BASIC PROBLEMS OF CONTEMPORARY METROLOGY

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The program of the CPSU (Communist Party of the Soviet Union) stresses that "the maximum speeding up of scientific and technical progress is the most important national task." The level of scientific, technological and industrial development determines the material wellbeing and the speed of constructing the material and technological foundations of communism. The decisions of the November (1962) plenary session of the CPSU central committee and the subsequent specific measures envisage a further development in our technical equipment, a further impetuous advance of all branches of our national economy.

For our industry, agriculture and science to be able to live up to the above tasks it is necessary for us to possess one of the most important instruments of research and control, a highly-developed measurement technology in the widest sense of that word.

The speeding up of scientific and technological progress is directly connected with an intensive advancement of metrology and the techniques of precision measurements, which are the basis for developing instrument making in general, and provide means for scientific experimentation, technical progress, and industrial testing and control in particular.

What are the basic tasks of modern metrology? Where should the efforts of our metrologists be directed in order to provide the rapidly-developing progressive branches of our science and technology with modern high-quality measuring equipment?

One basic metrological problem consists in establishing and applying in practice a scientifically-based system of units, without which it is impossible to carry out a single measurement. Such a system of units consists, as we know, of the SI system, which was recently adopted by the XI International General Conference on Weights and Measures and legalized in the USSR by GOST 9867-61. Its practical application is at present one of the most important tasks. It encounters, however, certain difficulties, entailing the smashing of established concepts, changing existing technical specifications and, in certain instances, even the technology of production, and it requires certain changes in the teaching of all technical subjects. Moreover, it is necessary to extend this system also to the sphere of ionizing radiation, where as yet units have not been established for all the quantities involved, since phenomena related to the effect of radiations on various objects and to their absorption have not been sufficiently studied.

However, it is not enough to develop a system of units; it is also necessary to provide physical reproduction of these units in the form of measures and standards for their practical comparison with measured quantities, i.e., for carrying out the measurement process.

Precision in reproducing measurement units rises with the accuracy of measurements. Although the precision now achieved in reproducing the basic units stands at a relatively high level, it is not always adequate for the growing requirements of modern science and technology, even though in many instances success depends precisely on the high precision of measurements. The tendency to raise considerably the precision of laboratory and production measurements in turn requires more accurate standards and reference instruments.

The new determination of one of the basic units of the SI system, the unit of length (the meter), in terms of the wave length of the orange radiation line of krypton 86, instead of platino-iridium prototype meter, has opened up the possibility of lowering the error in measuring length to 10^-8. The problem, therefore, consists in producing reference sources of radiation and high-precision interferometers which would raise the existing precision of measurements by an order of magnitude.

Wide prospects are opened up in producing precision means for measuring lengths (especially long ones) by using quantum mechanical generators and amplifier (lasers). The National Bureau of Standards, USA, is developing...
an equipment for measuring 100 m lengths with an error down to $10^{-8}$ by means of lasers, and encouraging results have already been obtained. It is also possible by means of these devices to obtain highly-stable electromagnetic oscillations, thus providing the reproduction of the second unit in the system, that of time (second), with an error not exceeding $10^{-10}$ to $10^{-11}$, which is required in practice.

However, the basic problem in modern metrology in the sphere of standards consists in the transition from artificial to natural standards, which provide the required stability and, under certain conditions, higher precision in reproducing measurement units. Four (the meter, second, degree Kelvin and candle) of the six basic units are natural; therefore, the task consists in replacing the remaining two artificial units, the kilogram and ampere, by natural units. This problem can be solved on the basis of a system of physical constants measured with the required high precision. For instance, by measuring with adequate precision the proton gyromagnetic ratio and the acceleration due to gravity, metrologists will be able to determine the units of mass and electric current by means of proton resonance and computed induction coils without resorting to a platinum kilogram prototype. It is also possible to use for this purpose other constants: for instance, the gravitational constant.

From the above we arrive at the important practical problem of measuring with precision several physical constants. Although this involves overcoming considerable experimental difficulties, staging expensive refined experiments and producing special measuring equipment, this problem must be solved; otherwise it is impossible to expect any substantial rise in the stability or precision of basic standards and, hence, in the precision of measurements generally.

At the same time in order to raise the accuracy of standards and other units it is necessary to use to the full extent the latest achievements of science and, in the first instance, of nuclear physics. For instance, proton resonance can be used for measuring the most diverse quantities, such as magnetic field strength, large electrical currents, etc. Recently this phenomenon has been used successfully for measuring low temperatures (from $4$ K and higher) which opens the possibility of reproducing with high precision the thermodynamic temperature scale in a range of importance for several fields of technology.

It is also very important to raise the precision of standards and instruments for measuring capacitance both over a wide range of its values and a wide frequency range, and to produce sets of measuring instruments for precise measurements of capacitances and loss angles. This is due not only to the necessity of reproducing a unit of capacitance with the utmost precision and expressing in terms of it units of inductance and resistance, but also to the practical requirements in manufacturing modern radio and electronic components. The above problem can be divided into two parts, consisting of producing high-precision capacitance standards and of manufacturing a set of measuring instruments for evaluating with precision electrical circuit parameters over a wide frequency range. The first part of the problem can be solved by producing the so-called calculated capacitor whose capacitance according to Lampard's theorem is determined by measuring its length, which improves considerably the precision in reproducing a unit of capacitance. There is every reason to believe that the application of this capacitor will raise the precision in reproducing a unit of capacitance by almost two orders. The second part of the problem amounts to producing a complete set of measuring instruments of various degrees of precision for practical measurements both in metrological institutes and in scientific-research and production laboratories.

It is particularly important to produce reference equipment for precision measurements of large stresses. The necessity for checking systematically a large number of testing machines in use and for precise measurements of large tensile stresses urgently reminds us of the need to speed up the practical solution of this problem. For this purpose it is necessary to design and manufacture special directly-loaded machines and hydraulic machines for specific use, which in turn entails large capital investment and the construction of new specialized buildings. Moreover, research is required for finding basically new methods for the absolute measurement of stresses in order to be able to carry out these measurements in different parts of our country.

For a complete metrological servicing of this important field of technology it is necessary to develop a comprehensive system of reference dynamometers for a wide range of stresses in order to transfer the unit of force from standards to operating machines.

The task of producing means for measuring pressure is of exceptional importance in modern metrology. Here, on the one hand, it is necessary to measure extremely high pressures (over $5 \cdot 10^9$ N/m$^2$) and, on the other, to measure extremely low pressures (below $10^{-9}$ N/m$^2$). It is known that for the direct production and measurement of large pressures it is necessary to have materials of extremely high strength. Therefore, in addition to searching for such