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Source
Verification regulation of weights (trial usage)
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Calibration of Weights

PURPOSE

This work instruction can be applied to the verification of new weights and calibration of weights in service, and after repair but not to special weights that are produced according to a contract.

WORK INSTRUCTION

1 Technical Requirements

1.1 Classification of Weights

1.1.1 Weights can be classified into two kinds, based on whether they have a revision value or not. The weights with revision value can be classified into first and second grade. The weights without a revision value can be classified into class 1 to class 7 (total nine): 1,2, 3, 4, 5, 5_1, 6, 6_1 and 7 (i.e. classes E_1, E_2, F_1, F_2, M_1, M_{11}, M_2, M_{22}, and O) .

1.1.2 In this working instruction for the first grade weights the vacuum mass value will be used. For the second grade weights and weights from the first class to the seventh, normally the reduced mass value will be used.

Note: The reduced mass of the weight is the mutual balance of the actual weight and the hypothetical weight with a material density of 8.0 g/cm^3 in the air with the density 0.0012 g/cm^3. The vacuum mass of the latter is named the reduced mass of the former, and 8.0 g/cm^3 is called the unified computed density.

The relationship between the reduced mass m^* and the vacuum mass m of the weight is:

$$m^*=m+(V^*-V)\rho_{1.2}=(1-\rho_{1.2}/\rho)m/0.99985 \quad \text{……………..} \quad (1)$$

or

$$m=m^*+(V-V^*)\rho_{1.2}=0.99985m^*/(1-\rho_{1.2}/\rho) \quad (2)$$

where,

ρ ---- the material density of the weight (g/cm^3);

$\rho_{1.2}$ ---- the computed standard density of the air (0.0012g/cm^3);

V---- the actual volume of the weight (cm^3);

V^* ---- the weight volume counted upon the computed material density (cm^3)

1.2 Nominal Mass Value and Mass Combination of Weights

1.2.1 The nominal mass value of the weights should usually be:

$$a\times 10^n \text{ kg} \quad (3)$$

where,

a 1,2,5;

n integer of 3 ~ -8, -8 is only for the case of 5×10^n kg.

Combination of weights

The weights can be combined in any of the following ways:

(1, 2, 2, 5) $\times 10^n$ kg (prior selected);

(1, 1, 2, 5) $\times 10^n$ kg;

(1, 1, 1, 2 5) $\times 10^n$ kg;

(1, 1, 2, 2, 5) $\times 10^n$ kg.

Calibration Precision, Revision Value and Allowable Error of Weights

1.2.2 Calibration precision of the weights

1.2.2.1 The calibration precision of all grade weights is listed in Table 1.

1.2.2.2 The error range of every error source should be restricted to controlling the precision of all class weights.

1.2.3 Mass revision value of weights

1.2.3.1 The mass revision values of all grade weights should be given in the calibration protocol.

1.2.3.2 The mass revision values of all class weights will not be given. But the mass revision value must not exceed one-third of the mass allowable error for the weight by the time of the first calibration or the calibration after its repair.

1.2.4 Mass allowable error of weights

1.2.4.1 The allowable errors of all grade weights are given in Table 1. New second grade weights should be manufactured upon the allowable errors of the third class weights given in Table 2.

1.2.4.2 The allowable errors of all class weights are shown in Table 2.

1.3 Construction, Material, Density, and Alignment of Weights

1.3.1 Construction of weights

1.3.1.1 All grade weights, first and second class weights, as well as all class milligram weights, must be solid and made of one whole block of material. The others are allowed to have a cavity for alignment.

1.3.1.2 All class 1g weights or their component weights can be made from sheet or strip material, to be easily clipped.

1.3.1.2.1 The sheet shape weights with the mass of 1g or their component weights must be polygonal. One edge of them must be folded vertical to the main plane of the weights to easily be clipped. The height of the folded edge must not be smaller than 1.5 mm or larger than 2.5 mm.
The relationship between the edge and the nominal mass of the sheet shape weights are:
relevant to 1, 10, 100, 1000 mg for the triangle;
relevant to 2, 20, 200 mg for the square;
relevant to 5, 50, 500mg for the pentagon.

1.3.1.2.2 The component weights of one gram in strip form must be one line segment or the folded line connected with several line segments. The folded line edge of one line segment among them should be raised up from 30^o to 45^o for easy clipping.
The relationship between the folded line segment number and the nominal value of the line shape weights are:
relevant to 1, 10, 100 mg for one line segment;
relevant to 2, 20, 200 mg for two line segments;
relevant to 5, 50, 500mg for five line segments.

1.3.1.2.3 The second or the third line shape weight with the same nominal value in the same weight group can be in turn bent into one or two small hooks.

Table 1 Allowable error of all grade weights (±mg)

Nominal mass value	First grade of accuracy		Second grade of accuracy		Remark
	Mass allowable error	Calibration precision	Mass allowable error	Calibration precision	
50kg	1.5×10^2	7.5×10	5×10^2	2.5×10^2	It should be calculated upon the actual value for the first and the second grade weights in service. The mass allowable error of the first and the second grade newly produced weights should be the half of the work instruction in this table.
30kg	8.5×10	4.2×10	2.8×10^2	1.4×10^2	
20kg	5.6×10	28	1.4×10^2	9×10	
10kg	3×10	14	9×10	4.5×10	
5kg	20	6	4×10	18	
3kg	12	4	25	12	
2kg	8	3	15	9	
1kg	4	0.5	5	2	
500g	2	0.4	3	1.2	
300g	1	0.3	2	0.9	
200g	0.5	0.2	1.5	0.6	
100g	0.4	0.1	1.0	0.3	
50g	0.3	0.1	0.6	0.3	
30g	0.2	0.06	0.4	0.2	
20g	0.15	0.04	0.3	0.12	
10g	0.10	0.02	0.2	0.06	
5g	0.05	0.01	0.15	0.03	
3g	0.05	0.007	0.15	0.03	
2g	0.05	0.005	0.10	0.03	
1g	0.05	0.005	0.10	0.03	
500mg	0.03	0.004	0.05	0.02	
300mg	0.03	0.004	0.05	0.02	
200mg	0.03	0.004	0.05	0.02	
100mg	0.03	0.004	0.05	0.02	
50mg	0.02	0.004	0.05	0.02	
30mg	0.02	0.004	0.05	0.02	
20mg	0.02	0.004	0.05	0.02	
10mg	0.02	0.004	0.05	0.02	
5mg	0.01	0.004	0.05	0.02	
3mg	0.01	0.004	0.05	0.02	
2mg	0.01	0.004	0.05	0.02	
1mg	0.01	0.004	0.05	0.02	
0.5mg	0.01	0.003			
0.2mg	0.005	0.002			
0.1mg	0.005	0.002			

1.3.1.3 It will not be rigidly regulated, if the first to the third class weights of the milligram group and the above ones have the button-head handle. They can also be made as straight cylinder.

1.3.1.3.1 The weights with the mass 20 kg and above can be made in the shape with low gravitational center, in order to be easily piled, so as not to slide down, to be conveniently slung and carried.

1.3.1.3.2 The weights for special weighing and measuring devices can be made of different constructional types according to the requirements of these apparatuses.

1.3.1.3.3 For the construction for the fifth to the seventh class weights of 50 kg and above refer to the Appendix 3.

1.3.2 Material of Weights

1.3.2.1 Material the Weights are Made of
1.3.2.2 Under normal service conditions the variations of the weight masses should not exceed the allowable error of their relevant degree of accuracy (acc. to their class weight) or the degree of calibration precision (for the grade weights).
1.3.2.3 The metal or the alloy of which all grade weights and from which the first to the fourth class weights are made must be nonmagnetic. All grade weights and first, the second-class weights may be made of Durimet. All grade weights and third, fourth class weights may also be made of brass,80-20 nichrome or bronze. All grade and the third to the fifth class weights of the milligram group, may also be made of aluminum. Fifth class weights with a mass of between 10 kg and 50 kg may be made of brass or the material whose quality is not inferior to brass. The fifth to 61 class weights with a mass of 50 kg and above as well as the sixth to the seventh class weights with a mass of 100 kg and above may be made of Ferro steel. Sixth class weights may also be made of brass.

Density of Material of Weights

The densities of the material of all grade weights are allowed to have a range of values. There is no restriction in the selection of the material. The volume of first grade weights for the gram group with masses of 20 g and above must be measured, as well as for the kilogram group of the second grade weights, and for the gram group with masses of 100 g and above. The material densities for the first grade weights of the gram group, with masses of 10 g and below must be measured, as well as for the second grade weights of gram group with mass of 50g and below, both of which are newly produced. The above measured results should not be less than the requirements given in Table 3.

Table 2 Mass allowable error of all class weights (±mg)

Nominal mass value	Class of accuracy									Remark
	1(E_1)	2(E_2)	3(F_1)	4(F_2)	5(M_1)	5_1(M_{11})	6(M_2)	6_1(M_{22})	7(O)	
5t 3t 2t 1t 500kg 200kg 100kg 50kg 25kg 20kg 10kg 5kg 2kg 1kg 500g 200g 100g	25 10 5 2.5 1.0 0.5 0.25 0.10 0.05	7.5×10 3.0×10 15 7.5 3.0 1.5 0.75 0.30 0.15	2.5×10^{2} 1×10^{2} 5×10 25 10 5 2.5 1.0 0.5	7.5×10^{4} 4.5×10^{4} 3×10^{4} 1.5×10^{4} 7.5×10^{3} 3×10^{3} 1.5×10^{3} 7.5×10^{2} 3×10^{2} 1.5×10^{2} 7.5×10 3×10 15 7.5 3.0 1.5	2.5×10^{5} 1.5×10^{5} 1×10^{5} 5×10^{4} 2.5×10^{4} 1×10^{4} 5×10^{3} 2.5×10^{3} 1.2×10^{3} 1×10^{3} 5×10^{2} 2.5×10^{2} 1×10^{2} 5×10 25 10 5	5×10^{5} 3×10^{5} 2×10^{5} 1×10^{5} 5×10^{4} 2×10^{4} 1×10^{4} 5×10^{3}	7.5×10^{5} 5×10^{5} 3×10^{5} 1.5×10^{5} 7.5×10^{4} 3×10^{4} 1.5×10^{4} 7.5×10^{3} 3.7×10^{3} 3×10^{3} 1.5×10^{3} 7.5×10^{2} 3×10^{2} 1.5×10^{2} 7.5×10 3×10 15	1.5×10^{6} 9×10^{5} 6×10^{5} 3×10^{5} $1\ .\ 5\times10^{5}$ 6×10^{4} 3×10^{4} 1.5×10^{4}	2.5×10^{4} 1.2×10^{4} 1×10^{4} 5×10^{3} 2.5×10^{3} 1×10^{3} 5×10^{2} 2.5×10^{2} 1×10^{2} 5×10	

Table 2 (continued) Mass allowable error of all class weights (±mg)

Nominal mass value	Class of accuracy									Remark
	$1(E_1)$	$2(E_2)$	$3(F_1)$	$4(F_2)$	$5(M_1)$	$5_1(M_{11})$	$6(M_2)$	$6_1(M_{22})$	7(O)	
50g	0.030	0.10	0.30	1.0	3		10			
20g	0.025	0.08	0.25	0.8	2.5		8			
10g	0.020	0.06	0.20	0.6	2.0		6			
5g	0.015	0.05	0.15	0.5	1.5		5			
2g	0.012	0.04	0.12	0.4	1.2		4			
1g	0.010	0.03	0.10	0.3	1.0		3			
500mg	0.008	0.025	0.08	0.25	0.8					
200mg	0.006	0.020	0.06	0.20	0.6					
100mg	0.005	0.015	0.05	0.15	0.5					
50mg	0.004	0.012	0.04	0.12	0.4					
20mg	0.003	0.010	0.03	0.10	0.3					
10mg	0.002	0.006	0.02	0.06	0.2					
5mg	0.002	0.006	0.02	0.06	0.2					
2mg	0.002	0.006	0.02	0.06	0.2					
1mg	0.002	0.006	0.02	0.06	0.2					

Note: (1) 1t is suggested to be prior taken as the maximum nominal mass.

(2) The weights with the nominal masses 25kg and 3t of the fifth, the sixth and the seventh class are allowed to be used.

Table 3 The measured precision of the volume and the density

Nominal mass	First grade, first class weights		Second grade, second class weights	
	Volume (cm^3)	Density (g/cm^3)	Volume (cm^3)	Density (g/cm^3)
50kg	5		50	
20kg	2		20	
10kg	1		10	
5kg	0.6		4	
3kg	0.4		3	
2kg	0.3		2	
1kg	0.05		0.5	
500g	0.04		0.25	
300g	0.03		0.20	
200g	0.02		0.10	
100g	0.01		0.09	
50g	0.01			0.03
30g	0.006			0.03
20g	0.003			0.03
10g		0.02		0.03
5g		0.02		0.03
3g		0.03		0.05
2g		0.03		0.05
1g		0.04		0.05

The actual material grades and the relevant densities of all grade newly produced weights, of the milligram group should be given.

The volumes of the first grade in service weights for the gram group with the mass of 10 g and below can be estimated, based on the average of the measured volumes for the group of the weights with masses between 500 g to 20g. The volumes of second grade gram group weights in service, with the mass of 50 g and below, can be estimated based on the average of the measured volumes for the group of weights with a mass between 500 to 100 g.

The requirements for the material density of all class weights are as follows:
The material densities or volumes of the first and the second class weights, for the gram and the kilogram groups, should be actually measured. The measured results should meet the values in Table 3. The manufacturer should give the average value of the actually measured material densities of the third class weights, for the gram and the kilogram groups. Their degree of precision should be controlled within ± 0.04g/cm^3.
In the normal case the following values can be used to estimate the material densities of the weights of the third class and below. Copper alloy: 8.4g/cm^3; stainless steel: 7.85g/cm^3; cast steel: 7.8g/cm^3; cast iron: 7.2g/cm^3; aluminum: 2.7g/cm^3.

1.3.3 Alignment Material of Weights
The same material of the weights should be used at the alignment for the third to the fourth class weights. Lead is allowed to be used for the alignment of the fifth to the seventh class weights

1.3.4 Alignment Cavity and Seals of Weights

1.4.3.1 The alignment cavities of new weights with the mass of 50 kg and above are not allowed to be located in the upper surface. The volume of the alignment cavity for third to seventh class weights with a mass of 50 kg and below must not exceed two-tenths of the total volume of the relevant weight. similarly for the fourth to the 6_1 class weights, with the mass of 50 kg and above, the value must not exceed a five hundredth of the total volume of the relevant weight. The one for weights with a mass of 500 kg and above must not exceed three hundredth of the total volume of the relevant weight (at the time of the first calibration, at least one hundredth of the remaining volume of the total should be kept).

1.4.3.2 The alignment cavity must be sealed after the alignment of each weight.

1.4 External Quality of Weights

1.4.1 The surfaces of all class weights should be smooth and neat and without any faults, such as obvious sand holes, cracks, burrs and sharp edges. The surfaces of all grade weights and the first to the fourth class weights should be well polished.

1.4.2 The weight surface is allowed to have a cladding material or be painted, which protects it against being eroded. This cladding material or the painted coat must be able to withstand impacts, abrasion and being affected by the atmospheric environment. The colour and the lustre of the surface should be well distributed, without any faults such as drop marks, blisters, cracks, burn marks, deep scratch marks, or signs of crumpling.

1.5 Mark of Weights

1.5.1 Mark on Weight Body

1.5.1.1 The nominal mass value must be marked in Arabic numbers on grade weights of mass 1mg and above. First grade weights of the milligram group, with masses of 100 mg and above, as well as for the gram group with masses of 50 g and above, and of the kilogram group, must all be marked with the national unified sequence device number for weights. The nominal mass values of all the first, the second class, and all the other class milligram group weights or riders, ring type weights will not be marked. Besides, the nominal mass values should be signed on all other class weights with Arabic numbers.

1.5.1.2 The way in which the nominal mass value signed on the weights with Arabic numbers is as follows:
weight of
- the milligram group use milligram as the unit;
- the gram group use gram as the unit;
- the kilogram group and above use kilogram as the unit,
- the 1000 kg group and above may also use ton as the unit.

Whether there is a unit sign behind the Arabic number will not be rigidly regulated for the milligram and the gram group weights. The sign ‘kg’ or ‘t’ may be marked behind the Arabic number for the kilogram group weights and above.

1.5.1.3 The marks showing a single point (‘·’), double points (‘··’), a single star (‘*’) or double stars (‘**’), should be marked on the second and third weights with the same nominal mass value in one group, to indicate the difference. When there are more than three weights with the same nominal mass value, the sequence numbers should be marked on all the weights in the group with the same nominal mass value, in Arabic numbers.

1.5.1.4 Sign label on the weight box
The following signs should be marked on a box of weights:
a. The grade or the class of the weights (main title);
b. Mass range;
c. Material grade and the kind of the protective layer;
d. Number of the weight box;
e. Date of production;
f. Name of manufacturer.

2 Condition of Calibration

2.1 Device for Calibration

2.1.1 A weight can be calibrated on a balance with the relevant degree of precision by use of standard weights of one level higher reference, whose masses are known, or a combination of several known weights. The milligram group standard weights, whose masses are known with the relevant precision should be provided for balancing the tiny mass difference during the weighing process and for measuring the division scale value of the balance. During the calibration process, the synthetic limit error of all the standard reference weights used, whose masses are known, should not exceed one-third of the precision of the calibrated weights for the grade weights and should not exceed one-third of the allowable error for the class weights. The synthetic limit indication error of the balance that is used, having the relevant precision, should not exceed one-third of the precision of the calibrated weights for the grade weights and should not exceed the one-third of the allowable error for the class weights.

2.2 Conditions during Calibration

2.2.1 The basic requirement for the room, in which the first and second grade weights, and the first to third class weights will be calibrated:

2.2.1.1 Vibrations and airflow are not allowed to exist in the calibration room, if they can be felt by the occupants. The room should be as far away as possible from the sources of vibration and magnetism.

2.2.1.2 The temperature of the thermostatic chamber in which the first grade, and first, second class weights are kept, should remain stable. The temperature fluctuation should not exceed 0.5℃ per four hours. The temperature fluctuation of the room for second grade and third class weights calibration should not exceed 1.0℃ per four hours.

2.2.1.3 A second grade standard mercury in glass thermometer with the minimum scale division value 0.1℃, a second grade standard mercury barometer with the precision 10 Pa and a ventilation psychrometer with a relative precision of 1% or another thermometer, barometer and hygrometer with a slightly lower precision, confirmed by an error analysis, should be installed at a proper position in the calibration room..
The relative air humidity in the calibration room should not exceed 70%.

2.2.1.4 The balance and the weights in the calibration room should be kept away from direct sunshine.

2.2.2 Fourth class weights and below can be calibrated under the condition of normal temperature and a relative humidity equal or less than 80%.

3 Subject and Method of Calibration

3.1 Exterior Examination

3.1.1 The weights can be calibrated by use of the observation method for all the technical items which have to be checked whether they meet the requirements given in the items 1.5 to 1.6 in this work instruction.

3.2 Cleaning and Storage of Weights

3.2.1 The weights should be cleaned according to the description in Appendix 1, and then kept in the balance room. The temperature of all grade weights and the weights from the first to the fourth class should be the same as the room temperature. First grade and first, and second class weights must be kept in the room for more than 24h. Second grade, third and fourth class weights must be kept in the room for more than 12h. Large fifth and sixth weights can be directly calibrated after being cleaned and dried.

3.3 Mass Calibration of Weights

3.3.1 The masses of first grade and first, second class weights can be measured by use of the quadratic substitution weighing method or the quadratic exchange weighing method. Those of other grades and class weights, can be measured on the basis of any one selected from the substitution, the exchange or the continuous substitution method. The masses of the weights below the fifth class can be also measured by use of the proportional weighing method. The arithmetic average value of two readings at the still position can be taken as the reading at the equilibrium position of the damped balance. In the case of an oscillating balance, the equilibrium position can be determined by calculation from continuous four consecutive readings or the first three readings at the reverse position according to formulae (4) or (5).

$$L = (l_1+3l_2+3l_3+l_4)/8 \quad (4)$$

$$L = (l_1+2l_2+l_3)/4 \quad (5)$$

The detailed procedures are as follows:

The quadratic substitution weighing method is shown in Table 4. The quadratic exchange weighing method is shown in Table 5. The single substitution weighing method is shown in Table 6. The single exchange weighing method is shown in Table 7. The continuous substitution weighing method is shown in Table 8.

Where in tables:

T ----- the tare weight;

A ----- the calibrated weights;

B ----- the standard weights;

m_A ---- The mass of A in vacuum;

$[K_A]$--- The mass revision value of A in vacuum;

$[K_B]$--- The mass revision value of B in vacuum;

V_A ----- The volume of A;

V_B ----- The volume of B;

ρ_K ---- The air density in the calibration room;

m_r ----- The vacuum mass of the small standard weight for measuring the scale division value of the balance;

d ----- the actual scale division value of the balance;

m_W --- the vacuum mass of the small standard weight which is added onto the balance lighter scale for its equilibrium by the time of the second part weighing;

a ----- the difference of m_B from m_A;

b ----- the difference of m_A from m_B.

The principle of the determination for the positive and the negative signs in the above weighing equations are as follows:

a) The determination of the positive and the negative signs before the calculation item of the equilibrium position.

"+"or "±" before the calculation item of the equilibrium position in any of the above weighing equations should be taken if the small weights added onto the balance scale at the side of the calibrated weight can increase the algebraic value of the reading L_{Br} of the balance equilibrium position relative to L_B or the reading L_{BAr} relative to L_{BA}; Otherwise, "-" should be taken.
b)The determination of the positive and the negative signs before the item of the small standard weight *u* or *W*.

When the small standard weight *u* or *W* is added onto the balance scale with the calibrated weight, or for the equilibrium of the standard weight and the tare weight, a small weight *W* is temporally added onto the balance scale together with the tare weight , "-" of the relevant *u* or *W* should be taken. At another hand, "+"of the relevant *u* or *W* should be taken when *u* or *W* is added onto the scale with the standard weight, or for the equilibrium of the calibrated weight and the tare weight, a small weight *W* is temporally added to the balance scale together with the tare weight.

3.3.2 The calibration of the fifth to the seventh class weights.
The standard weight should be set onto one scale of the balance. At the same time the tare weight should be set onto the other scale for the balance being equilibrium. Then the calibrated weight should be put onto that scale instead of the standard one. If the balance loses the equilibrium, the error allowable weight can be put onto the lighter scale and the balance should reach the equilibrium or over it. Otherwise the calibrated weight is unqualified.

3.3.3 The first grade and the first class weights can be comparatively calibrated in combination with standard weights on a balance with the relevant precision. Other weights can be calibrated by comparison with those of one level higher standard, with the same nominal mass values. They can also be compared with those of one level higher standard, by means of combination.
3.3.3.1 The combining comparative calibration of weights
For details see the Appendix. 1.

4 Treatment of Calibration Results and Calibration Period

4.1 <u>Treatment of Calibration Results.</u>

For weights which meet the requirements of this work instruction a calibration protocol for the working weight will be supplied.

The new weights which do not meet the requirements will be defined as unqualified. In service, weights which do not meet the requirements, have to be sent for repair, excepting the first andsecond grade weights of the gram and the kilogram groups only, whose allowable error is permitted to be over and they should be used with their actual masses. For those weights after repair that meet the requirement of this work instruction through re-calibration, a calibration protocol will be supplied giving the actual level reached (achieving a lower level is permitted). After the lowered treatment, if the weight still does not meet the requirement of this work instruction, a cancel mark will be stamped on it or a notice of the calibration failure will be supplied.

4.2 Calibration period

Calibration period of the weights: Two years for the first, second grade weights and the first to the fourth class weights of the kilogram group and above. For the others, one year; for frequently used weights, the calibration period should be shorter. Any special case should be approved. During the calibration period the mass change of the standard weight should not exceed the allowable error of that weight.

Table 4 Quadratic substitution weighing method Meteorological parameter in calibration room

Item	Unit	Time		Average	Remark
		Begin	End		
		Date/h/m	Date/h/m		
Air temperature *t*	℃				
Atmospheric pressure *p*	Pa				
Dry-bulb temperature of hygrometer	℃				
Wet-bulb temperature of hygrometer	℃				
Absolute humidity *h*	Pa				
Air density ρ_K	mg/cm^3				
$\triangle\ \rho_K = \rho_K - 1.2$	mg/cm^3				

Table 4 (continue) Quadratic substitution weighing method

Calibrated weight *A*		Standard weight *B*			$V_A - V_B =$ (cm^3)
Device No:	Material:	Device No:	Material:		
Nominal value: ( )	Volume: (cm^3)	Nominal value: ( )	Revision value: (mg)	Volume: (cm^3)	$\rho_k =$ (mg/cm^3)
Σ :	Σ : (= V_A)	Σ :	Σ :(=[K_B])	Σ : (=V_B)	$(V_A-V_B)\rho_k=$ (mg)

Reading of equilibrium position of balance

Observation order	Left scale	Right scale	Reading l_1	l_2	l_3	l_4	Equilibrium position L	Number of grid difference	Mass of small weights added to balance scale (mg): Left scale	Right scale
1	T	*B*					L_{B1}	L_{A1}- L_{B1}=		
2	*T*	*A*					L_{A1}			
3	*T*	*A*					L_{A2}	L_{A2} - L_{B2} =		
4	*T*	*B*					L_{B2}			
5	*T*	*B* + *r*					L_{Br}	$\lvert L_{Br} - L_{B2}\rvert$ =		m_r=

$a = (V_A - V_B)\rho_K \pm \lfloor (L_{A_1} - L_{B_1}) + (L_{A_2} - L_{B_2}) \rfloor d/2 \pm m_W$ (mg)		$d = m_r / \lvert L_{B_r} - L_{B_2} \rvert =$
[K_A]=[K_B]+a= (mg)	m_A=$m_{A\text{nomianl}}$+[K_A]=	b = -a = (mg)

Table 5 Quadratic exchange weighing method

Calibrated weight A		Standard weight B			$V_A - V_B =$ (cm^3)
Device No:	Material:	Device No:	Material:		
Nominal value: ( )	Volume: (cm^3)	Nominal value: ( )	Revision value: (mg)	Volume: (cm^3)	$\rho_k =$ (mg/cm^3)
Σ :	Σ : (= V_A)	Σ :	Σ :(=[K_B])	Σ : (=V_B)	$(V_A - V_B)\rho_k =$ (mg)

Reading of equilibrium position of balance

Observation order	Left scale	Right scale	Reading l_1	Reading l_2	Reading l_3	Reading l_4	Equilibrium position L	Number of grid difference	Mass of small weights added to balance scale (mg): Left scale	Mass of small weights added to balance scale (mg): Right scale
1	B	A					L_{BA1}	$L_{BA1} - L_{AB1} =$		
2	A	B					L_{AB1}			
3	A	B					L_{AB2}	$L_{BA2} - L_{AB2} =$		
4	B	A					L_{BA2}			
5	B	$A+r$					L_{BAr}	$\vert L_{BAr} - L_{BA2} \vert =$		$m_r =$

$a = (V_A - V_B)\rho_K \pm [(L_{BA_1} - L_{AB_1}) + (L_{BA_2} - L_{AB_2})]d/4 \pm m_u \pm m_W/2$		$d = m_r / \vert L_{BA_r} - L_{BA_2} \vert =$
$[K_A] = [K_B] + a =$ mg)	$m_A = m_{A\text{nomianl}} + [K_A] =$	$b = -a =$ (mg)

Note: m_u ----- The vacuum mass of the small standard weight added onto the balance scale for the balance equilibrium before exchange. It will be exchanged with the big weight at the same balance scale together in the later exchanging process.

m_W ----- The vacuum mass of the small standard weight added onto the lighter scale of the balance for the equilibrium of the balance after the weights being exchanged.

Table 6 Single substituting weighing method

Calibrated weight *A*		Standard weight *B*			$V_A - V_B =$ (cm³)
Device No:	Material:	Device No:	Material:		
Nominal value: ( )	Volume: (cm³)	Nominal value: ( )	Revision value: (mg)	Volume: (cm³)	$\Delta\rho_k =$ (mg/cm³)
Σ :	Σ : (= V_A)	Σ :	Σ :(=$[K_B]^*$)	Σ : (=V_B)	$(V_A - V_B)\Delta\rho_k =$ (mg)

Reading of equilibrium position of balance										
Observation order	Left scale	Right scale	Reading				Equilibrium position *L*	Number of grid difference	Mass of small weights added to balance scale (mg)	
			l_1	l_2	l_3	l_4			Left scale	Right scale
1	*T*	*B*					L_B	$L_A - L_B =$		
2	*T*	*A*					L_A			
3	*T*	A+r					L_{Ar}	$\lvert L_{Ar} - L_A \rvert =$		$m_r^* =$
$a^* = (V_A - V_B)\Delta\rho_K \pm (L_A - L_B)d \pm m_W^*$ (mg)									$d = m_r^* / \lvert L_{A_r} - L_A \rvert =$	
$[K_A]^* = [K_B]^* + a^* =$ (mg)				$m_A^* =$					$b^* = -a^* =$ (mg)	

Note: m_A* ----- The reduced mass value of *A*;

$[K_A]$* ---- The revision value of the reduced mass for *A*;

$[K_B]$* ---- The revision value of the reduced mass for *B*;

m_r* ----- The reduced mass of the small standard weights for measuring the scale division value of the balance;

m_W* ----- the reduced mass of the small standard weights which are added onto the balance lighter scale for its equilibrium by the time of the second part weighing;

$\Delta\rho_k$-----The deviation value $\Delta\rho_k = \rho_k - \rho_{1.2} = \rho_k - 1.2$ (mg/cm³) of the air density ρ_k in the calibration room relative to the computed standard air density

$\rho_{1.2} = 1.2$mg/cm³

a^* ----- the difference of m_B^* from m_A^*

b^* ----- the difference of m_A^* from m_B^*

The meanings of the other signs are as above mentioned.

Table 7 Single exchange weighing method

Calibrated weight A		Standard weight B			$V_A - V_B =$ (cm^3) $\Delta\rho_k =$ (mg/cm^3)
Device No:	Material:	Device No:	Material:		
Nominal value: ( )	Volume: (cm^3)	Nominal value: ( )	Revision value: (mg)	Volume: (cm^3)	$(V_A-V_B)\Delta\rho_k=$ (mg)

Reading of equilibrium position of balance										
Observation order	Left scale	Right scale	Reading				Equilibrium position	Number of grid difference	Mass of small weights added to balance scale (mg)	
			l_1	l_2	l_3	l_4	L		Left scale	Right scale
1	B	A					L_{BA}	$L_{BA}- L_{AB}=$		
2	A	B					L_{AB}			
3	A	$B + r$					L_{ABr}	$\lvert L_{ABr}- L_{AB}\rvert =$		$m_r^* =$
$a^* = (V_A - V_B)\Delta\rho_K \pm (L_{BA} - L_{AB})d/2 \pm m_M^* \pm m_W^*/2$ (mg)									$d = m_r^* / \lvert L_{AB_r} - L_{AB}\rvert =$	
$[K_A]^*=[K_B]^*+a^*=$ (mg)						$m_A^*=$ ( )			$b^* = -a^* =$ (mg)	

Note: m_M* ----- The reduced mass value of the small standard weights added onto the balance scale for the balance equilibrium before the exchange. They will be exchanged with the big weights at the same balance scale together in the later exchanging process;

m_W* ----- The reduced mass of the small standard weights which are added onto the balance lighter scale for its equilibrium after the weights have been exchanged.