*10th IMEKO TC7 International Symposium*
*June 30–July 2, 2004, Saint-Petersburg, Russia*

# CALIBRATION AND VERIFICATION PARTICULARS OF MEASURING INSTRUMENTS

*Aleksandr Doynikov, Edward Aslanyan, Victor Pivovarov*

VNIIFTRI, Moscow region, RF

**Abstract** − The requirements of the ISO 10012 and recommendations "Guide to the Expression of Uncertainty in Measurement" are not applicable to all measurement methods and instruments. The specific features of their metrological confirmation are shown on the example of hardness measurement instruments. The proposed in the present paper methodological approach can be used in the process of correct methods of calibration and verification of hardness measurement instruments.

**Keywords**: metrological adequacy confirmation of measuring instruments, hardness measurement scales

## 1. INTRODUCTION

The ISO 10012 [1] international standard contains, among requirements for managing the measurement process, a key requirement for metrological adequacy confirmation of measuring instruments (measuring equipment). Compliance with this requirement is based on calibration and verification of measuring instruments. At this the ISO 10012 standard in all the range of measurement management methods (from verification of basic equipment up to statistical methods of quality control) is oriented only on measurements with metric scales whose results can be traced back to SI units standards and it is recommended to calculate the uncertainty in measurements according to the "Guide to the Expression of Uncertainty in Measurement" (GUM) [2]. These requirements and recommendations, however, are not applicable to all measurement methods and instruments [3[. The specific features of their metrological confirmation are shown on the example of hardness measurement instruments.

## 2. METROLOGICAL CONFIRMATION OF HARDNESS MEASUREMENT INSTRUMENTS

Hardness measurement scales are non-metric scales of order in which there are no units of measurement. Hardness numbers are only bench marks on scales without proportionality. Such scales are reproduced by national standards, the traceability of which to SI units standards is performed by expressing hardness standards parameters and parameters of measurements done on them in SI units (Fig. 1). In the process of metrological certification of national standards of derived SI units, standards of other main and derived SI units are not infrequently used (borrowed from other types of measurements). Thus for example, for density units national standard certification, standards of the main unit of mass (kg) and derived unit of volume ($m^3$) are used. The situation with hardness standards traceability is basically similar, though in this case, a great many SI units standards and other means and data shall be involved. It makes it more complicated to provide the national standards equivalency in compliance with MRA. The scientists who are national standards keepers shall be highly qualified to be able to take into consideration a great variety of factors influencing hardness scale reproduction accuracy.

The lack of units of measurement in hardness measurement scales (due to fundamental uncertain non-linearity) predetermines the particulars of measurement results processing and presentation [4]. Firstly, the notion of "dimension of a quantity" (as a combination of the main SI units symbols) is not applicable to the hardness numbers due to the lack of the units of measurements. Secondly, fundamental non-linearity (lack of proportionality) of hardness numbers (hardness numbers are non-Archimedean values [3]) makes it impossible to apply the recommended [2] statistic measurements results processing methods (the result of the measurement is a median, but not an arithmetical mean, a repeatability of certain experimental data instead of square deviation) which are based on the probability theory notions. The lack of proportionality in hardness numbers does not allow having even intervals on the scales, which are necessary for construction of probability density functions and integral probability function, and also confidential with the predetermined probability intervals of value for measurement results. That is why computation algorithms, descriptions and presentations of the hardness measurements results uncertainty applied [5] in key verification cannot be considered correct. Measurements result processing methods adequate to the hardness numbers logical nature shall be developed in the future. Most likely, mathematical formalism of the theory of possibilities [6] in which function of belonging is used instead of probability density functions is more appropriate for such developments. When the notion of the "measurement error" is used for the scales of hardness, one should bear in mind that it has a bit different meaning due to non-linearity of scales in which subtraction in the algebraic (arithmetical) sense of the word is not present. That is why it is possible to introduce only conventional local error, which is the difference between nominal and measured hardness numbers. Such local errors do not have any proportionality their numerical equality on the different hardness levels (different scale sections) does not mean their similarity (equivalency). Due to the same reason, it is impossible to introduce local systematic errors in the form of mathematical formula, multiplicative and additional corrections. It is possible to introduce corrections by hardness numbers only in the form of a table. In accordance with CIPM resolution (2003), calibration is not a procedure of correspondence confirmation, while verification is. It's shown in Table 1.

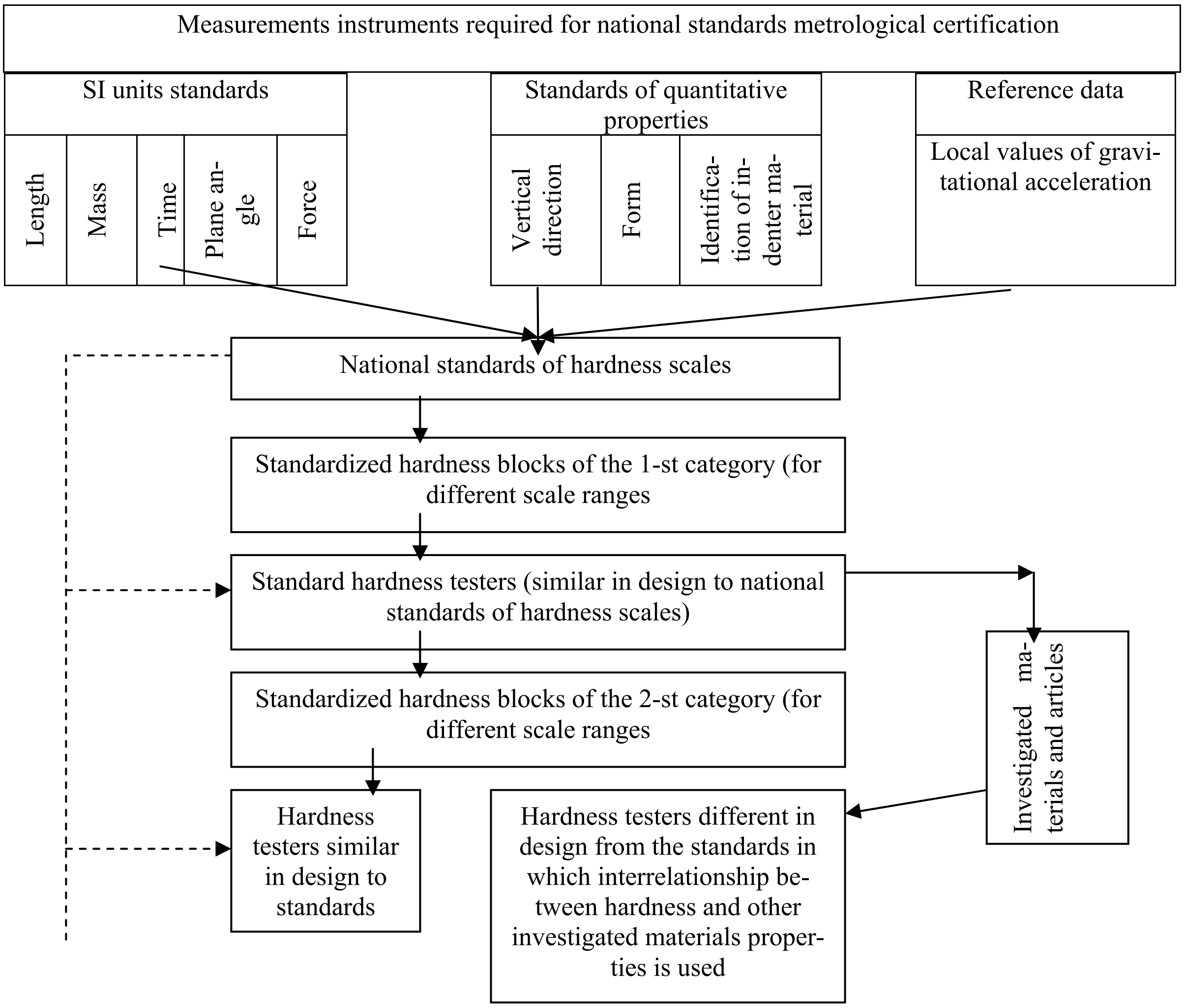


Fig. 1

Notes:

In principle, standard and regular hardness testers that are similar in design to the national standards and reproduce hardness scales in accordance with their definitions can be metrologically certified independently and as national standards. But both technically and economically, such expenses turn out to be unjustified.

Table 1

| | Standardized hardness block | Hardness testers |
|---|---|---|
| | Experiment:<br>1. Hardness number measurement on the standard | Experiment:<br>Measurement by hardness tester of a hardness number of a set of standardized hardness blocks (different hardness levels) |
| calibration | 2. Data processing: computation of several observation median – the result of the measurement and spread which characterizes the uncertainty of the result due to type A uncertainty and the block heterogeneity | 2. Data processing: comparison of the hardness tester readings with hardness numbers according to the calibration certificate (verification certificate) of the standardized blocks, computation of errors, corrections to the hardness tester readings, spread of uncertainty indications |
| verification | Operations 1 and 2 from calibration | Operations 1 and 2 from calibration |
| | The comparison of the obtained median value with the value obtained as a result of the previous verification (long-term stability disclosing). Conclusions: whether the hardness number changes over the time interval between the two verifications is consistent with the standard limits in compliance with the normative documentation considering the spread of uncertainty indications | The comparison of the hardness tester readings with standardized blocks hardness numbers (errors determination).Conclusions: whether the errors are consistent with the standard limits in compliance with the normative documentation considering the spread of uncertainty indications. |

## 3. CONCLUSION

The proposed in the present paper methodological approach can be used in the process of correct methods of calibration and verification of hardness measurement instruments.

## REFERENCES


[1] ISO 10012. Measurement management systems – Requirements for measurement process and measuring equipment.
[2] Guide to the Expression of Uncertainty in Measurement: First Edition, ISO, Switzerland, 1995
[3] A. Doinikov. Measured properties. Measuring instruments, №11, 2002, p.p.50-56.
[4] E. Aslanyan, A. Doinikov. On Expression of Hardness Measurement Result Uncertainty, Proc. Joint International Conference IMECO TC3/TC5/TC20, Celle, September 24-26, p. 499-503, 2002.
[5] E. Aslanyan, A. Doinikov, V. Pivivarov. Metrological characteristics of the national Shore D scale hardness standard. Proceedings of XVII IMEKO World Congress, Dubrovnik, Croatia, June 22-27, 2003
[6] D. Dubois, H. Prade. Theorie Des Possibilities. Applications a la representation des connaissances en informatique. 2[e] edition revue et augmentee. MASSON Paris Milan Mexico, 1988



**Authors:**

*Dr. Aleksandr Doynikov* - Principal Metrologist. Phone: 007-095-5359355, Fax: 007-095-5359334, E-mail: a_doynikov@vniiftri.ru

*Dr. Edward Aslanyan* - Head of the Scientific Research Department for Physical-Mechanical Measurements. Phone: 007-095-5359375, Fax: 007-095-5359181, E-mail: edward.aslanyan@vniiftri.ru

*Victor Pivovarov* - Deputy Head of the Department for Russian National Hardness Standards.
Phone/Fax: 007-095-5359181, E-mail: pivovarov@vniiftri.ru

Affiliation: All-Russian Scientific and Research Institute for Physical-Technical and Radiotechnical Measurements (VNIIFTRI, Russia). Address: Mendeleevo, Moscow region, 141570, Russia.