INTERNATIONAL STANDARD

ISO 8322-5

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

Part 5: Optical plumbing instruments

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

Partie 5: Instruments de plombage optique

Reference number
ISO 8322-5:1991(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 8322-5 was prepared by Technical Committee ISO/TC 59, *Building construction*, Sub-Committee SC 4, *Limits and fits in building construction*.

ISO 8322 consists of the following parts, under the general title *Building construction — Measuring instruments — Procedures for determining accuracy in use*:

— *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 up to 150 m*

— *Part 9: Electronic distance-measuring instruments up to 500 m*

— *Part 10: Testing short-range reflectors*

International Organization for Standardization
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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.

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

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

Part 5:
Optical plumbing instruments

1 Scope

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

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8322. 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 8322 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3534:1977, *Statistics — Vocabulary and symbols.*

ISO 4463-1:1989, *Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization, measuring procedures, acceptance criteria.*

ISO 7077:1981, *Measuring methods for building — General principles and procedures for the verification of dimensional compliance.*

ISO 7078:1985, *Building construction — Procedures for setting out, measurement and surveying — Vocabulary and guidance notes.*

3 General

3.1 Before commencing surveying, check and compliance measurements, when obtaining accuracy data or setting out, it is important that the operator investigate whether the accuracy in use of the measuring equipment is appropriate to the intended measuring task. This International Standard recommends that the operator carry 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 manufacturers' handbooks.

Assumptions: 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 standard deviations obtained in field tests

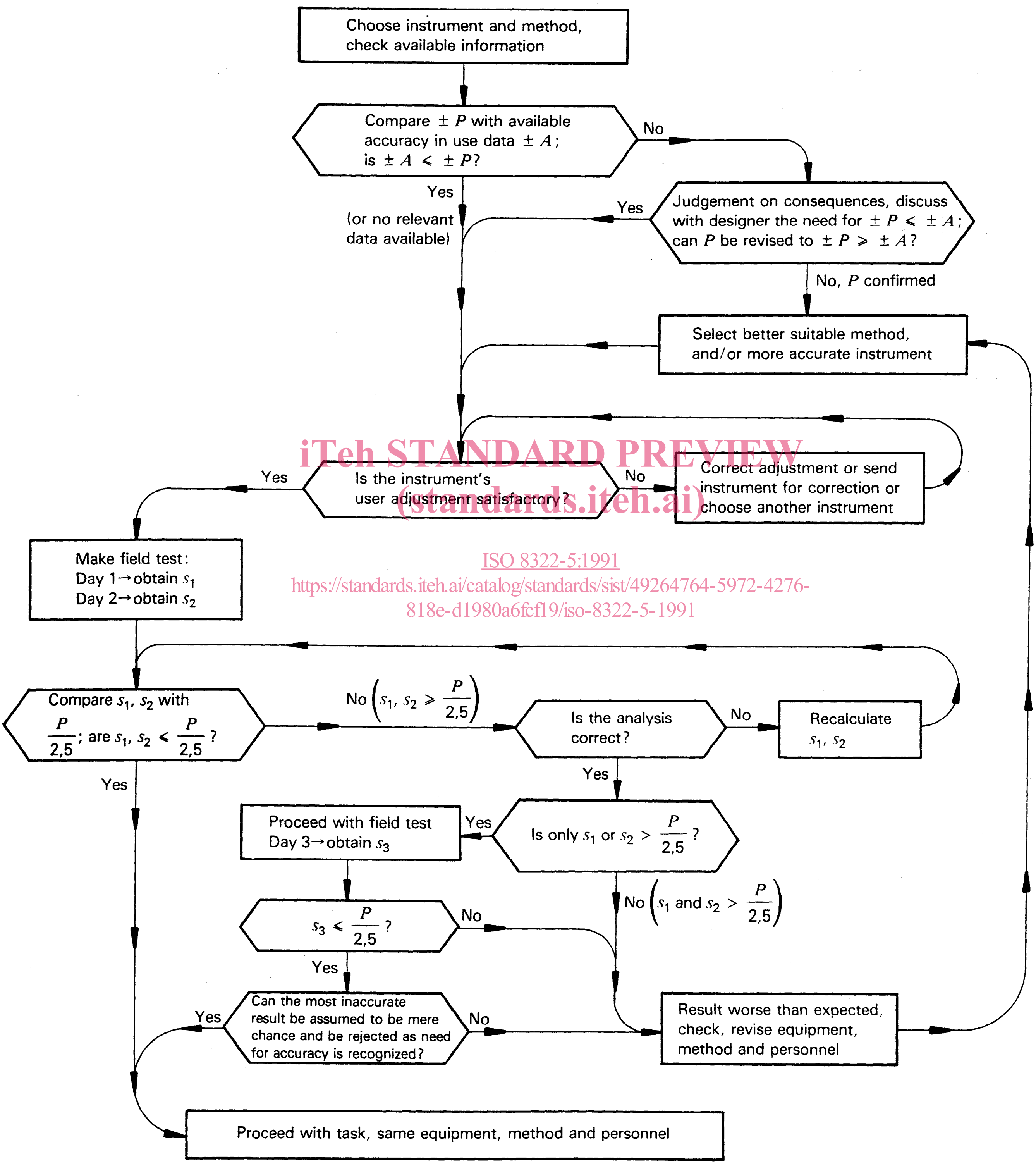

Figure 1 — Flow diagram for accuracy-in-use tests

Accuracy-in-use procedures require repeat 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.

3.2 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 P ($P = 2{,}5\ \sigma$) of the measuring task, be 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 indicate that the accuracy in use associated with the given measuring equipment does not meet 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 be compared, as indicated in figure 1, to 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 environmental conditions as near as possible similar to those which applied in that original series of measurements.

4 Procedures for optical plumbing instruments (optical plummets)

4.1 General

The accuracy of any type of plumbing instrument is dependent on the vertical distance over which the plumbing operation is carried out. Thus the achievable accuracy in use is commonly expressed as a relative lateral deviation defined as the ratio of the accuracy achieved against the difference in height.

4.2 Types of optical plumbing instruments

There are three types of optical plumbing instruments.

a) Instruments with a spirit-level. A cross levelling is recommended before each observation so that the line of sight is coincident with the plumb line.

b) Instruments with one compensator. The compensator ensures that the line of sight is in a vertical plane such that the plumb line is the intersection of two vertical planes perpendicular to each other.

c) Instruments with two compensators. The compensators work in two planes perpendicular to each other such that the plumb line is coincident with the line of sight.

Each of the three types of instruments can have either a simple telescope sight or one incorporating a laser.

Optical plumbing instruments (optical plummets) are able to sight either upwards or downwards or both. The procedure is the same in all cases.

4.3 Test methods for accuracy

4.3.1 General

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

Two alternative methods are proposed. The first is simpler to carry out (method 1); the second is more sophisticated, needs better ancillary equipment and more calculation (method 2). The ancillary equipment for method 1 is the cheaper, but method 2 gives an improved estimation of the accuracy in use.

To minimize the effects of systematic errors, it is recommended that each measurement with an optical plumbing instrument consist of two observations carried out by observing with the telescope in diametrically opposed positions.

4.3.2 Method 1

The measurement results should be given in a table (see table 1-B). An example of a completed table is given in table 1-A.

4.3.2.1 Observations

a) Design a target in such a way that marks can be made on the horizontal surface and their location read with reference to a transparent rectangular x, y grid overlay graduated in millimetres. The horizontal surface shall be formed of a material which will accept pencil and can be easily wiped clean. This will ensure that successive pencil marks are not biased in any way by previous marks. Fix the transparent overlay so that it always returns to the same position.

Establish such a target at a height comparable with that of the intended task and locate it approximately vertically above/below the mark over/under which the instrument is centred.

The orientation of the cross-hairs of the telescope shall be parallel to the axes of the target during every observation.

b) Table 1-A is an example using an optical plumbing instrument with one compensator.

Each measurement for x (or y) shall consist of two observations carried out by observing with the telescope in diametrically opposed positions. (See columns 3 and 5.)

If an instrument with a spirit-level or with two compensators is used, each position of the telescope provides values of x and y simultaneously. Thus two opposing positions of the telescope suffice.

c) Record the environmental conditions. Changes in environmental conditions during the construction period may render the test result inapplicable. In such a case repeat the test under the new conditions.

4.3.2.2 Calculation procedure

A complete example of the analysis is given in table 1-A, columns 4, 6, 7, 8, 9 and 10, for an optical plumbing instrument with one compensator using the measurements given in columns 3 and 5 and it is recommended that this form of presentation be generally adopted.

a) Calculate in column 4 the mean
$x = (x'_1 + x'_2)/2$
and in column 6 the mean
$y = (y'_1 + y'_2)/2$

EXAMPLE

Set 1: x = 20,00 mm y = 15,25 mm

b) Calculate the means $\bar{x}$ and $\bar{y}$ from $x_1, x_2 \ldots x_{10}$ and $y_1, y_2 \ldots y_{10}$.

EXAMPLE

$\bar{x}$ = 19,20 mm $\bar{y}$ = 15,02 mm

c) Calculate the deviations $v_x = (x - \bar{x})$ and $v_y = (y - \bar{y})$ in columns 7 and 9 from the arithmetic means.

To minimize the effect of rounding errors, the calculation of each deviation v should be carried out to the nearest 0,01 mm. As an arithmetic check, the sum of the 10 deviations in the x and y directions should be approximately zero.

EXAMPLE

Set 1: v_{x_1} = 0,80 mm v_{y_1} = 0,23 mm

d) Calculate the squares of the deviations v_x^2 and v_y^2 in columns 8 and 10.

EXAMPLE

Set 1: $v_{x_1}^2$ = 0,64 mm² $v_{y_1}^2$ = 0,05 mm²

e) Calculate the standard deviations for the first day as the square roots of the sums of squares divided by 9 (= number of redundant observations).

EXAMPLE

$$s_{x_1} = \sqrt{\frac{3,72}{9}} = 0,64 \text{ mm}$$

$$s_{y_1} = \sqrt{\frac{1,54}{9}} = 0,41 \text{ mm}$$

f) Repeat the calculation procedure using the second day's observations to produce s_{x_2} and s_{y_2}, the standard deviations for the second day.

EXAMPLE

s_{x_2} = 0,40 mm

s_{y_2} = 0,70 mm

g) The estimated overall standard deviations in the x and y directions for any single measurement of the plumbing line are:

$$s_x = \sqrt{\frac{s_{x_1}^2 + s_{x_2}^2}{2}}$$

$$s_y = \sqrt{\frac{s_{y_1}^2 + s_{y_2}^2}{2}}$$

EXAMPLE

s_x = 0,5 mm s_y = 0,6 mm

h) Calculate the radial estimated overall standard deviation of a plumbing measurement according to:

$$s = \sqrt{s_x^2 + s_y^2}$$

EXAMPLE

$s \approx 0,8$ mm

i) Calculate the relative deviation.

EXAMPLE

For $h = 20,9$ m: $s \approx 1:26\,000$

4.3.3 Method 2

The measurement results should be given in a table (see table 2-B). An example of a completed table is given in table 2-A.

4.3.3.1 Observations

a) Establish as target a target scale, graduated plate or checker-board. The spacing of the graduation marks, t, on the target should be such that the field width appears in the telescope as an angle not greater than 10′.

The value of t is obtained in millimetres:

$$t \leqslant \frac{h_m}{\Gamma} \times 2,9$$

where

h_m is the plumbing height, in metres;

Γ is the telescope magnifying power.

Express t to the nearest centimetre.

Fix the target at a height comparable with that of the intended task and locate it approximately vertically above/below the mark over/under which the instrument is centred.

In order to obtain measurements independent of each other, the target shall be mounted on a support and be moved by random amounts between the successive measurements. The amount of the possible support displacement shall be at least as large as the scale unit of the target. The support position is read at a micrometer-gauge screw, a micrometer watch or an equivalent apparatus with a precision such that the value of the support position can be included in the calculation as correct.

The orientation of the cross-hairs of the telescope shall be parallel to the axes of the target.

b) Each of the two series of measurements on separate days shall consist of 10 separate sets of measurements. Each measurement shall consist of four observations, carried out by observing with the telescope in the positions 0° (0 gon), 90° (100 gon), 180° (200 gon) and 270° (300 gon) (see table 2-B).

Table 2-B is an example for an optical plumbing instrument with a spirit-level. The readings shall be made in the four positions. Using an instrument with one compensator requires the sequence given in 4.3.2.1 b).

c) Record the environmental conditions. Changes in environmental conditions during the construction period may render the test result inapplicable. In such a case repeat the test under the new conditions.

4.3.3.2 Calculation procedure

A complete example of the analysis is given in table 2-A, columns 4, 6, 9, 10, 11, 12, 13 and 14, for an optical plumbing instrument with a spirit-level and a checker-board using the measurements given in columns 3, 5, 7 and 8. It is recommended that this form of presentation be generally adopted.

a) Calculate in column 4 the value
$x = (x'_1 + x'_2 + x'_3 + x'_4)/4$
and in column 6 the value
$y = (y'_1 + y'_2 + y'_3 + y'_4)/4$ of each test.

EXAMPLE

Set 1: $x = 367,0$ mm $\quad y = 720,5$ mm

b) Add to the value in column 4 the value b_x of the support in column 7, and to the value in column 6 the value b_y of the support in column 8 (columns 9 and 10).

EXAMPLE

Set 1: 369,15 mm and 725,84 mm

c) Calculate the means $\bar{x}$ and $\bar{y}$ of columns 9 and 10.

EXAMPLE

$\bar{x} = 369,95$ mm $\quad \bar{y} = 725,26$ mm

d) Calculate the deviations $v_x = [(x + b_x) - \bar{x}]$; $v_y = [(y + b_y) - \bar{y}]$ in columns 11 and 13.

To minimize the effect of rounding errors, the calculation of each deviation v should be carried out to the nearest 0,01 mm. As an arithmetic check the sum of each of the 10 deviations in x and y should be approximately zero.

EXAMPLE

Set 1: $v_x = -0,80$ mm $\quad v_y = -0,58$ mm

e) Calculate the squares of the deviations v_x^2 and v_y^2 (columns 12, 14).