

Note: This adjustment which makes it possible to avoid using standards of mass is the method most frequently used at present.

ANNEX B

DEVELOPMENT OF CERTAIN CALCULATIONS

B.1 Considerations relating to the density of weights (paragraph 3)

The equilibrium, in air of density a, between a weight of nominal value $\mathfrak{M}$ (where mass $m = \mathfrak{M}\,[1 + 1.2\,(1/\rho - 1/8000)]$, ρ being the density of the weight) and a standard of mass m', of density 8000 kg/m^3, is written:

$$m\,(1 - a/\rho) = m'\,(1 - a/8000).$$

$$\text{whence } m' = \mathfrak{M}\,[1 + (1.2 - a)\,(1/\rho - 1/8000)]$$

The mass m' of the standard achieving equilibrium must not vary by an amount exceeding one quarter of the maximum permissible error on the weight, when a differs by less than 10 % from the value of 1.2 kg/m^3.

This condition is written (ε being the absolute value of the maximum permissible relative error).

$$|\,\mathfrak{M}\,(1.2 - a)\,(1/\rho - 1/8000)\,| \le \frac{\varepsilon}{4}\,\mathfrak{M} \quad \text{si} \quad |\,1.2 - a\,| \le 0.12 \text{ kg/m}^3$$

or $$|\,1/\rho - 1/8000\,| \le \frac{\varepsilon}{0.48}\,,$$

which leads to the conditions of paragraph A.2.

B.2 Adjustments of weights

B.2.1 By reference to standards of mass (paragraph A.3.1)

Let m be the mass of the weight once adjusted, ρ its density, m' and ρ' the mass and the density of the standards achieving equilibrium.

The condition of equilibrium between the weight and the standards is written:

$$m\,(1 - a/\rho) = m'\,(1 - a/\rho')$$

The weight has been adjusted to a nominal value $\mathfrak{M}$

The relationship between this nominal value $\mathfrak{M}$ and the mass m of the weight is written:

$$m = \mathfrak{M}\,[1 + 1.2\,(1/\rho - 1/8000)]$$

From the two preceding relationships, it may be deduced that

$$m' = \mathfrak{M}\,[1 + 1.2\,(1/\rho - 1/8000) - a\,(1/\rho - 1/\rho')]$$

or $$m' = \mathfrak{M}\,[1 - a\,(1/8000 - 1/\rho') + (1.2 - a)\,(1/\rho - 1/8000)]$$

The density of the adjusted weight is such that the expression

$$\mathfrak{M}\,(1.2 - a)\,(1/\rho - 1/8000)$$

is less than one quarter of the maximum permissible error on the weight (paragraph B.1).

This quantity is therefore negligible and the mass m' of the standards making it possible to adjust the weight to a nominal value $\mathfrak{M}$ is equal to:

$$\mathfrak{M}\,[1 - a\,(1/8000 - 1/\rho')]$$

Note: m, m', $\mathfrak{M}$ represent kilograms
ρ, ρ', a represent kilograms per cubic metre

B.2.2 By reference to weights of higher accuracy (paragraph A.3.2)

$\mathcal{M}$ is the nominal value of the weight serving as a standard which has itself been adjusted according to the requirements of paragraph 4. Therefore its mass is:

$$m' = \mathcal{M}\ [1 + 1{,}2\ (1/\rho' - 1/8000)]$$

ρ' being its density.

Let m be the mass of the weight once adjusted, ρ its density.

The condition of equilibrium between this weight and the weight serving as standard is written:

$$m\,(1 - a/\rho) = m'\,(1 - a/\rho')$$

or

$$m = m'\,[1 + a\,(1/\rho - 1/\rho']$$

whence by replacing m' by its value as a function of $\mathcal{M}$

$$m = \mathcal{M}\ [1 + a\,(1/\rho - 1/\rho') + 1.2\,(1/\rho' - 1/8000)]$$

By multiplying the two sides of the equation by $[1 - 1.2\,(1/\rho - 1/8000)]$ we obtain the conventional value of the result of weighing the adjusted weight in air, which is equal to:

$$\mathcal{M}\ [1 + a\,(1/\rho - 1/\rho') + 1.2\,(1/\rho' - 1/8000) - 1.2\,(1/\rho - 1/8000)]$$

an expression which may be written:

$$\mathcal{M}\ [1 + (1.2 - a)\,(1/\rho' - 1/8000) - (1.2 - a)\,(1/\rho - 1/8000)]$$

The quantity $\mathcal{M}\,(1.2 - a)\,(1/\rho - 1/8000)$ is negligible because it is less than one quarter of the maximum permissible error on the adjusted weight.

The quantity $\mathcal{M}\,(1.2 - a)\,(1/\rho' - 1/8000)$ is all the more negligible because it is less than one quarter of the maximum permissible error on the weight serving as a standard.

The conventional value of the result of weighing the adjusted weight in air is therefore equal to $\mathcal{M}$

Note: In all the calculations the infinitesimals of an order greater than 1 are disregarded.

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