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Optics and optical instruments — Geodetic instruments — Field procedures for determining accuracy —

Part 3:
Electro-optical distance meters (EDM instruments)

Optique et instruments d'optique — Instruments géodésiques — Méthodes de détermination sur site de la précision —

Partie 3: Télémètres électro-optiques (instruments MED)

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 12857-3 was prepared by Technical Committee ISO/TC 172, *Optics and optical instruments*, Subcommittee SC 6, *Geodetic and surveying instruments.*

ISO 12857 consists of the following parts, under the general title *Optics and optical instruments — Field procedures for determing accuracy* :

— *Part 1 : Levels*

— *Part 2 : Theodolites*

— *Part 3 : Electro-optical distance meters (EDM instruments)*

Annexes A and B of this part of ISO 12857 are for information only.

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Optics and optical instruments — Geodetic instruments — Field procedures for determining accuracy —

Part 3:
Electro-optical distance meters (EDM instruments)

1 Scope

This part of ISO 12857 specifies field procedures to be adopted when determining and assessing the accuracy of electro-optical distance meters (EDM instruments) used in surveying for distances up to approx. 2 km.

These tests are intended to be operational and not tests for acceptance or performance.

The procedures are applicable to the determination of the accuracy of different instruments at one time or of one instrument at different times.

The field procedures can be applied everywhere without the need of special ancillary equipment and are designed to minimize atmospheric influences.

NOTE — Other International Standards for testing measuring instruments for building construction are available.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 12857. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 12857 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 3534-1:1993, *Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms*

ISO 9849:1991, *Optics and optical instruments — Geodetic instruments — Vocabulary*

3 Definitions

For the purposes of this part of ISO 12857, the terms and definitions given in ISO 3534-1 and ISO 9849 apply.

4 General

The EDM instrument and its ancillary equipment shall be in known and acceptable states of adjustment by the user according to methods specified in the manufacturers' handbooks and used with reflector equipment recommended by the manufacturer.

The accuracy of EDM instruments is expressed in terms of the standard deviation of a single distance measurement taken on a given test line.

The test procedures given in this part of ISO 12857 are intended for determining the standard deviation $s_{\text{ISO-EDM}}$.

They further serve to determine the zero-point correction o.

Statistical tests should be applied to determine whether the standard deviation s obtained belongs to the population of the instrumentation's standard deviation, whether two tested samples belong to the same population or whether the zero-point correction o is zero.

5 Procedures

5.1 General

The following field procedures shall be adopted for determining the accuracy of EDM instruments, by a single survey team with a single instrument and its ancillary equipment.

The field procedures described in this part of ISO 12857 are based on distance measurements in all combinations on a test line with unknown nominal distances (see figure 1).

With these procedures scale errors of the EDM instrument cannot be detected. But scale errors have no influence on the standard deviation s_0 and on the zero-point correction o. In order to determine the stability of the scale, the measuring frequency of the EDM instrument should be checked by means of a frequency meter.

The zero-point correction obtained by these procedures is considered to be constant, i.e. it will be an average value which refers only to the range of the distances of the test line.

The results of these tests are influenced by meteorological conditions. These conditions will include different air temperatures and pressures. They shall be eliminated by the atmospheric correction of the raw distances. An overcast sky guarantees the most favourable weather conditions. Tests performed in laboratories would provide results which are almost unaffected by atmospheric influences, but the costs for such tests are very high and therefore they are not practicable for most users.

5.2 Test configuration

A straight line approx. 600 m long with seven points shall be established in a horizontal area or in an area with a constant slope. The points should be stable during the test measurements. In order to obtain representative values for the standard deviation and the zero-point correction, the points should be selected in such a way that the parts of the measured distances determined by phase measurement with the fine frequency are evenly distributed over the unit length (measuring scale) of the EDM instrument.

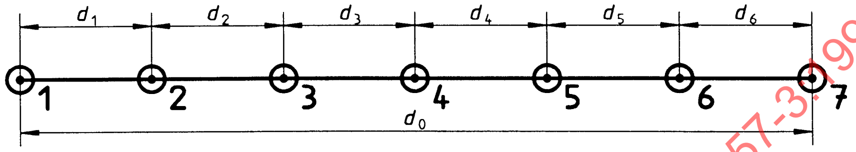

Figure 1 — Test configuration

A good configuration will be achieved if the six distances $d_1, \cdots, d_6$ between the seven points of the test line are derived by the following procedure: d_0 = 600 m is the approximate length of the projected test line, λ is the wavelength, λ/2 is the unit length (measuring scale) of the EDM instrument. From these two values

$$B_0 = \frac{d_0 - 6{,}5\lambda}{15}$$

is derived. B_0 is rounded to the nearest value

$$B = n \cdot \lambda / 2$$

where n is an integer number.

With

$$C = \frac{\lambda}{72}$$

the six distances of the test line and the whole length d are calculated:

$$\begin{aligned}
d_1 &= \lambda + B + 3C \\
d_2 &= \lambda + 3B + 7C \\
d_3 &= \lambda + 5B + 11C \\
d_4 &= \lambda + 4B + 9C \\
d_5 &= \lambda + 2B + 5C \\
d_6 &= \lambda + C \\
d &= 6\lambda + 15B + 36C
\end{aligned}$$

5.3 Observations

All possible twenty-one distances between the seven points shall be measured on the same day. Forced centring interchange should be used to eliminate centring errors. A sufficient number of prisms should ensure that all distances are measured with a good return signal. The observation of the distances should only be started when the visibility is good and a low insulation is to be expected. The air temperature and pressure should be measured frequently to insure that reliable atmospheric corrections can be derived.

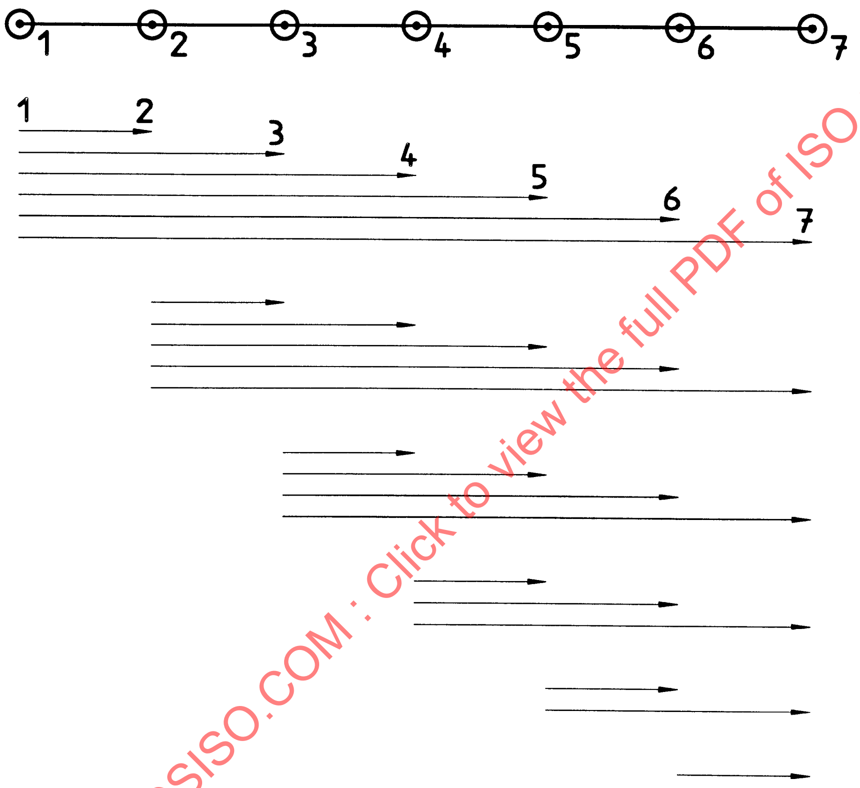

Figure 2 — Configuration of the test measurements

5.4 Calculations

The measurements (readings on the EDM instrument) $l_{i,j}$ shall be corrected for systematic effects (atmospheric correction, slope correction). These corrected values $l'_{i,j}$ shall be evaluated by an adjustment of observation equations. All weighting factors are set to 1. Parameters are six independent distances and the zero-point correction o.

The results are derived from:

$$a_i = \sum_{j=1}^{7-i} l'_{j,j+i} - \sum_{j=1}^{i} l'_{j,j+7-i} \quad ; \qquad i = 4,5,6$$

$$r_i = \frac{1}{7}\left(\sum_{j=i+1}^{7} l'_{i,j} - \sum_{j=1}^{i-1} l'_{j,i} \right) \quad ; \qquad i = 1,\ldots,7$$

The zero-point correction o results:

$$o = \frac{1}{35} \sum_{i=4}^{6} (2i-7) a_i$$

and the corrections $c_{i,j}$:

$$c_{i,j} = r_i - r_j - \frac{7+2(i-j)}{7} \cdot o - l'_{i,j} \quad ; \quad i = 1,\ldots,6; \quad j = i+1,\ldots,7$$

Twenty-one observations determine seven parameters. Therefore the degree of freedom is $f = 21-7 = 14$. After adding up the squares of the corrections, the standard deviation s_0 of any distance of the test line follows from:

$$cc = \sum_{i=1}^{6} \sum_{j=i+1}^{7} c_{i,j}^2$$

$$s_0 = \sqrt{\frac{cc}{f}} = \sqrt{\frac{cc}{14}}$$

$$s_{\text{ISO-EDM}} = s_0$$

5.5 Statistical tests

For interpretation of the results, statistical tests should be carried out using

- the standard deviation s_0 of a distance measured on the test line,
- the zero-point correction o of the EDM instrument

in order to answer the following questions (see table 1).

A) Is the calculated standard deviation s_0 smaller than the value σ_0 stated by the manufacturer or smaller than another predetermined value σ_0 ?

B) Do two standard deviations s_1 and s_2, as determined from two different samples of measurements, belong to the same population, assuming that both samples have the same degree of freedom f ?

The standard deviations s_1 and s_2 may be obtained from:

- two series of measurements by the same instrument but different observers;
- two series of measurements by the same instrument at different times;
- two series of measurements by different instruments.

C) Is the zero-point correction o equal to zero as supplied by the manufacturer or, if prisms are used with a given zero-point correction o_0, is $o = o_0$?

Table 1 — Statistical tests

Question	Null hypothesis	Alternative hypothesis
A	$s_0 \leq \sigma_0$	$s_0 > \sigma_0$
B	$\sigma_1 = \sigma_2$	$\sigma_1 \neq \sigma_2$
C	$o = o_0$	$o \neq o_0$

For the following tests a confidence level of $1 - \alpha = 0{,}95$ and according to the design of measurements a degree of freedom of $f = 14$ are assumed.

A) The null hypothesis stating that the empirically determined standard deviation s_0 is smaller than or equal to a theoretical or a predetermined value σ_0 is not rejected if the following condition is fulfilled:

$$s_0 \leq \sigma_0 \sqrt{\frac{\chi^2_{f,1-\alpha}}{f}}$$

$$s_0 \leq \sigma_0 \sqrt{\frac{\chi^2_{14;0,95}}{14}}$$

$$\chi^2_{14;0,95} = 23{,}68$$

$$s_0 \leq \sigma_0 \sqrt{\frac{23{,}68}{14}}$$

$$s_0 \leq \sigma_0 1{,}30$$

Otherwise, the null hypothesis is rejected.

B) In the case of two different samples No. 1 and No. 2, a test indicates whether the estimated standard deviations s_1 and s_2 belong to the same population. The corresponding null hypothesis $\sigma_1 = \sigma_2$ is not rejected if the following condition is fulfilled:

$$\frac{1}{F_{f,f,1-\alpha/2}} \leq \frac{s_1^2}{s_2^2} \leq F_{f,f,1-\alpha/2}$$

$$\frac{1}{F_{14;14;0,975}} \leq \frac{s_1^2}{s_2^2} < F_{14;14;0,975}$$

$$F_{14;14;0,975} = 2,98$$

$$0,34 \leq \frac{s_1^2}{s_2^2} \leq 2,98$$

Otherwise, the null hypothesis is rejected.

C) The hypothesis of equality of the zero-point corrections o and o_0 is not rejected if the following condition is fulfilled:

$$|o - o_0| \leq s_o \cdot t_{f,\, 1-a/2}$$

$$|o - o_0| \leq s_o \cdot t_{14;\, 0,975}$$

$$s_o = \frac{s_0}{\sqrt{5}}$$

$$t_{14;\, 0,975} = 2,14$$

$$|o - o_0| \leq \frac{s_0}{\sqrt{5}} \cdot 2,14$$

Otherwise the null hypothesis is rejected.

The degree of freedom and, thus, the corresponding test values $\chi^2_{f,1-\alpha}$, $F_{f_1,f_2,1-\alpha/2}$ and $t_{f,1-\alpha/2}$ (taken from reference books on statistics) change if a different number of observations is analysed.

Annex A
(informative)

Examples

A.1 Test configuration

A test line of approx. 600 m is established for an EDM instrument with a wavelength of $\lambda = 20$ m.

Auxiliary variables:

B_0 = 31,33 m
B = 30,00 m
C = 0,28 m

Distances:

d_1 = 0,84 m
d_2 = 111,96 m
d_3 = 173,08 m
d_4 = 142,52 m
d_5 = 81,40 m
d_6 = 20,28 m
d = 580,08 m

A.2 Observations

Table A.1 - Example of field observations and evaluation

i	j	$l'_{i,j}$ m	$r_i - r_j$ m	$\frac{7+2(i-j)}{7} \cdot \sigma$ mm	$c_{i,j}$ mm	$c^2_{i,j}$ mm²
1	2	50,801	50,8048	0,9	2,9	8,41
1	3	162,806	162,8088	0,6	2,2	4,84
1	4	335,904	335,9027	0,2	–1,5	2,25
1	5	478,407	478,4010	–0,2	–5,8	33,64
1	6	559,810	559,8084	–0,6	–1,0	1,00
1	7	580,098	580,1001	–0,9	3,0	9,00
2	3	112,007	112,0040	0,9	–3,9	15,21
2	4	285,096	285,0979	0,6	1,3	1,69
2	5	427,594	427,5962	0,2	2,0	4,00
2	6	509,004	509,0036	–0,2	–0,2	0,04
2	7	529,292	529,2953	–0,6	3,9	15,21
3	4	173,091	173,0939	0,9	2,0	4,00
3	5	315,592	315,5922	0,6	–0,4	0,16
3	6	396,999	396,9996	0,2	0,4	0,16
3	7	417,295	417,2913	–0,2	–3,5	12,25
4	5	142,494	142,4983	0,9	3,4	11,56
4	6	223,904	223,9057	0,6	1,1	1,21
4	7	244,200	244,1974	0,2	–2,8	7,84
5	6	81,409	81,4074	0,9	–2,5	6,25
5	7	101,697	101,6991	0,6	1,5	2,25
6	7	20,293	20,2917	0,9	–2,2	4,84
	Σ				–0,1	145,81

$l'_{i,j}$ = observed distances corrected for atmospheric correction
$c'_{i,j}$ = residuals of the observations

A.3 Results

The following values are calculated:

$$a_4 = 0{,}0090 \text{ m}$$
$$a_5 = 0{,}0070 \text{ m}$$
$$a_6 = 0{,}0030 \text{ m}$$
$$r_1 = 309{,}6894 \text{ m}$$
$$r_2 = 258{,}8846 \text{ m}$$
$$r_3 = 146{,}8806 \text{ m}$$
$$r_4 = -26{,}2133 \text{ m}$$
$$r_5 = -168{,}7116 \text{ m}$$
$$r_6 = -250{,}1190 \text{ m}$$
$$r_7 = -270{,}4107 \text{ m}$$
$$o = 1{,}29 \text{ mm}$$

The corrected measurements $l'_{i,j}$, the zero-point correction o and the values $r_{i,j}$ determine the corrections $c_{i,j}$ (see table A.1) and their square sum:

$$cc = 145{,}8 \text{ mm}^2$$

With the degree of freedom of $f = 14$, the standard deviation s_0 of a distance of the line is:

$$s_0 = \sqrt{\frac{145{,}8}{14}} \text{ mm} = 3{,}2 \text{ mm}$$

$$s_{\text{ISO-EDM}} = 3{,}2 \text{ mm}$$

A.4 Statistical tests

Example of a test according to question A:

$$\sigma_0 = 3{,}00 \text{ mm}$$
$$3{,}2 \text{ mm} \leq 3{,}00 \text{ mm} \cdot 130$$

Since the above inequality is true, the null hypothesis stating that the empirically determined standard deviation s_0 = 3,2 mm is smaller than or equal to the manufacturer's value σ_0 = 3,00 mm is not rejected.

Example of a test according to question B:

$$s_1 = 5{,}8 \text{ mm}$$
$$s_2 = 3{,}2 \text{ mm}$$
$$0{,}34 \leq \frac{33{,}6 \text{ mm}^2}{10{,}2 \text{ mm}^2} \leq 2{,}98$$
$$0{,}34 \leq 3{,}29 \leq 2{,}98$$