Measuring the distances wyth topographic equipment in the geodesic base of the National Institute of Metrology from Bucharest

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Abstract
This article presents some theoretical and practical aspects of topographic devices calibration topographic. It highlights how important it is to pay attention before you start working with these devices, namely to consider introducing the atmospheric parameters for setting the EDM instrument. It is very important to monitor and take into account the environmental conditions before starting the measurements?

Keywords
EDM, distance measurement, correlation, precision.

1. Introduction

EDM tool is the ability to measure distance by electronic means, a basic function of topographic instruments. Many users of surveying equipment, unfortunately, do not know the importance to be attached EDM instruments to measure correctly with these devices without introducing significant errors.

2. Description of the laboratory work

Laboratory Dimensional Sizes and Acoustic of the INM dealing inter alia with calibrating of the surveying equipment. Below are some general aspects of the work to be carried out in the laboratory.

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In the laboratories of the National Institute of Metrology Bucharest the staff is competent both in terms of specific services and processes perform calibration/verification. INM staff of the laboratory activities that require control (legally) authorized by the BRML (Romanian Office of Legal Metrology) [1,2].

The environment in the laboratory fall within those required by international organizations representing reference conditions: temperature (20°C ± 0.5°C), humidity (60 ÷ 70%), however, we try thrue various technical methods that during the calibration process to reduce it to an acceptable level (40 ÷ 45%), atmospheric pressure (750÷770) mmHg.

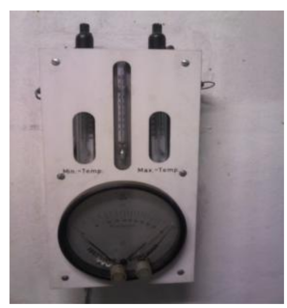

Fig. 1 Thermohygrometer. It is located in the geodesic base to monitor temperature and humidity.

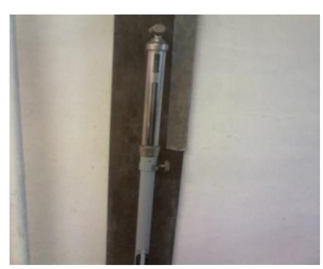

Fig. 2 Barometer is located in the geodesic base to monitor atmospheric pressure.

The geodesic base of the Lengths Laboratory is mainly used to calibrate the ribbon and measuring tapes. Geodetic base consists of the following main parts: the foundation of the floor plate, the base length is 65 m and the cross-sectional dimensions are 0.8 m x 0.55 m, mounted on a concrete foundation frame carrying two-way measurement, the steel plate measuring (-10...10) mm (placed at equidistant intervals of 0.5 m), and guide means movable measuring carriage, the carriage moving on the surface of the geodesic base measuring microscope, laser interferometer to register displacement of the measuring mobile trolley.

3. Calibration of geodesic distance measurement devices with multiple functions in INM

Inside the laboratory are considered three parameters that have enough influence in the process of measuring distances in the range (0…50 m), temperature, pressure and humidity of the environment. Operating temperature range of these devices is (-20ºC to 40ºC).

Were simulated in laboratory conditions of temperature and we concluded that the environmental parameters monitoring is very important.

In a change of 1°C of temperature accuracy has insignificant influence in determining the distances indicated by the device, using geodetic reference points base on which is desired the length calibration.

In practice, the temperature of the calibration process is the same, so that the measurement accuracy is not affected by the temperature variation is less than ± 0.5°C. Different conditions were simulated (artificially) for environmental values of all three atmospheric parameters for these devices throughout their working field.

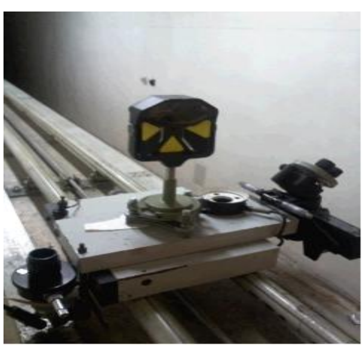

Fig. 3 Measuring trolley and support.

The table above shows geodetic Leica TCR device calibration under laboratory conditions. Distances measuring was performed on the geodetic base usable length on measurement range (0 ÷ 50) m back and forth. Geodetic apparatus was positioned on a tripod taking care to level the vertical axis. The points in which the measurements were made are shown in the table.

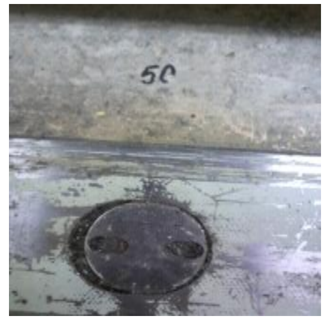

Fig. 4 Steel metal plate which marks the 50 m point of the geodetic base

Before measurements, was determined at 20°C in temperature correction program of the EDM instrument. It was of interest to see EDM instrument behavior in different temperature conditions, in order to know how the distance measurement accuracy varies throughout the temperature range of the instrument.

Table 1 Measuring distances in geodesic base with the total station Leica TCR Power 407

T[°C]	-20	-10	0	10	20	30	40
Ppm	-36	-23	-12	-1	9	18	27
Device indication[m]-forward							
0	2,406	2,407	2,407	2,406	2,407	2,407	2,407
10	12,407	12,407	12,407	12,407	12,407	12,407	12,407
20	22,407	22,406	22,407	22,407	22,408	22,408	22,408
30	32,406	32,406	32,407	32,407	32,407	32,407	32,408
40	42,405	42,406	42,406	42,407	42,408	42,408	42,408
50	52,404	52,404	52,405	52,406	52,406	52,408	52,407
Device indication [m]-back							
50	52,404	52,404	52,405	52,406	52,406	52,407	52,407
40	42,405	42,406	42,407	42,407	42,407	42,408	42,408
30	32,406	32,406	32,406	32,407	32,407	32,407	32,408
20	22,407	22,406	22,407	22,407	22,407	22,408	22,408
10	12,407	12.407	12,407	12,407	12,407	12,407	12,407
0	2,406	2.407	2,407	2,406	2,407	2,407	2,407

Since the practical point of view it is recommended not to simulate actual conditions on the range of temperature (-20°C to 40°C), here refers more to the values given by extreme limits of temperature range -20°C to + 40°C, it was agreed that it is useful to be simulated artificially. All distances are measured at 20°C and then simulating all the temperature range (-10°C to 40°C). Basically these values have been entered in temperature correction instrument of EDM, and for every point measured the temperatures were simulated. The results of distance measurement can be seen in the table above. In case of simulating the temperature at -20°C, it was observed that the precision of the geodetic devices with multiple functions for the first 30 m is relatively good, with deviations of 1 ... 2 mm, this keeping the whole measuring range. Not applicable to generalize these errors, they have a purely informational purpose only practical experiments based on various geodetic instruments.

Therefore, from extensive research and extensive

measurements in laboratory we can say that conditions using these devices is not recommended between the minimum and maximum operating range in terms of temperature, as errors in measuring distances in a short distance (50 m) can vary significantly depending enough of the accuracy class of device.
Below is the table containing the results of geodetic base calibration over a distance of 50 m using laser interferometry (a reference system that is used for the annual calibration of the geodetic base).

Table 2 Calibration of geodetic base of the INM. The reference values

The length's of the geodetic base [m]	Standard values read on the measuring scale [m]	Geodetic base correction [mm]
0	0,0116452	0
0,5	0,0497743	0
1	1,0458834	0
2	1,9999928	0
3	2,9998388	0,1
4	3,9998761	0,1
5	5,0760817	0,2
10	10,181172	0,2
15	14,9999495	-0,1
20	19,9998146	-0,2
25	24,9996155	-0,4
30	29,9996155	-0,4
35	35,1058525	-0,5
40	40,0232697	-0,6
45	44,9999884	-0,8
50	49,9988637	-0,6

The table above represents the latest results of geodetic base calibration process using laser interferometry.
These results were collected during 2013. In the following measured values are further explained in the previous table. As described above, based on the geodetic has a useful length of 50 m, on which are disposed steel plate spacing of 0,5 m to 0,5 m with a field of measurement (-10...10 mm). In the left column in the table are described in (expressing distance in m), the calibration was performed. Y must say that the calibration was performed using the most precise method of measuring the length in a precise way at present, laser interferometry. In the second column are given the values measured by the laser interferometer to calibrate these measuring points. They are provided with the best accuracy. Results can be displayed with a resolution of 7 digits. In the third column is given their correction, which is obtained from the difference between the standard and reference values for length (distance) measured.
These values are updated annually in the case of the geodetc base, there use is possible every year and corrected especially improving results in terms of distance measurement errors being made using this instalation in the laboratory.

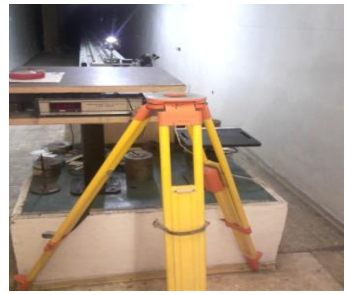

Fig. 5 The way of measuring mobile trolley at the point, " 0 " m the geodetic base

3.1. Principles of operation of electronic instrument for measuring distances-EDM. Electromagnetic energy.

Electromagnetic theory and operation principles of EDM are well covered in most books and online surveying. The intention here is to provide a general understanding of EDM, so that error sources are better understood and controlate. An EDM tool uses a pulse of electromagnetic energy (EM) to determine the length of a line.
The energy comes from an instrument at one end of a line and transmitted to a "reflector" at the other end, where it is returned to the original instrument. Nature "reflector" is dependent on the type of EM. If energy is the type electro-optical (infrared or laser) is used when EM "reflector" which is usually a passive medium in which the signal bounces back.
If EM is "microwave", the second reflector is a tool that captures energy input and re-throughput him back to instrument.In by origin in both cases, the measurement is the total distance from instrument to instrument reflector and back [1, 4].
Many typical errors instrumental and natural distance measurements are misunderstood. Systematic errors may be found by "closing" because of the relative error. If these errors are not removed, distances will be inaccurate [1, 2]. Some of these are purely systematic errors.
Others are constant and does not change with conditions variables. But other errors are systematic in nature but generally random. Such errors can become randomly distributed.
The first type of error will be simply called systematically,
the second will be called constant, and the third will be called quasi - systematic.The errors discussed above are the most common, but the list is not complete. The aim is to encourage the achievement of the highest precision measurements practice. Modern surveying instruments began to measure distances standardized or correct relative positions a few hundredths of m (according to the "class" field and scope of the measurement).
To achieve any particular positional accuracy, distances should be more accurate than permissible positional error because the error in effect also contributes to positional error. To control the systematic errors in the electronic

measuring distances, the error constant and scale instrument must be correctly determined using a baseline of 4 points must be controlled temperature and pressure errors, reflector constants must be known and applied optical tribrach and prisms, must be kept adjusted circular bubbles and slope measurements should be reduced accordingly on the horizon.

In many cases (eg, urban studies), the use of reflectors mounted on a tripod may be necessary to place the measurement using reflective prisms[1, 2]

3.2. EDM instrument errors

As a "rule," an error of 1°C air temperature causes an error of about 1 ppm to as deterministic her. Also, an error of 2.54 mmHg pressure affects the measured distance of 1 ppm, as well as a difference in altitude of 100 meters.

Such errors are negligible for surveying, but may be significant for special cases, such cadastre. Suppose that the field teams PPM variable will not change the total station during times when there are large temperature changes.

If the temperature goes from 5°C to 24°C on a spring day and PPM correction has not been changed from morning to afternoon, the team on the ground will have a difference of 18 mm to 1 m, over a distance of 1000 m in the two different pressure points.

The atmosphere can also change, several tens of centimeters in a few hours when the weather is unstable. Since 3 m elevation difference 2.54 mmHg pressure difference causes, topography have an additional problem to constantly look that pressure changes with altitude[1,3].

Without going into complicated theoretical aspects, we can say that two EDM measurement errors associated with: constant error and scale error (PPM).

This tool can measure electronic distances and can be easily calibrated to discover these corrections. Errors in future measurements from these sources can be controlled within a few millimeters.

However, the test must be done carefully and properly. As a general specification, try not to have more than 1 ... 2 mm error in measuring distances on land. In this way, once more sources of errors can become perhaps combined, which is the result of a precise calibration inaccuracies introducing a few millimeters [1,4].

Generally, the intervals between points are corrected to a few tenths of a millimeter. It is not important to understand how these accuracies have been achieved. Suffice it to say that the ranges published is "truth" where topography. Values are accurate, in the horizontal plane in măsuarea distances and at an angle (slope) [1].

3.3 Adjusting EDM instrument errors

For those who remember how we calibrate a steel band, you know that a measuring tape is not optimal to be normalized to some given values of textbooks in terms of temperature and pressure exerted on it (tension force, tension thereof). the same is true for EDM instrument[1].

To be exact distances, with a band, the surveyor must calibrate it after that spans a baseline from a known distance and very accurate, and then must follow the reading on the tape markings. An EDM instrument should be checked in the same way. [1, 2]

In a measuring tape, we must take into account the temperature and voltage. If the instrument EDM, we must take into account the temperature and pressure. With a band, we will simply record the calibration temperature and voltage. These are conditions of "standardization".

With a total station, we can make natural effects of errors caused by repeated readings of the instrument to be negligible.

The EDM instrument calibration in this way, the test will result in an error and constant scale, which is really an instrument error affected by temperature and pressure.

To avoid deviations distances less than one millimeter, we

an apply the above "general rules" for temperature and pressure. Most baselines for EDM instrument has a full length of about 1000-1500 meters.

Keeping this error below 1 millimeter distance translates to an error of about 0.7 ° C and 1,778 mm of mercury. [1, 3]. The second requirement when EDM calibrate the instrument is to have a tripod, the optical, adjusted by a margin of about 1 millimeter.

The reflectors must be placed on tripods with stalling performed. A good calibration would be impossible using a prism hand (stick topography) [1, 2].

A single reflector is used to calibrate the instrument EDM, and constant reflector must be known and set in the instrument. Doing so this constant offset. Thus, the test can give better results than constant instrument. If the reflector constant is set to "0" in the tool, the test results in a "Constant" are only good to use an instrument with a special reflector[1, 4].

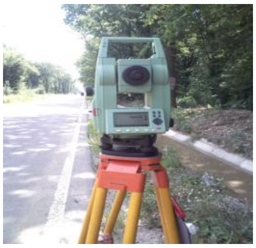

Fig. 6 Measuring distances with a total station field length of 1000 m on a outside geodetic base

Minimum a surveyor can introduce and measure many errors constant and scale of the instrument EDM error is given by the lengths of up to 1,500 meters.

A data set optimally, which produces better results, requires six measurement intervals. During this time, temperature and pressure must be monitored.

It is best to make calibration daytime, when these variables are expected to be quite stable and then to work efficiently to complete all measurements.

It is advisable to about 6 to 10 sets of measurements for each distance, using an average of the set [1, 2]. You can use either horizontal or slope distance, as long as you are consistent.

A total station automatically calculates the horizontal distance is most useful, because there is no need to measure the height of the tripod[1, 2].

For old tools do not calculate the horizontal distance automatically determining the reflector at the same height as the EDM and slope distances is inconvenient.

After data is collected, used mathematical method of linear regression, which is to determine the constants corrections and scale[1].

These numbers are used to correct further distances, the theory is the same as when using calibration error tape to correct the altitude difference of distances between the correction tape and correction EDM ladder.

The existence of the error of the scale creates a need to take in to consideration the four points of the base line measurement of six intervals in one place and linear regression calculations.

The easiest done to achieve topographic measurements is to go on the field and check intervals along a baseline. This is insufficient because it does not isolates the scale error of the constant error [1, 2].

Whether the error was small, EDM readings could check on the baseline length for short distances, but will begin to diverge in an inevitable and thus become longer distances[1].

As an example, the total station has been tested. Correction constant was 0.4 mm (negligible) and the correction scale was 21.5 ppm. A reading in the range of 1000.00 meters, should be equal to the reading observed, plus the correction, the basic equation is:

$$T=C+R \quad (1)$$

"R" is the reading observed in the EDM instrument, "C" is the sum of the two corrections.

Constant correction (after conversion units) is 0.001 meters, and scale correction is 19.35 mm, for a total correction of 19.8 mm. Thus, the nearest one-hundredth, the exact value of m is T = 1000.0233 [1].

3.4. Systematic errors

Check optic is more accurate than checking plumb, unless plumb deviation by definition point along the vertical. Optical rectification can easily become unadjusted.

They can be checked and adjusted within a millimeter or two. If the adjustment tribrach is uncertain, use the plumb may also be appropriate[1, 2].

Prism leveling bubbles are another source of error.

The topography engineers on the field should be instructed to check the adjustment rod measuring bubble frequently, using one of several simple tests.

The constants of the reflector may be in the range of a few millimeters, as given by the manufacturer.

The value can be determined by one or two millimeters by a simple field test.

Most topographic distances are measured on the ground, and are horizontal, not the slope or surveying.

Unless horizontal distance is calculated using the total station, ensure that the height of the reflector instruments and be equalized so that distances slope (slope) is correct.

When it is desired to design a flat surface distances to other geometric error exists because the earth is round, not flat.

When using plane coordinates, for example, the altitude scale factors must be carefully determined by applying the standard rules in force.

Clearly, any one of the sources may be small and often insignificant.

If enough mistakes are overlooked, the accuracy may be far from what is desired to obtain, and minimum standards of accuracy can be achieved regardless of the precision indicated by the closing lines of the base (here referred only to distances geodetic determined straight and steep (slopes) [1, 2].

4. Conclusions

This article was written in order to highlight the importance to be given if the correct use of these devices in terms of their calibration.

We presented some important aspects of the functioning of these devices that should be considered before starting the measurement process itself.

It is imperative to take into account general periodic adjustments of the surveying that must be made to specialized companies regarding their calibration.

It is also necessary to understand that we can never measure perfectly without introducing errors and especially we can not know the true value of the measurand (the object intended to be measured).

So we can say that every time we topographic equipment in measurements we introduce errors and it is important to take into account, to try to reduce them as much as possible.

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