# Testing of the accuracy of Leica TCRP 1201 total stations, Topcon GPT-7001 and Topcon GPT-8203M

*Jana Mazalová[1], Kateřina Valentová[2] a Lenka Vlčková[3]*

***Ověřování totálních stanic Leica TPC 1200, Topcon GPT-7001 a Topcon GPT-8203M***

*The Institute of Geodesy and Mine Surveying VŠB-TU Ostrava bought new total stations – TCRP 1201 made by Leica, GPT- 7001 by Topcon and GPT-8303M by Topcon.*

*TCRP 1201 is a motorized total station extended by GPS – SmartStation. GPT 7001 is a total station with a pulse rangefinder. The GPT-8203M motorized total station also has a pulse rangefinder and it is possible to use it as a 3D scanner. Among others, each of these total stations enables non-prism measuring.*

*It is common to test whether a new geodetic apparatus meets characteristics declared by the manufacturer before it is introduced into everyday usage. The testing of geodetics apparatus procedures on IGMD are proceeded in such a way they correspond with the CSN ISO 17123 standards. Besides these standard procedures the tests were extended by non-prismatic measuring properties testing.*

***Key words**: Total station, testing of accuracy, Leica TCRP 1201, Topcon GPT-7001, Topcon GPT-8203M.*

## Introduction

The calibration of the geodetic apparatus is nowadays viewed as common. It is recommended to test it as soon as the new apparatus has been purchased, as it is necessary to find out whether the apparatus meets the parameters declared by the manufacturer. It is also necessary to test it at regular intervals (during the period of two or three years), after it has been repaired, or if any deviation has been found during the process of measuring. This paper deals with the calibration of three new total stations, that is TCRP 1201 by Leica, GPT 7001, and GPT 8203 by Topcon, which were recently bought by the institute of Geodesy and Mine Surveying, VSB-TU Ostrava. The research of total stations' accuracy without the use of reflecting prism on the surface of various colours is specifically presented in this paper.

## The accuracy of the apparatus

The GPT 7001 total station has the manufacturer's declared accuracy of 0,3mgon. It is equipped with a laser pulse rangefinder, which enables distance measurement in prism as well as non-prism mode. The apparatus has a built-in graphic touch screen. The total stations of the GPT-8203M series are monitorized, with the angle accuracy of 1mgon. For distance measuring it is equipped with prism, non-prism and a long non-prism mode, which enables non-prism distance measuring up to the distance of 1200 metres. It is also equipped with a scanning system. The TCRP 1201 monitored total station has the accuracy of angle measurement of 0,3 mgon, it is equipped with a rangefinder which works in infrared as well as the visible spectrum. It is also equipped with GPS – SmartStation. The range of the non-prism angle measurement is declared to be 400 metres. It is also equipped with a touch screen. The testing of the apparatus was done straight after the purchase and before its introduction into everyday use.

## Testing the accuracy

All three apparatus were tested in order to verify the manufacturer's declared angle measurements and distance accuracy. The verifying angle measurement accuracy tests were done in a calibration laboratory of the Institute of Geodesy and Mine Surveying (further as IGDM). The testing of distance measurement accuracy in a prism as well as in non-prism mode was done on the IGDM rangefinder base in Ostrava – Krasne Pole. The base with the length of 250,620 metres is divided into 6 sections with unequal length. It is fixed by concrete pillars with the depth of 130 cm, and the diameter of 70 cm at the pillar's foundation.

[1] *doc. RNDr., Jana Mazalová, CSc.,* VŠB-TU Ostrava, Hornicko-geologická fakulta, Institut geodézie a důlního měřictví, 17.listopadu 15, 708 33 Ostrava- Poruba, jana.mazalova@vsb.cz

[2], *Ing. Kateřina Valentová,* VŠB-TU Ostrava, Hornicko-geologická fakulta, Institut geodézie a důlního měřictví, 17.listopadu 15, 708 33 Ostrava- Poruba, katerina.valentova.st@vsb.cz

[3] *Ing. Lenka Vlčková,* VŠB-TU Ostrava, Hornicko-geologická fakulta, Institut geodézie a důlního měřictví, 17.listopadu 15, 708 33 Ostrava- Poruba, lenka.vlckova.st2@vsb.cz

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Above the terrain, the fixation is done by using a casing pipe with the diameter of 40 cm, which is filled with concrete. The surface is marked by metrical signs. During the testing, the method of distance measurements in all combinations with excessive measurement is used.

During the accuracy verification of distance measurement in the prism mode reflection prisms of appropriate companies have been used for tested apparatus.

*Fig. 1. IGDM rangefinder base in Ostrava – Krasne Pole.*

For the past few years the manufacturers have been offering the opportunity to use total stations without the usage of a reflecting prism in the distance measurements. The range and the accuracy of the non-prism distance measurement is guaranteed by the manufacturer only when used on a white mat Kodak grey card surface. When practice measurements are taken, different coloured surfaces occur in the terrain. Therefore, we decided to explore the effect of the surface reflection on the accuracy of distance measurement in non-prism mode. We work on the assumption that the strength of the reflected signal is influenced (apart from the distance, the angle of incidence, atmospheric conditions) by the reflecting properties of the surface. White surfaces provide strong reflection, on the contrary the reflection of black surfaces is weak. The effects of colourful surfaces are determined by the prismatic laser characteristics (lasers radiating in green, red, or infrared part of the spectrum).

A kit of seven targets in white, black, grey, red, green, yellow and silver gloss foils with the proportion of 20 x 20 cm has been developed, and because for GPT-8203M, due to its large divergence of the laser volume, is by the manufacturer required for the distance of 30 to 500 metres with its reflection area of 1x1 metre, colourful targets of the same colours with the proportion of 1x1 metres were made. Each target is composed of a coloured field and directive signs enabling accurate targeting.

Reflection ρ has been discovered at all targets. The relation of

$$E \cdot \rho = \pi \cdot L$$

applies for equal diffuser between brightness, exposure and integral factor of the reflection.

Where:

E is exposure in the measured point in luxes (measured by calibrated luxmetre),

L is luminance measured in point in candelas / $m^2$ (measured by calibrated luminance meter),

ρ is a reflection factor for exposure by white day light [ $\rho = \int_{380}^{780} \rho_\lambda d_\lambda$ ].

Discovered reflection of the targets

- White – 83 %
- Black – 4 %
- Grey – 22 %
- Red - 13 %
- Green – 14 %
- Yellow – 81 %
- Silver foil -61 %

*Fif. 2. Coloured targets with the dimension of 1x1m.*

Tests‘ results

**The accuracy of angle measuring**

In the laboratory the accuracy of horizontal and vertical angles as well as collimation error have been tested in both positions on a distance meter. The accuracy is expressed by a standard deviation of $\sigma_{Hz}$, $\sigma_{V}$, $\sigma_{c}$. for each value an extended measurement uncertainty of UHz, Uv, Uc is given, which is the product of standard measurement uncertainty and the coefficient of enlargement k = 2, which in standard dividing matches the probability coverage of 95 %. The Standard measurement uncerainty corresponds with the EA4/02 document. The results of the measuring are presented in tab. 1.

*Tab. 1.*

| **apparatus** | $\sigma_{Hz}$ [mgon] | **Uhz** [mgon] | $\sigma_{V}$ [mgon] | **Uv** [mgon] | $\sigma_{c}$ [mgon] | **Uc** [mgon] |
|---|---|---|---|---|---|---|
| **GPT-7001** | +0,3 | ±0,3 | +0,2 | ± 0,3 | +0,4 | ±0,4 |
| **GPT-8203M** | +0,5 | ±0,3 | +0,6 | ±0,3 | +0,6 | ±0,4 |
| **TCRP-1201** | +0,3 | ±0,3 | +0,3 | ±0,3 | +0,4 | ±0,4 |

Resulting values from verifying angle measurement test confirmed the accuracy declared by manufacturers.

**The accuracy of distance measurements**

The accuracy of the distance measurements on reflective prism of appropriate companies is expressed by additional constants and is shown in tab. 2 in the first column. The gained values are nearly the same, and very good, for all apparatus.

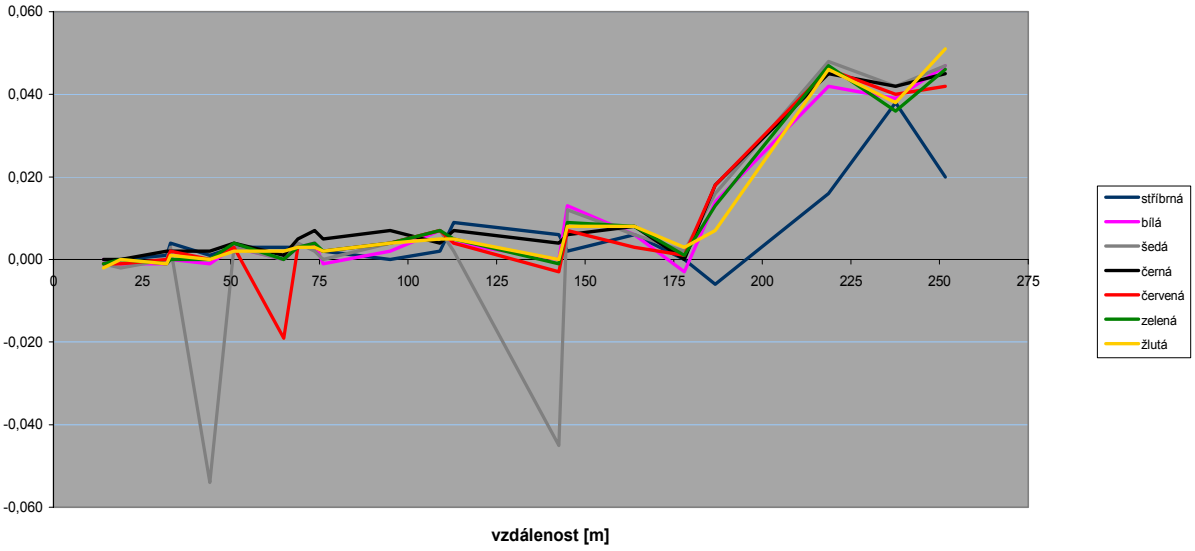
Another test consisted of testing the accuracy of non-prism distance measurement of the coloured target with the proportion of 20x20 cm. Before starting the measurement, up to date temperature values and values of the atmospheric pressure were set in the apparatus. A mild (accurate) measurement mode with repetition 1 was set. Each distance was measured five times. If the apparatus measured all distances for a given colour, addition constant was specified. Its size is shown in tab. 2.

*Tab. 2. Addition constant.*

| apparatus | reflector [mm] | Silver [mm] | White [mm] | Grey [mm] | Black [mm] | Red [mm] | Green [mm] | Yellow [mm] |
|---|---|---|---|---|---|---|---|---|
| **GPT 7001** | -0,52 | +4,510 | +2,400 | +1,837 | * | +1,823 | +1,857 | +1,547 |
| **GPT 8203M** | -0,43 | -1,740 | -7,540 | -8,080 | -2,870 | +17,130 | -6,920 | -7,310 |
| **TCRP 1201** | -0,48 | +3,745 | -3,989 | +1,593 | ** | +0,427 | +0,916 | +1,147 |

* *The rangefinder did not measure the distances of 1-7 and 2-7*
** *The rangefinder did not measure the distances of 1-7, 2-7, 3-5*

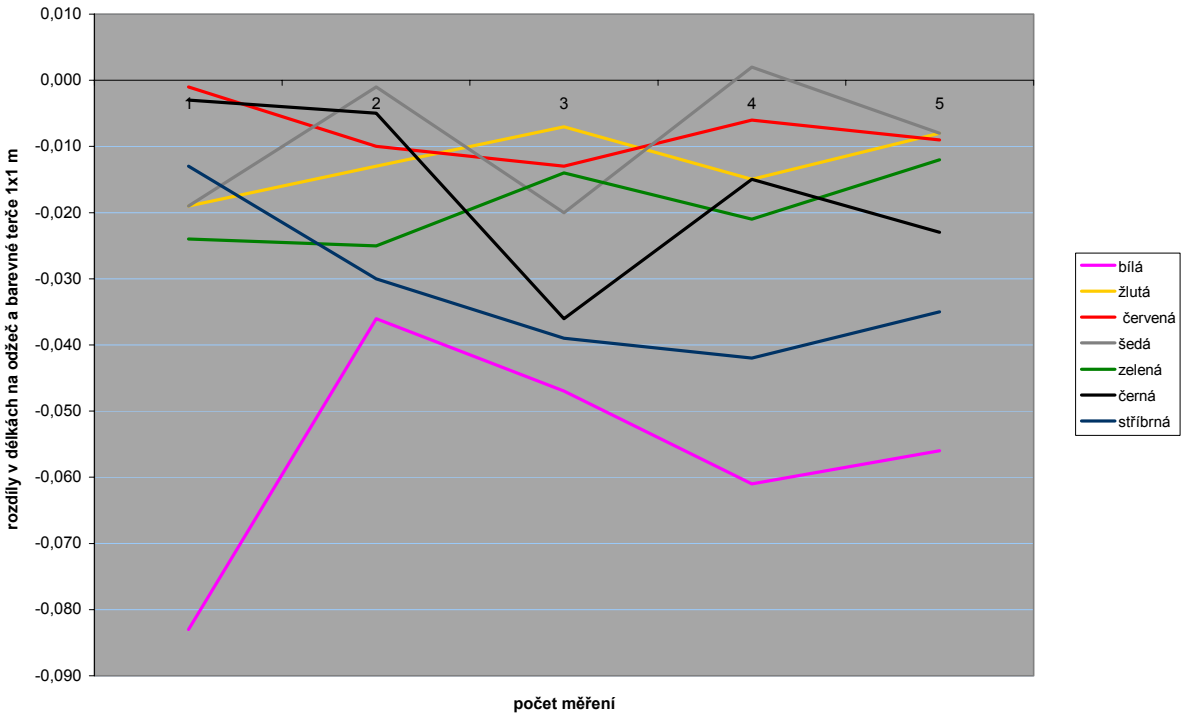
From tab. 2 and graph 1 it is obvious that the biggest deviations were shown by GPT 8203M rangefinder. Because these deviations had been discovered when measuring distances larger than 30 metres, the distances were repeatedly tested, this time on targets with the proportions of 1x1 m, as required by the manufacturer. Tab. 3 shows measured values on the longest distance base, between pillars 1 and 7, which is 250,600 m. Even here significant differences have been found. That is between the individual measurements on the same targets, and between the distances gained form measuring targets of different colours. The difference between the measured distance on a reflective prism and coloured targets are shown in graph 2.




*Graph 1. differences in distances between the reflector and coloured targets of 20x20 cm, GPT 8203M.*

*Tab. 3. Distance 250,600 m measured by GPT 8203M total station on 1x1 m coloured 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 |
| **grey** | 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 2. Distance 250,600 m measured by GPT 8203M total station on 1x1 m coloured targets.*

The results of the experiments are summarised in tab. 4.

*Tab. 4. the Maximum deviances in the distance measured on a reflector and a coloured target. Positive value – distance on the reflector was longer, than the one on a coloured target (values in mm).*

| Apparatus | White reflectivity 83 % | Yellow reflectivity 81 % | Red reflectivity 13 % | Green reflectivity 14 % | Grey reflectivity 22 % | Black reflectivity 4 % | Silver reflectivity 61 % |
|---|---|---|---|---|---|---|---|
| **GPT 7001** | +5 | +4 | +6 | +5 | +6 | * | +9 |
| **GPT 8203M Target 20x20cm Target 1x1m** | +47<br>-15 | +51<br>+43 | +46<br>-84 | +47<br>-29 | -54<br>+43 | +45 | +38<br>-26 |
| **TCRP 1201** | -8 | -8 | -7 | -7 | -6 | ** | -5 |

* *The rangefinder did not measure the distances of 1-7 and 2-7*
** *The rangefinder did not measure the distances of 1-7, 2-7, 3-5*

## Conclusion

The results of the experiment showed the differences between the accuracy of distance measurements on reflecting prisms and on coloured targets with different reflectance. The target reflectance did not significantly influence the accuracy, but the fact, that the distance on dark targets were not measured at all by some apparatus. The increase of the number of individual distance measurement did not lead to the increase of measured distance accuracy, on the contrary, the dispersion of measured values increased. The enlargement of targets to manufacturer's dimension of 1x1 m in the case of U GPT 823 M did not lead to a significant distance measurement accuracy improvement. On the contrary, the black colour was not measured at all.

None of the measuring exceeded the manufacturers' declaration of accuracy on a white mat Kodak grey card surface. By writing this paper we do not mean to undermine the quality of the tested apparatus. We just want to make you aware of the fact, that it is necessary to take in consideration the suitability

of non-prismatic distance measurement technology use, or to test the measurement accuracy for every particular case.

The fact that some rangefinders show better results does not mean that it is a better apparatus for different and specific tasks.

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