INTERNATIONAL STANDARD

ISO 8322-3

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Building construction — Measuring instruments — Procedures for determining accuracy in use —

Part 3: Optical levelling instruments

Construction immobilière — Instruments de mesure — Procédures de détermination de l'exactitude d'utilisation —

Partie 3: Instruments optiques de nivellement

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8322-3 was prepared by Technical Committee ISO/TC 59, *Building construction.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Building construction — Measuring instruments — Procedures for determining accuracy in use —

Part 3: Optical levelling instruments

0 Introduction

This International Standard consists of a series of parts specifying test procedures to be adopted when determining and assessing the accuracy in use of measuring instruments in building construction. The first part gives the theory; subsequent parts give the procedures for determining the accuracy in use of measuring instruments for measurements. The complete series will consist of the following parts:

- Part 1: Theory.
- Part 2: Measuring tapes.
- Part 3: Optical levelling instruments.
- Part 4: Theodolites.
- Part 5: Optical plumbing instruments.
- Part 6: Laser instruments.
- Part 7: Instruments when used for setting out.
- Part 8: Electronic distance-measuring instruments.

Other International Standards for testing measuring instruments for land surveying purposes, and for measuring procedures in ordnance survey, are in preparation.

1 Scope

This part of ISO 8322 specifies test procedures to be adopted when determining and assessing the accuracy in use of optical levelling instruments for measurement purposes.

2 Field of application

The procedures given in this part of ISO 8322 apply when these optical levelling instruments are used in building construction for surveying, check and compliance measurements, and also when obtaining accuracy data.

3 References

ISO 3534, *Statistics — Vocabulary and symbols.*

ISO 4463-1, *Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization, measuring procedures, acceptance criteria.*

ISO 7077, *Measuring methods for building — General principles and procedures for the verification of dimensional compliance.*

ISO 7078, *Building construction — Procedures for setting out, measurement and surveying — Vocabulary and guidance notes.*

ISO 8322-1, *Building construction — Measuring instruments — Procedures for determining accuracy in use — Part 1: Theory.*

4 General

4.1 Before commencing surveying, check and compliance measurements, when obtaining accuracy data or setting out, it is important that the operator investigates that the accuracy in use of the measuring equipment is appropriate to the intended measuring task. This International Standard recommends that the operator carries out test measurements under field conditions to establish the accuracy achieved when he uses a particular measuring instrument and its ancillary equipment.

To ensure that the assessment takes account of various environmental influences, two series of measurements need to be carried out under different conditions. The particular conditions to be taken into account may vary depending on where the tasks are to be undertaken. These conditions will include variations in air temperature, wind speed, cloud cover and visibility. Note should also be made of the actual weather conditions at the time of measurement and the type of surface over which the measurements are made. The sets of conditions chosen for the tests should match those expected when the intended measuring task is actually carried out. See ISO 7077 and ISO 7078.

The procedures are designed so that the systematic errors are largely eliminated and assume that the particular instruments are in known and acceptable states of user adjustment according to methods detailed in the manufacturer's handbooks.

Accuracy in use procedures require tests to be made with the same instrumentation and the same observer, within a short interval of time. These are "repeatability conditions" as defined in ISO 3534.

The accuracy in use is expressed in terms of the standard deviation.

4.2 Figure 1 indicates schematically the decisions to be made when establishing that the accuracy associated with a given surveying method and particular measuring equipment is appropriate to the intended measuring task. In particular, the decisions apply when adopted by a particular operator under a range of environmental conditions which are likely to occur when the task is actually carried out. Where the contract documentation specifies the required tolerance for the intended measuring task, it is recommended that this tolerance, which is normally given in terms of the permitted deviation $\pm P$ ($P = 2,5\,\sigma$) of the measuring task, is compared with the accuracy in use data obtained either from previous accuracy in use tests or from general data A which indicate the expected accuracy in use of given measuring equipment. On those occasions that the previously obtained data indicates that the accuracy in use associated with the given measuring equipment exceeds the specified permitted deviation of the measuring task, consideration should be given to either selecting a different method and/or a more precise instrument, or discussing with the designer the need for such a small permitted deviation. See ISO 4463-1.

Before obtaining an overall estimate of the accuracy in use, it is recommended that each standard deviation for a given series of measurements undertaken under particular environmental conditions is compared, as indicated in figure 1, with the specified permitted deviation. Where the comparison shows that the specified permitted deviation has not been achieved for one series of measurements, an additional series of measurements should be carried out under as near as possible similar environmental conditions to those which applied in that original series of measurements.

Assumptions: $\pm P$ is the permitted deviation of the measuring task

A is the accuracy in use, generally expressed as deviation $\pm A$; (both $\pm P$ and $\pm A$ are considered to include the dimensional variability associated with $\pm$ 2,5 times the standard deviation σ)

s are the deviations obtained in the field tests

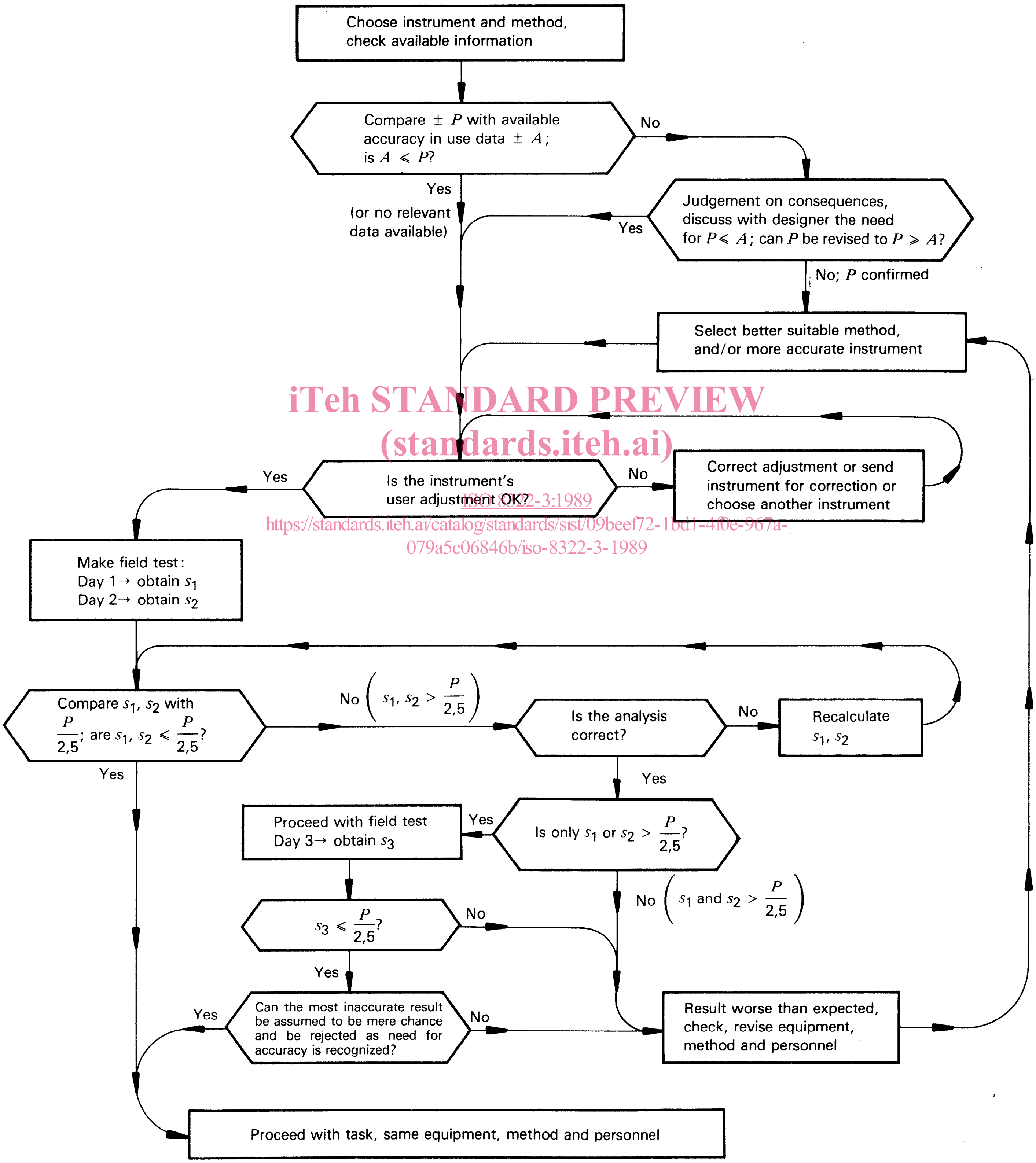

Figure 1 — Flow diagram for accuracy in use tests

5 Procedures for optical levelling instruments

5.1 General

The normal practice is for measuring accuracy to be referred to 1 km of double levelling. However, the operating distance in building construction will not normally exceed 40 m. Therefore this part of ISO 8322 recommends that the accuracy in use is presented in terms of a standard deviation for a distance of 1 km (method 1) or for a distance of 40 m (method 2). Each presentation should be in terms of double levelling. The operator shall choose the method most relevant to this requirement.

The following test procedures should be adopted for determining the accuracy in use by a particular survey team with a particular instrument and its ancillary equipment.

5.2 Method 1

5.2.1 Observation procedure (see table 1)

5.2.1.1 Establish two levelling points approximately 250 m apart. The points shall be reliably defined for the duration of the test measurements.

5.2.1.2 Each of the two series of measurements on separate days shall consist of five double levellings: the forward and reverse levelling are considered to be measurements independent of each other. When establishing the accuracy in use for very accurate levels (sometimes incorrectly called "precision levels": see ISO 7078 regarding the difference between "accuracy" and "precision"), sighting distance should be approximately 20 m; otherwise the sighting distance should be about 40 m. All measurements should be taken to the nearest millimetre or to the nearest 0,1 mm when using a level fitted with a parallel plate micrometer.

5.2.1.3 The ancillary equipment used and the environmental conditions shall be similar to those expected in the intended actual measurement.

5.2.1.4 Record the environmental conditions. Changes of environmental conditions during the construction period may render the test result inapplicable. In such a case the test should be repeated under the new conditions.

5.2.2 Calculation procedure (see table 1)

A complete example of the analysis is given in table 1 (columns 3, 4 and 5) for an engineer's level and it is recommended that this form of presentation be generally adopted. All calculations are in terms of the value of the differences of level between the two stabilized level points.

5.2.2.1 Calculate the arithmetic mean $\bar{x}$ (column 3).

For example: 318,5

5.2.2.2 Calculate the deviations v of each value from arithmetic mean (column 4).

For example: level 2 reverse: − 1,5 mm

To minimize the effect of rounding errors, the calculation of each deviation v should be carried out to the nearest 0,1 mm if the values are in millimetres and to the nearest 0,01 mm if the values are in 0,1 mm.

As an arithmetic check the sum of the ten deviations should be zero.

5.2.2.3 Calculate the squares v^2 of all values in column 4 and the sum of the squares.

For example: level 2 reverse: 2,25 mm²
the sum of the squares: 94,50 mm²

5.2.2.4 Calculate the standard deviation s_1 of a difference in level for a line of 250 m length on the first day as the square root of the sum of squares divided by 9 (= number of redundant observations).

For example: $s_1 = \sqrt{\frac{94,50}{9}} = \sqrt{10,5} = 3,2$ mm

5.2.2.5 Calculate the standard deviation $s_{1(\mathrm{km})}$ of a difference in level for a line of 1 km as the standard deviation of the line of 250 m length multiplied by the square root of 4.

For example: $s_{1(\mathrm{km})} = 3,2\sqrt{4} = 6,4$ mm

5.2.2.6 Calculate the standard deviation of a difference in double levelling for a line of 1 km as the standard deviation of a 1 km levelling line divided by the square root of 2.

For example: $s_{1(\mathrm{km\ double\ level})} = \frac{6,4}{\sqrt{2}} = 4,5$ mm

5.2.2.7 Repeat procedures 5.2.1.2 to 5.2.2.6 on a second day to obtain s_2.

5.2.2.8 The overall standard deviation to be expected of any 1 km double levelling is

$$s_{(\mathrm{km\ double\ level})} = \sqrt{\frac{s^2_{1(\mathrm{km\ d.l.})} + s^2_{2(\mathrm{km\ d.l.})}}{2}}$$

For example $s_{(\mathrm{km\ double\ level})} = 6$ mm

Table 1a) — Field observations and calculations: example

Date: ....
Location: ....
Observer: ....
Instrument: Engineer's level
Conditions: Warm, sunny, light wind
Series: I

Measurement		Difference in level mm	Mean mm	v mm	v^2 mm^2
1		2	3	4	5
1	Forward	320		+ 1,5	2,25
	Reverse	315		− 3,5	12,25
2	Forward	324		+ 5,5	30,25
	Reverse	317		− 1,5	2,25
3	Forward	319		+ 0,5	0,25
	Reverse	319		+ 0,5	0,25
4	Forward	314		− 4,5	20,25
	Reverse	316		− 2,5	6,25
5	Forward	323		+ 4,5	20,25
	Reverse	318		− 0,5	0,25
			318,5	$\sum v = 0,0$	$\sum v^2 = 94,50$

$$s_1 = \sqrt{\frac{94,50}{9}} = 3,2 \text{ mm}$$

$$s_{1(\text{km})} = 2,0 \times 3,2 = 6,4 \text{ mm}$$

$$s_{1(\text{km double level})} = \frac{6,4}{\sqrt{2}} = 4,5 \text{ mm}$$

$$s_{2(\text{km double level})} = 7,8 \text{ mm}$$

$$s = \sqrt{\frac{4,5^2 + 7,8^2}{2}} = 6,4 \text{ mm}$$

$$s = 6 \text{ mm}$$

Table 1b) — Field observations and calculations: data sheet

Date: ....
Location: ....
Observer: ....
Instrument: ....
Conditions: ....
Series: ....

Measurement	Difference in level mm	Mean mm	v mm	v^2 mm^2
1	2	3	4	5
1 Forward Reverse				
2 Forward Reverse				
3 Forward Reverse				
4 Forward Reverse				
5 Forward Reverse				
			$\sum v =$	$\sum v^2 =$

$s_1 = \sqrt{\frac{\quad}{9}} = \quad$ mm

$s_{1(\text{km})} = \quad \times \quad = \quad$ mm

$s_{1(\text{km double level})} = \frac{\quad}{\sqrt{2}} = \quad$ mm

$s_{2(\text{km double level})} = \quad$ mm

$s = \sqrt{\frac{\quad + \quad}{2}} = \quad$ mm

$s = \quad$ mm

5.3 Method 2

5.3.1 Observation procedure (see table 2)

If the required levelling task only involves distances up to 40 m or the transferring of a level to a different floor, for example a flight of steps, the following procedure shall be taken.

5.3.1.1 Establish at least four levelling points [figure 2a)]. The distances between the points and the distances between the levelling instrument and the points (sight-distances) shall be approximately the same as those expected on a particular construction site. In general, they are not equal. Five of the possible differences in height (level) are to be measured, for example at first the difference between B and C and so on. Other configurations of five differences in height are acceptable [for example figure 2b)]. The points shall be in stable locations for the duration of the test measurements. In the case of a rombus-shaped or triangle-shaped test field [figure 2a)], the resulting loop conditions will not be considered.

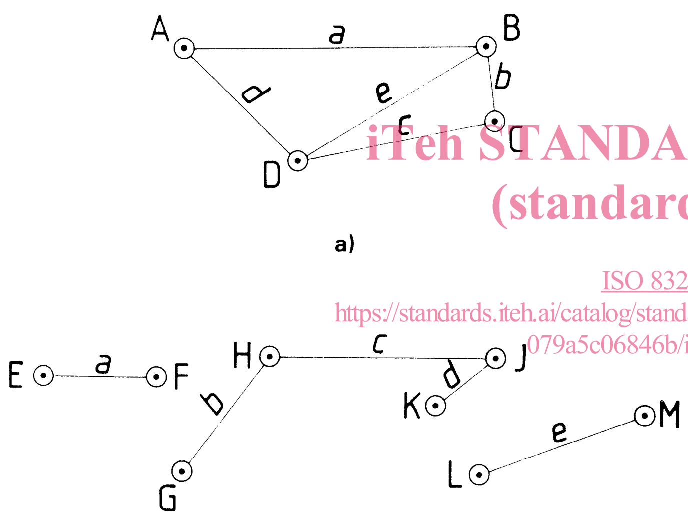

Figure 2 — Selection of levelling points

5.3.1.2 Each of the two series of measurements on separate days shall consist of five double measurements of the differences in height (level). This has to be organized in such a way that after the first determination of the difference in height, the level has to be disturbed and reset. All measurements should be taken to the nearest millimetre.

5.3.1.3 The ancillary equipment used and the environmental conditions shall be similar to those expected in the intended actual measurement.

5.3.1.4 Record the environmental conditions. Changes of environmental conditions during the construction period may render the test result inapplicable. In such a case the test should be repeated under the new conditions.

5.3.2 Calculation procedure (see table 2)

A complete example of the analysis is given in table 2, columns 8, 11, 12, 13, for an engineer's level using the measurements given in columns 6, 7, 9, 10, and it is recommended that this form of presentation be generally adopted.

5.3.2.1 Calculate the differences between reading reverse and reading forward (column 6 minus column 7 and column 9 minus column 10).

For example: Measurement 2: − 2080 and + 2077

5.3.2.2 Calculate the absolute difference d between column 8 and column 11.

For example: Measurement 2: $d = 3$

5.3.2.3 Calculate the square of d and the sum of the squares.

For example: Measurement 2: $d^2 = 9$
Sum of squares: 143

5.3.2.4 Calculate the standard deviation of a once-measured difference in height as the square root of the sum of the squares divided by 10 (number of measurements multiplied by 2).

For example: $s_1 = \sqrt{\dfrac{143}{10}} = \sqrt{14,3} = 3,8$ mm

5.3.2.5 Calculate the standard deviation of a double-levelled difference in height on the first day as the standard deviation of a once-measured difference in height divided by $\sqrt{2}$.

For example $s_{1\ \text{double}} = \dfrac{3,8}{\sqrt{2}} = 2,7$ mm

5.3.2.6 Repeat procedures 5.3.1.2 to 5.3.2.5 on a second day to obtain $s_{2\ \text{double}}$.

5.3.2.7 The overall standard deviation of a double-levelled difference in height is

$$s_{\text{double}} = \sqrt{\frac{s_{1\text{double}}^2 + s_{2\text{double}}^2}{2}}$$

For example: $s_{\text{double}} = 3$ mm