MEASUREMENTS OF MASS

REORGANIZING THE USE OF UNIT OF MASS STANDARDS

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The basic quantity for establishing uniform mass measurements on the territory of the USSR is the mass of the basic USSR standard, the platinum-iridium kilogram No. 12. Up to 1956 the transfer of the value of this mass to reference and then working measures of mass was made by means of the first reference copy, the platinum-iridium kilogram No. 26, and the second reference copy, the platinum-iridium kilogram \( R_1 (PtIr/1 \text{ kg}) \) [1].

Kilogram No. 26 serves to replace the basic standard, kilogram No. 12, when the latter is in the hands of the International Bureau of Weights and Measures. The second reference copy was used up to 1955 for comparisons with the unit of mass working standards.

Up to 1941 the institutes of the Committee of Standards, Measures, and Measuring Instruments had 4 working standards of mass which served to check reference grade 1 weights. These standards were checked against the weight \( R_1 (PtIr/1 \text{ kg}) \) once every two years.

Since the war the requirement in working standards has greatly increased, and their number has been raised to 9, thus considerably increasing the use of the second reference copy. In the near future the number of working standards will increase still further, since the Committee of Standards, Measures, and Measuring Instruments has established many grade 1 State inspection laboratories for measuring equipment, some of which will have to be equipped with working standards of mass, owing to the nature of their work.

Up to 1950 it was aimed to compare the weight \( R_1 (PtIr/1 \text{ kg}) \) with the basic USSR standard not more than once in every 5 years; however, the experience of subsequent years has shown that more frequent comparisons are required. The increase in the number of working standards will require, unless special measures are undertaken, a yearly comparison of the \( R_1 (PtIr/1 \text{ kg}) \) standard with the basic USSR standard, thus producing increased wear of the basic standard and the need for more frequent international comparisons. Such a situation is, obviously, inadmissible, and in order to avoid it, the checking system of the higher order weights and scales has been reorganized.

The necessity for such a reform is also due to the fact that the kilogram \( R_1 (PtIr/1 \text{ kg}) \) as well as the basic USSR standard and all the national prototype kilograms of other countries are made of highly-stable alloy of platinum and iridium [2]. This alloy, however, is expensive, and it is not advisable to make working standards of it.

Both in the USSR and in other countries the working standards of mass are made of less expensive materials. Up to 1955 working standards made of various alloys, mainly of bronze, were used in the USSR. The density of bronze amounts to 8.4 g/cm\(^3\), and that of the platinum-iridium alloy to 21.4 g/cm\(^3\). Hence, the correction for the aerostatic force effect which had to be introduced in comparing the bronze working standard with the copy \( R_1 (PtIr/1 \text{ kg}) \) was very large, amounting to 90 mg. The error in comparing the working standards with this copy must not exceed 0.01 mg, hence, the aerostatic force correction must be determined with an error not exceeding 0.01 mg. Under stable meteorological conditions during the comparison it is difficult, but nevertheless possible, to determine this correction with an error not exceeding 0.01 mg. However, if the air density varies considerably, the aerostatic force correction is calculated on the basis of an assumed mean air density, thus leading to an error exceeding the tolerance. Moreover, owing to variations in the aerostatic force acting on the compared weights, the oscillation of the scales is disrupted, the balanced position "drifts", and the deviations increase. These circumstances made it necessary to make a large number of comparisons (up to 16-20) of each bronze standard with the copy \( R_1 (PtIr/1 \text{ kg}) \) for the purpose of certifying each standard with the required accuracy. In the reorganization this had also to be taken into consideration. The condition of the working standards of mass had also to be improved.

Investigations carried out by the VNIIM (All-Union Scientific Research Institute of Metrology) and abroad have shown that bronze standards with a polished surface as well as with a gilded surface do not meet the requirements specified for the stability of working standards of mass [3, 4, 5]. The variations in the mass of bronze working
standards amounted in one year to 0.7 mg, which is altogether inadmissible. Hence, the substitution of bronze working standards of mass by new, more stable standards is also a pressing problem.

Thus, the improvement of the units of mass affected the copies of the basic USSR standard and involved the production of new working standards with the required stability.

These problems were solved while taking into consideration similar work carried out by the International Bureau of Weights and Measures and by several higher metrological institutions in foreign countries [8, 6, 7].

International practice [7] confirms the correctness of dividing the standards into three categories as is done in the USSR (the basic USSR standard, reference copies, and working standards).

It was found advisable to introduce into the checking system an intermediate link between the working standards and the reference copies in order to preserve the basic USSR standard and its copies. This problem was solved by increasing up to five the number of copies of the basic USSR standard [8]. Moreover, these copies must be of the same "grade" as weights No. 26 and R$_4$ (PtIr/1 kg).

The material for making the new copies was chosen with a view to providing the greatest stability of their mass and their maximum reliability and accuracy in their comparison with the working standards. The advisability of making the copies of a material of a density approaching that of the working standards is obvious.

The International Bureau of Weights and Measures has conducted for several years investigations of materials for making grade 2 standard units (our copies according to the terminology of the International Bureau of Weights and Measures are classed as grade 2 standards). Less expensive alloys than those of platinum and iridium were used, with a density varying between 19 and 7.8 g/cm$^3$ [5]. Investigations have shown that making standards of alloys approaching in density the platinum-iridium alloy is not advisable, since weights made of such alloys do not possess a sufficiently high stability. The mass of weights made of stainless steel proved to be more stable. Investigations carried out during 17 years have made it possible to recommend the following types of stainless steel: alloy Uranus 10, consisting of 20% Cr and 10% Ni, and alloy Nicral containing 20% Cr and 20% Ni. The stability of kilogram weights made from these alloys has proved to be satisfactory.

From 1951 to 1954 the VNIIM also conducted experiments on materials for making high precision weights [3]. These experiments showed that weights made of stainless steel Kh18N9T, which contains 18% Cr and 9% Ni, possess the greatest stability of mass. This steel approaches in its composition the alloy Uranus 10, which is recommended by the International Bureau of Weights and Measures.

On the basis of this work, it was decided to make the new copies of the basic USSR standard of stainless steel type Kh18N9T.

It has already been pointed out that bronze working standards are unsatisfactory with respect to the stability of their mass, and it was, therefore, decided to replace them by new ones made of stainless steel type Kh18N9T of the same smelt as the new reference copies. This will lead to the maximum reliability and accuracy in comparing working standards with reference copies, and to the minimum expenditure of labor in their checking. Such a substitution of the existing working standards by new ones is also advisable because at present the reference grade 1 weights, which are compared with the reference standards, are made exclusively of stainless steel. Thus, in calibrating standard weights maximum accuracy will be achieved with the minimum expenditure of labor.

In 1985 the Riga plant "Étalon" made for the VNIIM 17 kilogram weights of stainless steel type Kh18N9T of the same smelt. The weights have the shape of straight cylinders whose height is equal to their diameter. The top phase of each weight is engraved with its number by means of an electrical polisher.

From the above kilogram weights three weights Nos. 6, 8, and 15 were chosen as copies of the basic USSR standard and designated for comparison as V (St/1 kg) No. 6, N (St/1 kg) No. 8, and V (St/1 kg) No. 15.

Weights Nos. 1, 2, 3, 4, 5, 7, and 9 were selected as working standards for the Sverdlovsk branch of the VNIIM, the VNIK (All-Union Scientific Research Institute of the Committee of Standards, Measures, and Measuring Instruments), the KhGIMP (Kharkov State Institute of Measures and Measuring Instruments), the NGIMP (Novosibirsk State Institute of Measures and Measuring Instruments), the checking and test laboratory of the VNIIM and the Latvian checking and test laboratory of the VNIIM.