TESTING OF ACCURACY OF REFLECTORLESS DISTANCE MEASUREMENT OF SELECTED LEICA AND TOPCON TOTAL STATIONS

TESTOVÁNÍ PŘESNOSTI BEZHRANOLOVÉHO MĚŘENÍ DÉLEK VYBRANÝCH TOTÁLNÍCH STANIC FIREM LEICA A TOPCON

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Abstract

Each new geodetic instrument before being put into normal operation is verified for compliance with the manufacturer declared parameters. The procedures for testing of geodetic instruments at the Institute of Geodesy and Mine Surveying, VŠB – Technical University of Ostrava (hereinafter referred to as IGMS) are processed to meet the ČSN ISO 17123 standards. However, standard methods for calibration of geodetic instruments do not include the procedures for testing of reflectorless distance measurement.

IGMS VŠB-TU Ostrava has bought new total stations – Leica TCRP 1201 and TCRP 1202, Topcon GPT 7001 and GPT- 8203M. Each of these total stations provides, inter alia, the reflectorless distance measurement.

During the calibration of the new total stations we proceeded to the research of distance measurement accuracy without the use of reflecting prisms at the telemetering base of IGMS in Ostrava-Krásné Pole.

Abstrakt

U každého nového geodetického přístroje se před uvedením do běžného provozu ověřuje, zda splňuje výrobcem deklarované parametry. Postupy zkoušek geodetických přístrojů na Institutu geodézie a důlního měřictví VŠB-TU Ostrava (dále jen IGDM), jsou zpracovány tak, aby vyhovovaly normám ČSN ISO 17123. Standardní metody kalibrace geodetických přístrojů však nezahrnují postupy pro testování bezhranolového měření délek.

IGDM VŠB-TU Ostrava zakoupil nové totální stanice – TCRP 1201 a TCRP 1202 fy Leica, GPT 7001 a GPT- 8203M fy Topcon. Každá z těchto totálních stanic umožňuje, mimo jiné, bezhranolové měření délek.

Během kalibrace nových totálních stanic, bylo přistoupeno k výzkumu přesnosti měření délek bez použití odrazného hranolu, na dálkoměrné základně IGDM v Ostravě – Krásném Poli.

Key words: total station, testing of accuracy, reflectorless distance measurement, Leica TCRP 1201, Leica TCRP 1202, Topcon GPT-7001, Topcon GPT-8203M

1 INTRODUCTION

Calibration of geodetic instrument is nowadays regarded as completely normal. Recommended is its implementation just after the purchase of new instruments to ascertain, whether the instruments comply with the manufacturer declared parameters and during their use at regular intervals (2 to 3 years), after repair, or when detected any measurement deviation. However, standard calibration procedures for geodetic instruments do not provide the procedures for the testing of reflectorless distance measurement.

The paper deals with the calibration of four new total stations, in particular Leica TCRP 1201, TCRP 1202 and Topcon GPT 7001, GPT 8203M, which have been recently purchased by the Institute of Geodesy and Mine Surveying of VŠB-TU Ostrava. The paper particularly solves the research of the accuracy of distance measurement without the use of a reflecting prism on surfaces of various colours.

2 ACCURACY OF INSTRUMENTS

The motorized TCRP 1201 total station has an angle measuring accuracy of 0.3mgon, is equipped with a rangefinder operating in infrared and visible parts of spectrum and extended by GPS – SmartStation. The radius of reflectorless distance measurement is declared up to 400m. It is equipped with a touch screen display. The motorized TCRP 1202 total station with an angular measurement accuracy of 0,6mgon, is equipped as well with a rangefinder operating in infrared and visible range and extended by GPS – SmartStation. The radius of reflectorless distance measurement is up to 1000m. It is also equipped with a touch screen display. Both instruments have a manufacturer's stated accuracy of distance measurement with pointing to a reflecting prism (± 1mm + 1.5 ppm) and for distances to 500 meters also in a non-prism mode (± 2mm + 2ppm). [5]

The GPT 7001 total station has the manufacturer declared angular accuracy of 0,3mgon. To measure distances it has a pulsed laser rangefinder capable to measure distances in both prism and non-prism modes. The accuracy of measurement in the prism mode for lengths over 25m is (±2mm + 2ppm). For measuring distances in the non-prism mode the manufacturer declared accuracy is ±5mm. The radius of reflectorless measurement is up to 1000m. The instrument has a built-in graphic touch screen.

The GPT-8203M series total station is motorized, its angular accuracy is 1mgon and for measuring distances it is equipped with prism, non-prism and long-range non-prism modes allowing the reflectorless distance measurement up to a distance of 1200m. The declared measurement accuracy of the prism – soft mode is (±2mm + 2ppm). For measuring distances in the non-prism mode, long-range mode – soft mode, the manufacturer gives the accuracy of ±10mm + 10ppm. The total station is completed with a scan system .[6]

The instruments were tested immediately after their purchase, before placing them into normal operation.

3 ACCURACY VERIFICATION

All four instruments were tested to verify the accuracy of distance and angular measurements declared by the manufacturer. The verification tests of accuracy the angle measuring were made in the calibration laboratory of the Institute of Geodesy and Mine Surveying (IGMS). The testing of the accuracy of distance measurement in the prism and non-prism modes took place at the telemetering base of IGMS in Ostrava-Krásné Pole. The base 251.620m in length is divided into 6 unequal-length sections. Stabilization is performed by concrete pillars into a depth of 130cm and the pillar base is 70 cm in diameter. Above ground the stabilization is performed by means of a casing pipe 40cm in diameter, which is filled with concrete. The top surface is fitted with a survey mark. In testing the method of distance measurement is used in all combinations with redundant measurements.

When verifying the accuracy of distance measurement in the prism mode the reflecting prisms of appropriate firms were used for the instruments being tested.

Fig. 1 Telemetering base of IGMS in Ostrava-Krásné Pole

Manufacturers of most total stations have offered for several years the option to measure distances without the use of any reflecting prism. The manufacturers warrant the radius and accuracy of the reflectorless distance measurement only on the Kodak gray card matt surface. In practical measurements in situ, however, also other colour areas occur to a great extent. So we decided to study the influence of surface reflectivity on the accuracy of distance measurement in the non-prism mode. We followed the assumption that the strength of the reflected signal is affected (except for distance, angle of impacte, atmospheric conditions) by reflective properties of the surface. White surfaces provide a strong reflection, while the reflection from black surfaces is weak. Effects of colour surfaces are influenced by the spectral characteristics of lasers (lasers emitting in green, red or infrared parts of spectrum).

For this purpose, a set of seven targets in white, black, gray, red, green, yellow colours and a 20x20 cm shiny silver foil were prepared, and because the manufacturer requires for GPT-8203M, due to the large laser beam divergence, the reflection area of 1x1m for lengths from 30 to 500m, also 1x1m targets of the same colours were made. Each target consists of a colour field and directional signs allowing accurate targeting.

For all targets reflectance ρ was determined. For an even diffuser the following relation between luminance, illuminance and integral reflection factor applies:

$$E \cdot \rho = \pi \cdot L \qquad [1]$$

Where:

E - in the measured point in lux (measured by calibrated luxmeter),

L –luminance of the measured point in candela / m^2 (measured by calibrated luminance meter),

ρ – reflection coefficient for illuminance (white daylight) [$\rho = \int_{380}^{780} \rho_\lambda d_\lambda$].

The determined reflectance of targets:

- White – 83 %
- Black – 4 %
- Gray – 22 %
- Red - 13 %
- Green – 14 %
- Žlutá – 81 %

- Silver foil -61 %

 

Fig. 2 1x1m size colour targets

4 TEST RESULTS

4.1 Accuracy of distance measurement

The accuracy of distance measurement on reflecting prisms of appropriate firms is expressed by an additive constant and is listed in the first column of Table 1. Values obtained are similar for all instruments and meet the manufacturer declared parameters.

Another test consisted of testing the accuracy of reflectorless distance measurement on colour 20x20cm targets. Before starting the measurement current values of temperature and atmospheric pressure were entered into the instruments. The soft (precise) measurement mode was set with a repetition rate of 1. Each distance was measured five times. After measuring all distances for a given colour, the additive constant was determined. Its magnitude is given in Table 1.

Tab. 1 Additive constants

Instrument	Reflector [mm]	Silver [mm]	White [mm]	Gray [mm]	Black [mm]	Red [mm]	Green [mm]	Yellow [mm]
TCRP 1201	-0,48	+3,75	-3,99	+1,59	*	+0,43	+0,92	+1,15
TCRP 1202	-1,14	+3,23	+4,29	+4,62	+2,89	+1,97	+4,94	+3,07
GPT 7001	-0,52	+4,51	+2,40	+1,84	**	+1,82	+1,86	+1,55
GPT 8203M	-0,43	-1,74	-7,54	-8,08	-2,87	+17,13	-6,92	-7,31

* Rangefinder did not measure the distances 1-7, 2-7 and 3-5.

** Rangefinder did not measure the distances 1-7 and 2-7.

Graph 1 shows the differences in lengths measured on the reflecting prism and colour 20 x 20cm targets for the Leica TCRP 1201 total station. Graph 2 shows that the Leica TCRP 1202 total station achieved slightly worse results than Leica TCRP 1201. However, no changes in signs of distance differences measured on the reflecting prism and colour 20 x 20cm targets took place. The testing results for the Topcon GPT 7001 total station are plotted in Graph 3.

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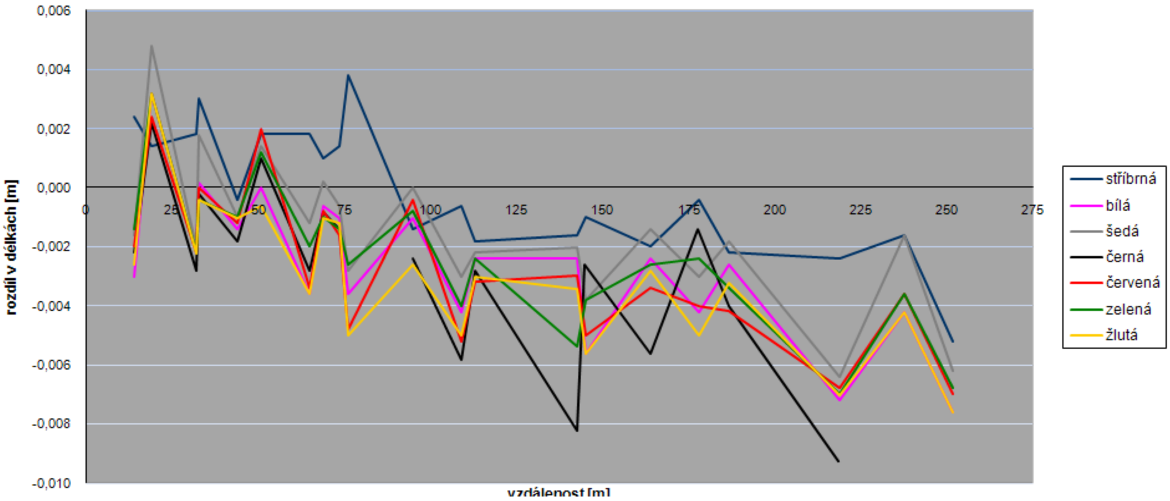
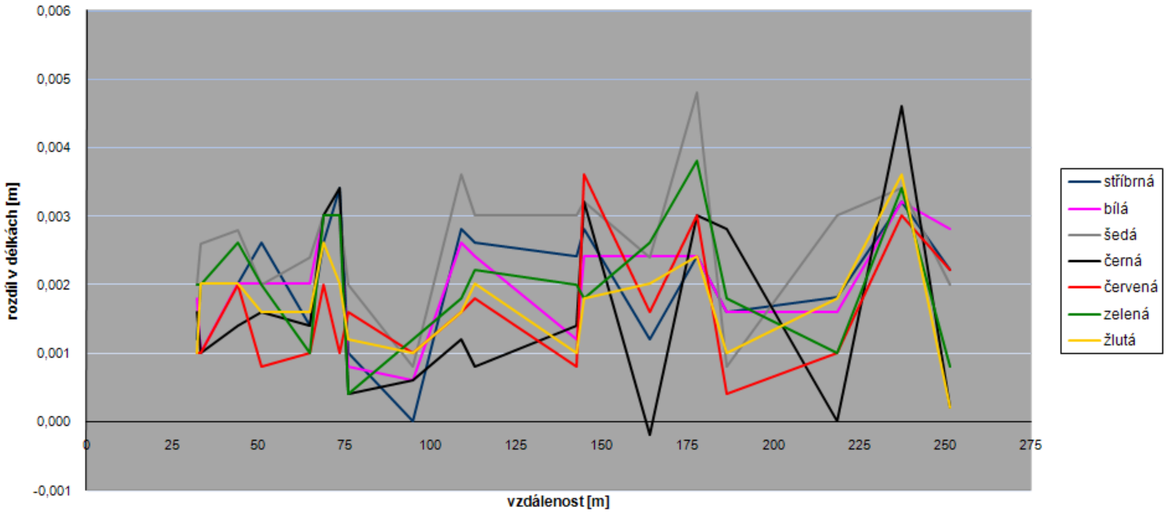
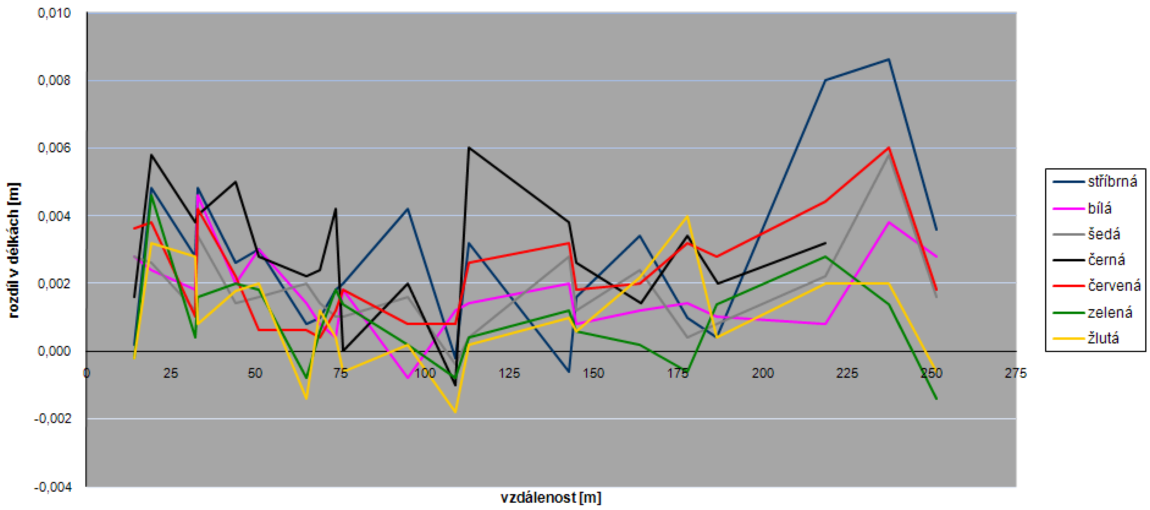


Graph 1: TCRP 1201 – differences in length between the reflector and 20×20cm colour targets

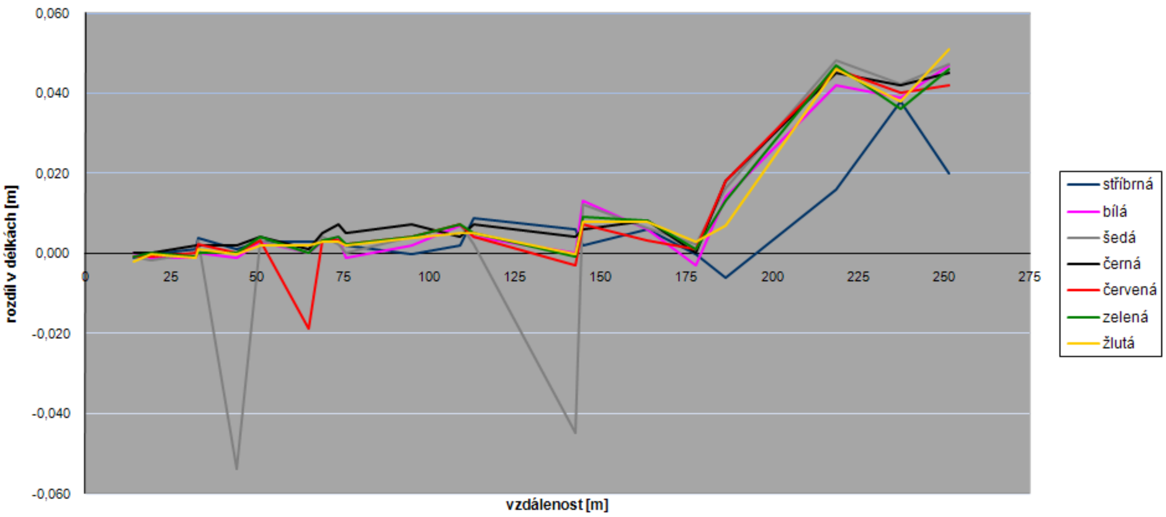


Graph 2: TCRP 1202 – differences in length between the reflector and 20×20cm colour targets



Graph 3: GPT 7001 – differences in length between the reflector and 20×20cm colour targets

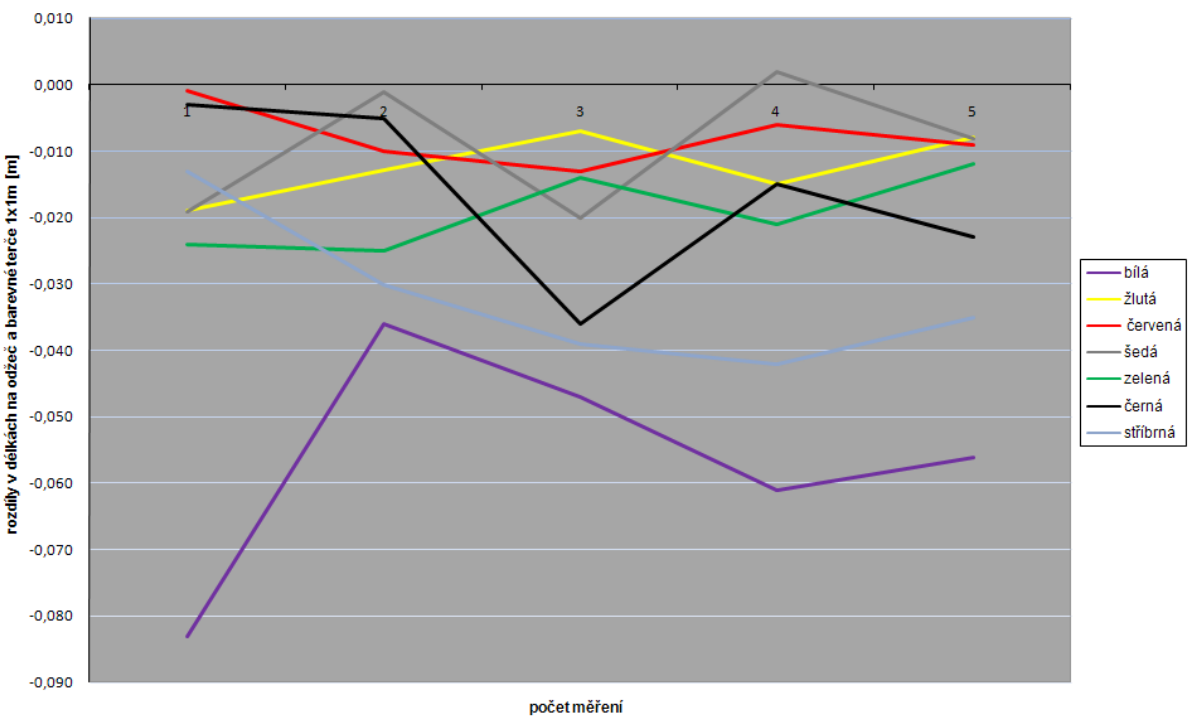
Table 1 and Graph 4 present that the largest deviations were showed by the rangefinder of GPT 8203M. But as the deviations were found at distances over 30m, the lengths were retested, this time on 1x1m targets, required by the manufacturer. Table 2 presents the values measured on the longest distance of the base between pillars 1 and 7 that is 251.620m. See also revealed significant differences between both individual measurements on the same targets and the values of lengths from measurements on targets of different colours. The differences between the distances measured on the reflecting prism and on colour targets are shown in Graph 5.



Graph 4: GPT 8203 – differences in length between the reflector and 20×20cm colour targets

Tab. 2 The length of 251.620m measured by the GPT 8203M total station on colour 1x1m targets

white	251,705	251,655	251,666	251,681	251,676
yellow	251,641	251,632	251,626	251,635	251,628
red	251,623	251,629	251,632	251,626	251,629
green	251,646	251,644	251,633	251,641	251,632
gray	251,641	251,620	251,639	251,618	251,628
black	251,625	251,624	251,655	251,635	251,643
silver	251,635	251,649	251,658	251,662	251,655



Graph 5: GPT 8203M - differences of the distance of 251.620m on the reflector and 1×1m colour targets

The experiment results are summarized in Table 3.

Tab. 3 The length of the maximum deviation in distance measured on reflector and colour target

Positive value – length on reflector was longer than the length on colour target (values in mm)

Instrument	White Reflectance 83 %	Yellow Reflectance 81 %	Red Reflectance 13 %	Green Reflectance 14 %	Gray Reflectance 22 %	Black Reflectance 4 %	Silver Reflectance 61 %
TCRP 1201	-8	-8	-7	-7	-6	*	-5
TCRP 1202	+3	+4	+4	+4	+5	+5	+3
GPT 7001	+5	+4	+6	+5	+6	**	+9
GPT 8203M 20x20cm target 1x1m target	+47 -15	+51 +43	+46 -84	+47 -29	-54 +43	+45	+38 -26

* Rangefinder did not measure the distances 1-7, 2-7 and 3-5.

** Rangefinder did not measure the distances 1-7 and 2-7.

5 CONCLUSIONS

Experiment results showed the differences between the accuracy of distance measurement on reflecting prisms and colour targets with different reflectance. Hereat the target reflectance did not dramatically affect the accuracy, but the distances on dark targets were not measured at all. Increase the number of measurements of individual distances did not increase the accuracy of the measured length, on the contrary, increased the variance of the measured values. For GPT 8203M the increase of target size to the size of 1x1m required by the manufacturer did not significantly increase the accuracy of the measured distances. Conversely, the black colour was not measured at all.

None of the measurements, however, did not exceed the accuracy given by the manufacturers on the gray card Kodak white matt surface.

The paper does not intend to decrease the quality of the tested instruments. It just wants to draw attention to the fact that for accurate work it is necessary to carefully consider the appropriateness of the use of the reflectionless technology of distance measurement, or test the accuracy of measurements for each specific case.

The fact that a rangefinder shows better results than another does not mean that it is a better instrument for other specific tasks.

REFERENCES

[1] HAVELKA, B. *Geometrická optika1*. 1st ed. Praha : Nakladatelství Československé akademie věd, 1955.

[2] MAZALOVÁ, J. Výsledky ověřovacích zkoušek teodolitů a nivelačních přístrojů. In *Měřické přístroje a výpočetní technika*. Place : Ostrava, 1993, pp. 91-93.

[3] MAZALOVÁ, J. Kalibrace geodetických přístrojů a laserových dálkoměrů - záruka jakosti důlního či stavebního díla. In *Jakost 2001*. Place: Ostrava, 2001, pp. H11-H14.

[4] MAZALOVÁ, J. & MURYSOVÁ, R. Kalibrace elektronických dálkoměrů. In *Aktuální problémy důlního měřictví a geologie.* Place: Nový Hrozenkov, 1999, pp. 85-86.

[5] Internetové stránky firmy Gefos [cit.8.10.2008] http://www.gefos.cz/cz/leica/produktyl/40/tps1200-

[6] Internetové stránky firmy Geodis [cit.8.10.2008] http://obchod.geodis.cz/www/index.php?page=totalni_stanice.html

[7] IŽVOLTOVÁ, J. Kalibrácia diaľkomerov v laboratórnych podmienkach. VIII. Mezinárodní konference geodézie a kartografie v dopravě. Place: Ostrava 2002, str 245-249

[8] IŽVOLTOVÁ, J. PISCA,P., POLÓNYI,P. Implementation of Uncertainty into Evaluation of Geodetic Measurements. XV Russian-Slovak-Polish Seminar: Theoretical Foundation of Civil Engineering. Moscow - Rostov on Don – Warszawa 2006. p. 281-284.

RESUMÉ

Kalibrace geodetických přístrojů je v dnešní době považována za zcela běžnou. Doporučuje se její provádění ihned po zakoupení nových přístrojů, kdy se zjišťuje, zda přístroje splňují výrobcem deklarované parametry a během užívání pak v pravidelných intervalech (2 až 3 roky), po opravě, nebo při každé zjištěné odchylce při měření. Standartní postupy kalibrace geodetických přístrojů však neobsahují postupy pro testování bezhranolového měření délek.

Příspěvek řeší kalibraci čtyř nových totálních stanic TCRP 1201, TCRP 1202 fy Leica a GPT 7001, GPT 8203M fy Topcon, které byly v nedávné době zakoupeny Institutem geodézie a důlního měřictví VŠB-TU Ostrava. V příspěvku je zejména prezentován výzkum přesnosti měření délek bez použití odrazného hranolu na povrchy různých barev.

Výsledky experimentu ukázaly na rozdíly mezi přesností měření délek na odrazné hranoly a na barevné terče s různou odrazivostí. Přitom přesnost výrazně neovlivnila odrazivost terče, ale to, že vzdálenosti na tmavé terče nebyly některými přístroji změřeny vůbec. Zvýšení počtu měření jednotlivých vzdáleností nevedlo ke zvýšení přesnosti změřené délky, naopak, zvětšil se rozptyl naměřených hodnot. U GPT 8203M zvětšení velikosti terčů na výrobcem požadovaný rozměr 1x1m nevedlo k výraznému zvýšení přesnosti měřených vzdáleností. Naopak, černá barva nebyla změřena vůbec.

Žádné z měření však nepřekročilo přesnost uváděnou výrobci na bílý matný povrch Kodak gray card.

Příspěvk nehodlá snižovat kvalitu testovaných přístrojů. Chce jen upozornit na fakt, že pro přesné práce je třeba pečlivě zvážit vhodnost použití bezhranolové technologie měření délek, popřípadě otestovat přesnost měření pro každý konkrétní případ.