INTERNATIONAL STANDARD

ISO 12857-1

First edition
1997-08-15

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

Part 1:
Levels

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

Partie 1: Niveaux

Reference number
ISO 12857-1:1997(E)

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 12857-1 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 — Geodetic instruments — Field procedures for determining accuracy* :

— *Part 1: Levels*

— *Part 2: Theodolites*

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

Annex A of this part of ISO 12857 is for information only.

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Printed in Switzerland

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

Part 1:
Levels

1 Scope

This part of ISO 12857 specifies field procedures to be adopted when determining and assessing the accuracy of levels used in surveying.

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 edition indicated was 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 level and its ancillary equipment shall be in known and acceptable states of adjustment by the user according to methods specified in the manufacturers' handbooks.

The accuracy of levels is expressed in terms of the standard deviation of 1 km double-run levelling.

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

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 offsets of the levelling staffs are equal.

5 Procedures

5.1 General

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

The results of these tests are influenced by meteorological conditions. These conditions will include different air temperatures and pressures, wind speed, cloud cover and visibility. 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

Two levelling staffs shall be set up vertically approx. 50 m apart. The level shall be placed approximately halfway between the two staffs to reduce the influence of displacement of the collimation axis. To ensure reliable results, instrument and levelling staffs should be set up in stable positions. The positions for the levelling staffs should be reliably fixed during the test measurements.

The influence of refraction should be kept as small as possible. Therefore, a horizontal test area should be chosen. The ground should be compact; roads covered with asphalt or concrete should be avoided. If there is direct sunlight, the instrument shall be shaded, for example by an umbrella. See figure 1.

5.3 Observations

First readings $r_{a,1}$ and $r_{b,1}$ are taken. After that, the tripod shall be picked up and put down again in the same place but at a somewhat different height. The readings of the two staffs shall be taken again. This procedure shall be performed for a total of 20 times ($r_{a,2}$ and $r_{b,2}$, $\cdots$, $r_{a,20}$ and $r_{b,20}$).

Then the two levelling staffs shall be interchanged and the procedure shall be performed another 20 times ($r_{a,21}$ and $r_{b,21}$, ⋯, $r_{a,40}$ and $r_{b,40}$).

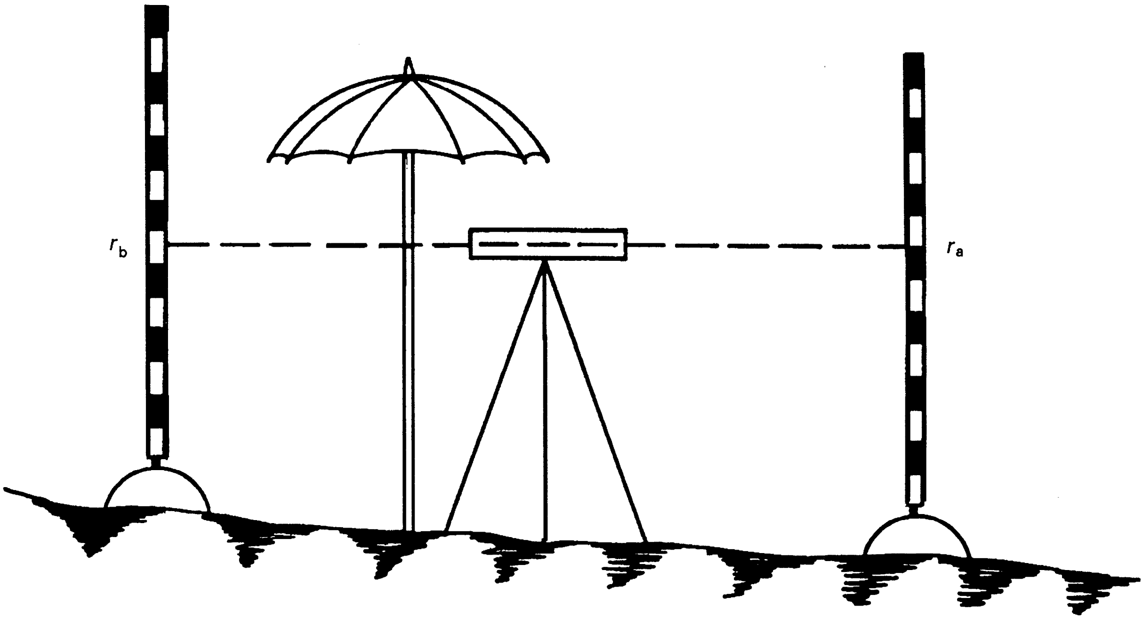

Figure 1 — Test configuration

6 Expression of results

NOTE — An example of field results and calculations is given in annex A.

6.1 Calculations

Evaluation of the measured values:

$$l_i = r_{b,i} - r_{a,i} \qquad i = 1, \cdots, 20$$
$$l_k = r_{b,k} - r_{a,k} \qquad k = 21, \cdots, 40$$

Determination of the arithmetic mean values x and y:

$$x = \frac{1}{20} \cdot \sum_{i=1}^{20} l_i$$

$$y = \frac{1}{20} \cdot \sum_{k=21}^{40} l_k$$

The difference d between x and y

$$d = x - y$$

has no influence on the standard deviation, but it is an indicator for a difference in the zero-point offsets of the two levelling staffs.

For adequate interpretation, refer to 6.2.

Calculation of the corrections c:

$$c_i = x - l_i \qquad i = 1, \cdots, 20$$
$$c_k = y - l_k \qquad k = 21, \cdots, 40$$

Checks:

$$\sum_{i=1}^{20} c_i = 0$$
$$\sum_{k=21}^{40} c_k = 0$$

Calculation of the standard deviation s valid for a distance of 50 m at a degree of freedom of $f = 38$:

$$cc = \sum_{i=1}^{20} c_i^2 + \sum_{k=21}^{40} c_k^2$$
$$s = \sqrt{\frac{cc}{f}} = \sqrt{\frac{cc}{38}}$$

Standard deviation of 1 km double-run levelling:

$$s_0 = \frac{s}{\sqrt{2}} \sqrt{\frac{1000\text{m}}{50\text{m}}} = s\sqrt{10}$$
$$s_{\text{ISO-LEV}} = s_0$$

6.2 Statistical tests

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

- the standard deviation s_0 of 1 km double-run levelling,
- the difference d produced by differences in the zero-point offsets of the levelling staffs

in order to answer the following questions.

A) Is the calculated standard deviation $s_{\text{ISO-LEV}}$ 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 difference d equal to zero or have differences in the zero-point offsets of the levelling staffs been effective?

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	$d = 0$	$d \neq 0$

For the following tests a confidence level of $1 - \alpha = 0{,}95$ and according to the design of measurements a degree of freedom of $f = 38$ 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:

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

$$s_0 \leq \sigma_0 \sqrt{\frac{\chi^2_{38;0,95}}{38}}$$

$$\chi^2_{38;0,95} = 53{,}38$$

$$s_0 \leq \sigma_0 \sqrt{\frac{53{,}38}{38}}$$

$$s_0 \leq \sigma_0 \cdot 1{,}19$$

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:

$$\frac{1}{F_{f;f;1-\alpha/2}} \le \frac{s_1^2}{s_2^2} \le F_{f;f;1-\alpha/2}$$

$$\frac{1}{F_{38;38;0,975}} \le \frac{s_1^2}{s_2^2} \le F_{38;38;0,975}$$

$$F_{38;38;0,975} = 1,91$$

$$0,52 \le \frac{s_1^2}{s_2^2} \le 1,91$$

Otherwise, the null hypothesis is rejected.

C) The hypothesis of equality of the mean values x and y (null hypothesis of d) is not rejected if the following condition is fulfilled:

$$|d| \le s_d \cdot t_{f;1-\alpha/2}$$

$$|d| \le s_d \cdot t_{38;0,975}$$

$$s_d = \frac{s_0}{10}$$

$$t_{38;0,975} = 2,02$$

$$|d| \le \frac{s_0}{10} \cdot 2,02$$

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)

Example of calculation

A.1 Observations

Table A.1 — Example of field observations and evaluation

i	$r_{a,i}$ mm	$r_{b,i}$ mm	l_i mm	c_i mm	c_i^2 mm²
1	1048	1232	184	– 0,7	0,49
2	1017	1200	183	0,3	0,09
3	1061	1245	184	– 0,7	0,49
4	1048	1231	183	0,3	0,09
5	1012	1195	183	0,3	0,09
6	1051	1235	184	– 0,7	0,49
7	1054	1238	184	– 0,7	0,49
8	1038	1221	183	0,3	0,09
9	1036	1219	183	0,3	0,09
10	1052	1235	183	0,3	0,09
11	1031	1214	183	0,3	0,09
12	1028	1212	184	– 0,7	0,49
13	1039	1222	183	0,3	0,09
14	1040	1223	183	0,3	0,09
15	1031	1213	182	1,3	1,69
16	1050	1233	183	0,3	0,09
17	1056	1239	183	0,3	0,09
18	1028	1212	184	– 0,7	0,49
19	1034	1218	184	– 0,7	0,49
20	1049	1232	183	0,3	0,09
Σ			3666	0,0	6,20
mean value		x = 183,3 mm			

k	$r_{a,k}$ mm	$r_{b,k}$ mm	l_k mm	c_k mm	c_k^2 mm²
21	1005	1188	183	0,	0,01
22	1013	1196	183	0,1	0,01
23	1035	1218	183	0,1	0,01
24	1057	1241	184	– 0,9	0,81
25	1045	1228	183	0,1	0,01
26	1027	1211	184	– 0,9	0,81
27	1009	1192	183	0,1	0,01
28	1017	1199	182	1,1	1,21
29	1030	1213	183	0,1	0,01
30	1034	1216	182	1,1	1,21
31	1043	1226	183	0,1	0,01
32	1037	1220	183	0,1	0,01
33	1025	1208	183	0,1	0,01
34	1050	1232	182	1,1	1,21
35	1039	1222	183	0,1	0,01
36	1024	1207	183	0,1	0,01
37	1030	1214	184	– 0,9	0,81
38	1041	1225	184	– 0,9	0,81
39	1012	1196	184	– 0,9	0,81
40	1019	1202	183	0,1	0,01
Σ			3662	0,0	7,80
mean value		y = 183,1 mm			

A.2 Results

$$d = 0{,}2\,\text{mm}$$

$$cc = 14{,}00\,\text{mm}^2$$

$$s = \sqrt{\frac{14{,}00\,\text{mm}^2}{38}} = 0{,}61\,\text{mm}$$

$$s_0 = 0{,}61\,\text{mm} \cdot \sqrt{10} = 1{,}93\,\text{mm}$$