Information on the developed and improved State Standards of hardness is presented. New standard technical documentation on methods and instruments for measuring hardness is described, and the results of international key comparisons of the standards are presented. The concept of calculating the uncertainty of the results of hardness measurements is put forward and modern developments in the field of portable hardness meters are described.

**Key words:** State Standards of the hardness of metals, methods and instruments for measuring hardness, key comparisons, measurement uncertainty, portable hardness meters.

The measurement of hardness is the most accessible and easily performed method of determining the mechanical properties of materials. Since monitoring hardness is a much less time consuming operation than the majority of other forms of tests, and does not involve destruction of the article, this form of testing is widely used in industry. Hardness measurements are the basis for monitoring technological processes in different areas of the national economy, and is also used to determine the operational characteristics of articles under different stresses, to choose mechanical processing procedures, etc.

Hardness is the property of the material (a solid) which resists indentation, deformation, and the introduction of other solids into it [1]. The physical theories of a solid are not in a state of being able to describe the hardness of different materials, due to the undefined variety of factors on which it depends. Hence, the idea of “hardness” without indicating the method of measurement and the measurement conditions is vague. When speaking of hardness, one does not imply a physical constant, characterizing the material, but one of the quantities measured by one of the methods and which depends not only on the material but also on the conditions and method of measurement.

Of the whole variety of methods of measuring the hardness of metals and alloys, the most widely used methods are based on the Rockwell, Vickers, Brinell and Shore scales. These methods are standardized throughout the whole industry of developed countries. Moreover, there are hardness measurement scales for other materials: rubber, plastic, etc., established in numerous standards on the testing of different forms of production [2]. The metrological backup of such scales is provided in using standard systems of other forms of measurement (mass, force, length etc.). Hence, there is no practical need to set up State Standards based on these scales.

We will consider the following fundamental areas of the metrological facilities for measuring hardness:

1. Uniformity of measurements.
2. International collaboration.
3. Fundamental metrological investigations.
5. The material-economic base.
The first area is based on State checking schemes for hardness measuring instruments and standard documents on checking methods and instruments. It assumes the design of new State Standards and improvements in existing ones, the construction and modernization of working standards, and improvements in methods of checking and their universalization.

Since one of the methods of establishing the reliability of the metrological parameters of the State Standards is international comparisons, the second area is based on participation in international comparisons of standards, including at the highest level – in key comparisons along the lines of the Consultative Committee on Mass of the International Bureau of Weights and Measures (CCM/BIPM). The development of this area also requires the exchange of scientific information on achievements in the area of hardness measurements in the form of papers and contributions to international conferences, and participation in the work of international groups and technical committees on hardness measurements. Moreover, the VNIIFTRI is a member of the working group on hardness (WGH CCM/BIPM) and IMEKO TC5 on Hardness Measurements, and also heads the COOMET SC 1.6.4 on Hardness.

The third area is based on metrology as a science and assumes the development and use of methods of analyzing measurement uncertainty and searching for ways of reducing it, as it applies to the specific features of hardness measuring instruments, and also of indicating the metrological characteristics of these instruments and their correct standardization. The development and introduction into industry of new instruments for measuring hardness is the main fourth area. They possess a number of undoubted advantages and, primarily, enable one to monitor hardness on parts of articles that are difficult to access, i.e., at points where the use of stationary hardness meters is impossible. However, since the majority of new hardness meters are portable and indirectly use methods of measuring hardness, then when they are introduced into the State Register of measuring instruments it is necessary to carry out careful tests to confirm the type of measurement and to allow only those measuring instruments to be used in Russia which are provided with methods and means of checking. When carrying out such testing, specialists with high qualifications should be employed, having considerable experience in the area of hardness measurements, so that imported or domestic measuring instruments and documentation on them, including the checking method, correspond to the State Checking Schemes and ensure uniformity of measurements.

The fifth area is based on the economic and technical possibilities of the State and departmental metrological services and assumes the provision of modern standard hardness meters, measures of hardness and checking systems, the training of qualified teams, etc.

Uniformity of hardness measurements is based on the storage and reproduction of scales of hardness by the State Primary Standards and the transmission of their dimensions using standard measuring instruments to working measuring instruments in accordance with the State Checking Schemes, which have the same structure (see the figure) for instruments which measure hardness on the Rockwell, Vickers, Brinell, and Shore D scales.

The State Standards of Metal Hardness based on the Rockwell and Super-Rockwell (GÉT 30-94), Vickers (GÉT 31-79), Brinell (GÉT 33-85), and Shore D (GÉT 161-2001) scales are the upper section of the checking scheme. These are stored in the hardness measurement laboratory of the VNIIFTRI – the national center of hardness standards of Russia. The first three standards support static methods on measuring hardness and are unique systems for direct loading with a set of points and special instruments for measuring the parameters of their impressions. The Shore D standard supports the dynamic method of measuring hardness and is stationary equipment with a clever and complex means of measuring the height of its recoil. Standard measures of hardness of class I are calibrated against the State Standards of hardness; they are used at ten Centers for Standardization and Metrology, accredited for hardness measurements, of the Federal Agency for technical regulation and metrology of the Russian Federation for adjusting and checking hardness meters and comparators. Stationary working hardness meters, on which increased requirements are imposed as regards their metrological characteristics in accordance with the State Checking Schemes [3–6], are used as hardness meters and comparators, specially designed for industry. The hardness meters and comparators are used to calibrate standard measures of hardness of Class II, which are stored and employed wherever instruments for measuring hardness are used. Using these measures, one can check the correctness of readings of working measuring instruments, which include stationary, movable and portable hardness meters. The appropriate type of standard measures are chosen for each type of hardness meter, which uses one method of measuring hardness or another.

An important condition for ensuring uniformity of hardness measurements is to set up a new and improved standard base. During the last ten years, due to automation and new structural designs, it has become possible to increase the accura-