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INVESTIGATION AND IMPROVEMENT OF METROLOGICAL CALIBRATION TESTS OF THE "DIGITAL LEVEL-BARCODE ROD" SYSTEM

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ABSTRACT

The features of metrological calibration tests of surveying instruments, particularly digital levels are described. The procedures for investigating "digital level – barcode rod" system are offered that allow determining for a barcode-rod image scale. Such procedure can be used both in the laboratory of industrial company having digital levels and in the field conditions. The laboratory bench is also offered to determine basic specifications of levels with visual reading, "digital level – barcode rod" system, and total stations as well. The necessity for carrying out instrumentation calibration in the field is caused due to mechanical shocks of a digital level when transporting that can lead to the disadjustment of a level's electronic system. As a result of this a barcode-rod image scale can be changed.

Keywords: digital level - barcode rod system, total station, metrological certification.

INTRODUCTION

Measuring errors in the levelling process occur essentially due to incorrect mutual arrangement of the level's geometric elements. It is necessary to reveal these problems and when possible remove them during calibration of levels before levelling, because to eliminate the effect of instrumental errors after field measurements is practical impossible.

To fulfil the requirements applicable to the mutual position of geometric elements, instruments should pass through calibration and metrological certification (Spiridonov, A.I., 2003), (Yambayev, Kh.K., 2009).

Calibration of basic geometric conditions applicable to the level design are widely considered in the geodetic literature. Until recently calibration of the main geometrical conditions and optical micrometer division was of main interest. Since the advent of digital levels the calibration of "digital level - barcode rod" system came out on top. This calibration refers to determination of a barcode-rod image scale.

As distinct from optical levels digital levels have a number of key points in design which are in following:

a) digital levels are always provided with a compensator a self-calibration error of which is less than 0,10″;

b) code rod reading is sensory. A surveyor does not take part directly in the process of rod reading;

c) a set of digital level includes a set of single-sided barcode rods;

d) a level permits to measure the distance to the rod with an error of 2 - 3 cm;

e) the results of measurements can be written in a journal or recorded into the memory.

As known, surveying instruments (total stations and levels) are related to multivalued measuring tools that make possible to measure and set a number of similar angular and linear values of various sizes in a wide range. So the total station is directly used for measurement of horizontal and vertical angles, inclination angles as well as distances. Additionally they can measure a height difference at a station by horizontal beam using a metric rod. It is possible to get the increase of coordinate and height differences in terms of these measured values.

Optical and digital levels are intended to be used for measurement of height difference as well as a distance directly at the levelling station. Therefore, basic performance specifications of these instruments to be subject to metrological certification are:

a) for total stations - values of measuring errors for horizontal and vertical angles, inclination angles and distances as well;

b) for levels - values of measuring errors of height difference at the levelling station.

In this respect the tasks of metrological certification of surveying instruments include:

a) conformity assessment of defined metrological characteristics to design features and the specify of using measuring tools data;

b) assessment of the fullness determining of normalized metrological characteristics of measuring instrument;

c) providing the possibility of determining metrological characteristics by recommended methods and procedures, and verifying the instrument with necessary accuracy;

d) the necessity of determining metrological characteristics for the purpose of using this measuring tools in normal conditions (GOST R 53340-2009), (GOST 8.009-84).

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The following three factors should be considered in choosing basic metrological characteristics of surveying instruments (Yambayev, Kh. K., 2009):

a) surveying instruments are multivalued measuring tools as a rule with regular (metric) scale of reading system;

b) as a rule surveying instruments are used outside the system or complex; they are intended for each using individually;

c) when measurements are made by surveying instruments accidental errors are occurred which essentially influence on their total error in the results of measurements.

The most important factor by performing geodetic measurements is obligatory checking of obtained results. Such checking is achieved by increasing the number of measurements at a given point (station) and using different observation programs.

An important feature of metrological certification of surveying instruments, for example, levels, before nowadays was the fact that a level and a rod were calibrated separately. With the advent of digital levels calibration of the level and barcode rod has become very difficult. In addition, it requires a special comparator for their calibration.

Taking into account before-mentioned we set a mission on making it possible to determine metrological characteristics of the "digital level - barcode rod" system in the laboratory and in the field conditions.

The local verification schedule for level calibration

To provide the reliability and accuracy of the results of geodetic measurements, applied instruments must correspond to certain metrological characteristics. The procedure for determining these characteristics is governed by the local verification schedule which is based on the state verification schedule (Spiridonov, A.I., 2003).

Verification schedule of levels including the reference standard and two working standards of the first and second orders is shown in Figure-1.

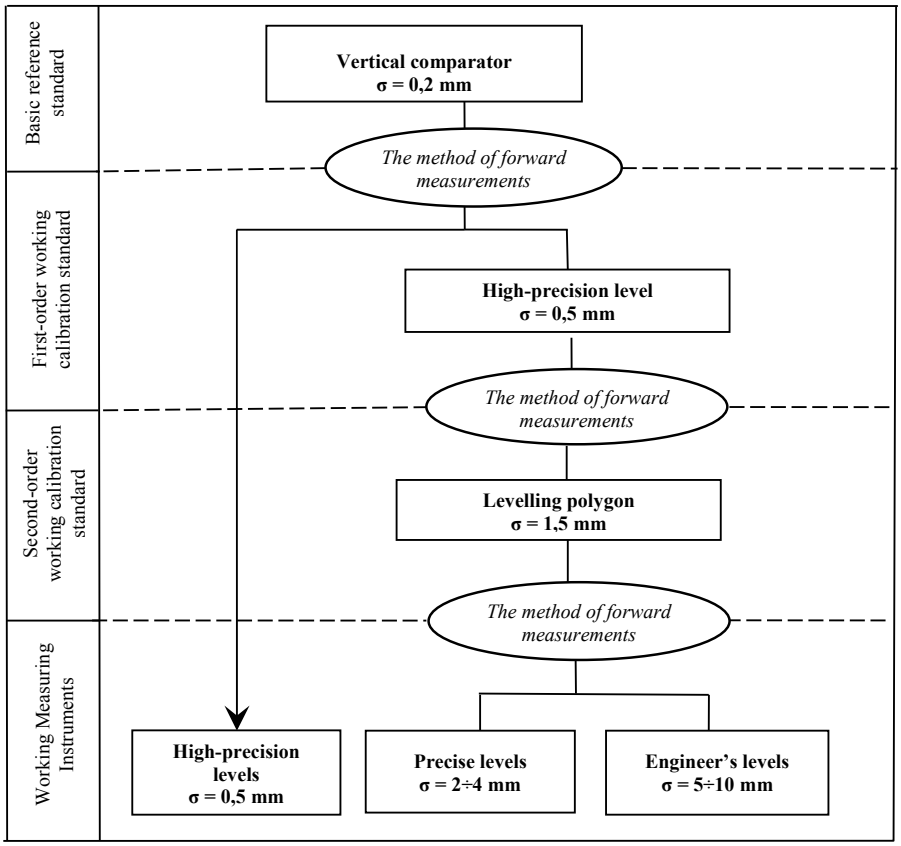

Figure-1. Existing local verification schedule for certification of levels with visual reading.

This local verification schedule allows determining the basic metrological characteristics of level that is the RMS error of difference of height measurement for 1 km of simultaneous level line (Spiridonov, A.I., 2003), (Spiridonov, A.I., Matveev, S.I., 2003).

Investigation of basic metrological characteristics of levels

An important aspect of certification of levels is taking account special levelling factors in determining subsidences and deformations of buildings, constructions and equipment. During levelling there is no need to

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determine the RMS error for 1 km of levelling line but it requires only to determine the RMS error at the levelling station.

Therefore, to our opinion, in these cases additionally as the main metrological characteristics of the "level - rod" system it is necessary to accept the RMS error of measuring the difference of height at the station. For this purpose it is necessary to develop the procedure for such certification.

Concerning the "level – rod" system the main specification is the RMS error of height difference measurements for 1 km of simultaneous level line. Another feature is the RMS error of height difference measurements at the station for one-rodded line. This is very important while carrying out high-precision short range levelling during installation and maintenance engineering structures and equipment.

Relating to the "level - rod" system where the digital level and barcode rod are used to perform investigation separately in full volume (by analogy with "level - rod" system where the optical level and invar bar code rod are used) for the level and bar-code rod is extremely difficult.

This is because of the bar-code rod, at first, does not have a metric scale graduated in 5 or 10 mm and, therefore, it is impossible to use the geneva ruler or standard optical-mechanical comparators. Secondly, in reading by digital level not two adjacent graduated lines of rod take part but the sequence of many lines with different intervals. The investigation of the digital level and bar-code rod separately is possible only in specialized laboratory with the use of interference comparators (Travkin, S.V., 2007), (Yambayev, Kh. K., 2009). In this case, for investigating only the digital level is necessary to have a standard scale the position of lines which corresponds to their theoretical values. To investigate the actual position of individual lines only bar-code rod (set of rods) and their comparison with the theoretical values we use vertical or horizontal interference comparators (Travkin, S.V., 2006), (Travkin, S.V., 2007), (Yambayev, Kh.K., 2009), (Golygin, N.Kh., Kovalev, S.V., Lebedev S.V., Peglivanyan, G.G., Fedoseev, Yu.Ye., 2009), (Vasiliev, V.V., Morozov, A.I., 2010), (Vizirov, Yu.V., Kovalev, S.V., Spiridonov, A.I., 2002), (Golygin, N.Kh., Shaimkulov D.A., 2003), (Ustavich, G.A., Yambayev, Kh.K., 2013).

At the final stage the "digital level – barcode rod" system is investigated on the interference comparator. The purpose of such procedure is to compare standard height (movement) given by laser interferometer with the height (movement) measured by "digital level – barcode rod" system. As a result of these investigations is value of RMS error of linear value measurements similar to RMS error of height measurement at the station (without environmental effect).

Procedures for investigation of the "digital level-barcode rod" system

Procedures for investigation of the "digital level - barcode rod" systems are offered which can be used in laboratory conditions of industrial company having digital levels, as well as in the field:

1) Procedure for calibration with a micrometer screw, while subject to the following conditions (Figure-2):

a) Basement with a uniform illumination of 25 - 30 m long;

b) Standard micrometer screw with the range of measured movements not less than 25 mm and providing RMS error of 0,005 - 0,010 mm for these movement measurement (Ustavich, G.A., Ryabova, N.M., Salnikov, V.G., Rakhymberdina, M.Ye., 2011), (Rakhymberdina, M.Ye., 2013).

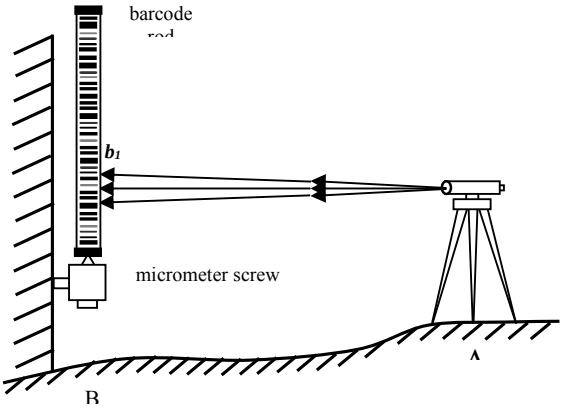

Figure-2. Calibration of level with a micrometer screw.

2) Certification of level by changing horizon of level (Figure-3), which can be used both in laboratory and field conditions.

When the "digital level - barcode rod" system is working properly height differences obtained at different horizon height of the instrument, as well as in direct and reverse measurements should be equal to each other (within the accuracy of measuring) i.e.

$$h_1 = b_{m1} - c_{m1},$$
$$h_2 = b_{m2} - c_{m2}, \quad (1)$$
$$h_n = b_{mn} - c_{mn},$$

and

$$h_1 = h_2 = h_3 = ... = h_n.$$

The values of differences: $h_1 - h_2 = \Delta$, $h_2 - h_3 = \Delta$, $h_1 - h_2 = \Delta$, …, $h_{n-1} - h_n = \Delta$ will indicate the quality of work of the "digital level – barcode rod" system performance (Ustavich, G.A., Ryabova, N.M., Salnikov, V.G., Rakhymberdina, M.Ye., 2011).

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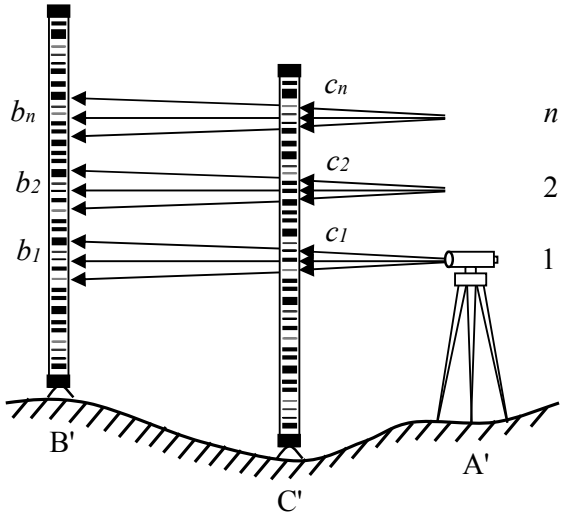

Figure-3. Calibration of level by measuring the height difference according to level horizon changes.

A feature of this procedure is that there is no need to know the "true" height difference between points.

Supplement to existing local verification schedule for level calibration

Taking into account the foresaid for providing the more complete metrological certification of "digital level - barcode rod" system and manufacturing verification in the field we offer to make the following additions to the existing Regulatory document RD 68-8.817-98 "Local verification schedule for surveying and cartographic means of measuring" for levels presented in Figure-4:

1) In basic reference standard relating to high-precision short range geometric levelling take additional quantity σ_{h_p} equals to 0.01 mm;

2) In basic reference standard for the working measuring instruments to take additional quantity σ_{h_p} equals to 0.05 mm;

3) To supplement existing local verification schedule by the procedure for certification of "digital level - barcode rod" system.

Basis requirements taken into account in developing laboratory reference standard for certification of levels ans total stations

In the development of laboratory reference standard (a comparator) should strive to ensure that it lets to certificate high-precision, precise and engineer's levels, as well as total stations which are used for trigonometric short range levelling.

With regard to certification of levels, it relates to the provision of normal length of collimating rays for all orders of the nationl levelling.

With regard to certification of total stations, laboratory reference standard is required to provide the RSM error of height difference measurements at the levelling station for short ranges to reflectors used for trigonometric levelling.

Laboratory reference standard shall provide the determining basic specifications of levels with the visual reading, "digital level - barcode rod" system, and total stations as well.

To solve these problems in laboratory must be possible to specify normal distances when carrying out national levelling and short range levelling to determine subsidences and deformations of engineering structures and equipment.

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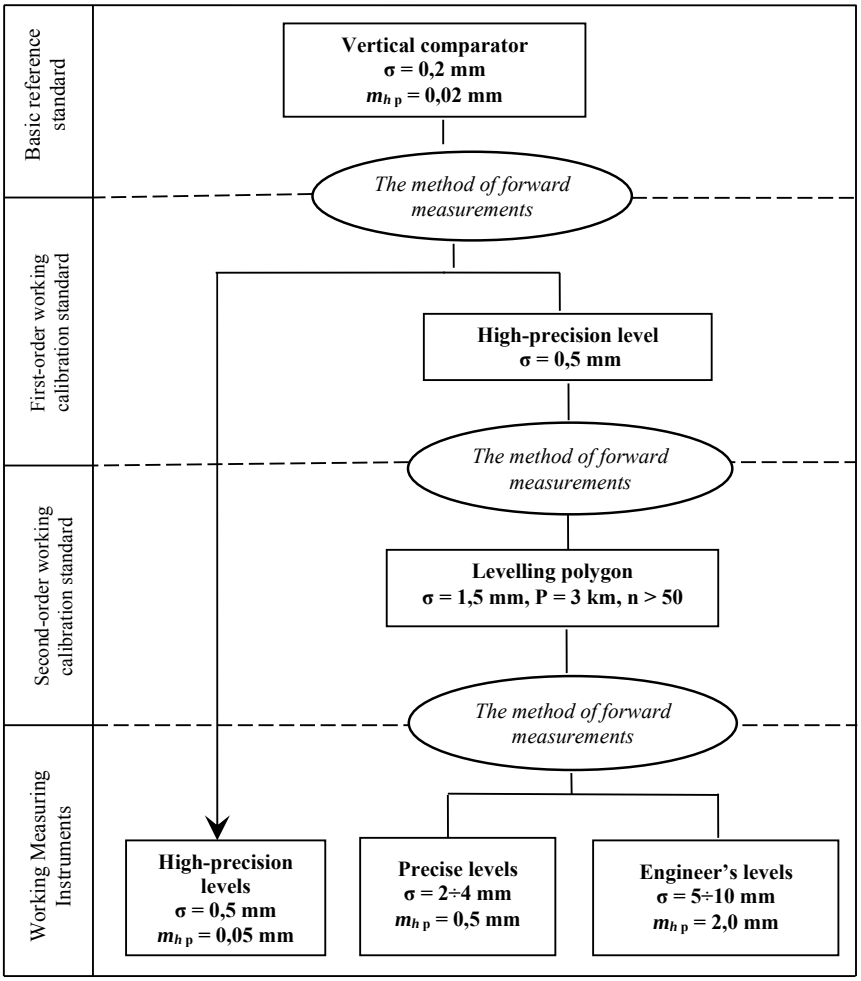

Figure-4. Recommended verification schedule for level certification.

Laboratory reference standard for certification of levels and total stations

Laboratory reference standard is shown in Figure-5. It consists of 8 embedded marks on the respective distances. Between these marks can be done measurements at any combination of distances to rods. Height difference between the marks must be not less than 0.3 - 0.5 m. A level or a total station is set up at points A, B and C and used for measurements on each of the eight points of the laboratory reference standard in any combination (Rakhymberdina, M.Ye., 2013), (Ustavich, G.A., Rakhymberdina, M.Ye., 2014).

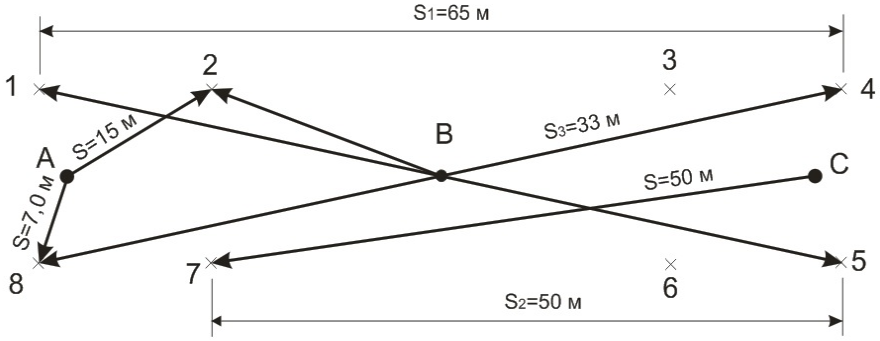

Figure-5. Laboratory reference standard for certification of levels.

Metrological certification of the "digital level - barcode rod" system using above mentioned procedures for different distances is carried out according to any of the schemes shown in Figure-6.

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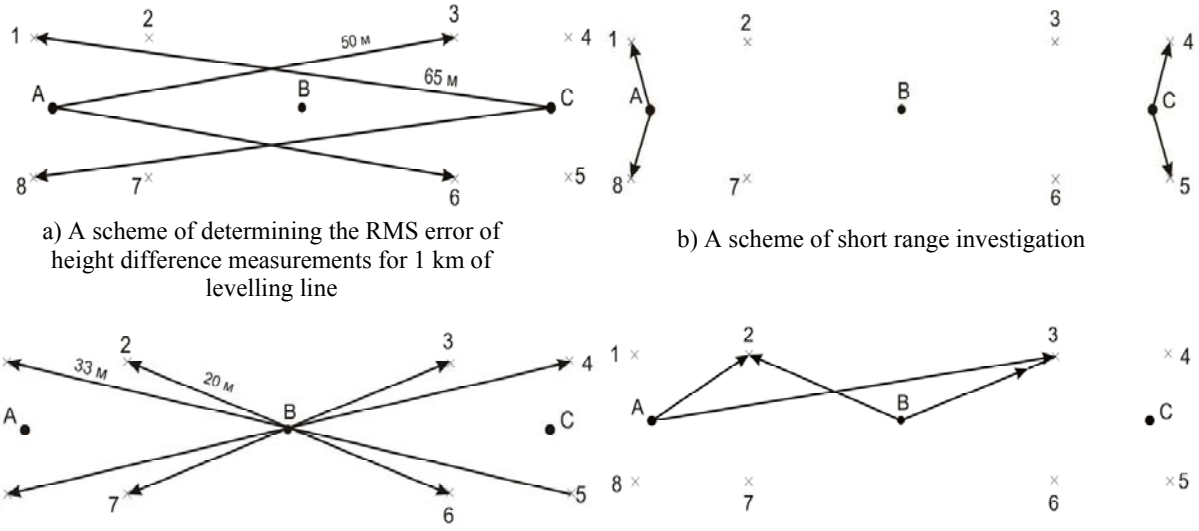

a) A scheme of determining the RMS error of height difference measurements for 1 km of levelling line

b) A scheme of short range investigation

c) A scheme of determining the RMS error of height difference measurements for 1 km of levelling line by short ranges

d) Determination *i* angle using the method "from the middle"

Figure-6. Metrological certification of digital levels and total station for different distances.

The developed vertical comparator can be used to determine the angle *i* and the effects of temperature variations on the angle *i* (Figure-7).

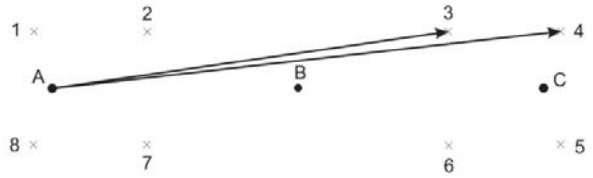

Figure-7. Determining the effect of temperature variations on the the angle *i*.

CONCLUSIONS

Thus, taking into account a number of basic features in digital level design and on the basis of investigations carried out, we can make the following conclusions:

1) To recommend the developed technique of metrological calibration of "digital level - barcode rod" system for performing exceptional verification in the laboratory and the field. Such verification should be considered and manufacturing;

2) It is necessary to make additions to the existing Regulatory document LPS RD 68-8.817-98 "Local verification schedule for surveying and cartographic means of measuring" to provide metrological verification of digital levels in the field;

3) The developed vertical comparator provides determination of the basic metrological characteristics of levels that is the RMS error of difference of height measurement for 1 km of simultaneous level line. It can be used for verification of total stations as well.

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