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ISO 8322-8

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

Part 8:
Electronic distance-measuring instruments up to 150 m

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

Partie 8: Appareils de mesure de distances à train d'ondes jusqu'à 150 m

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Contents

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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 8322-8 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*

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

Annexes A and B of this part of ISO 8322 are for information only.

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

Part 8:
Electronic distance-measuring instruments up to 150 m

1 Scope

This part of ISO 8322 specifies test procedures to be adopted when determining and assessing the accuracy in use of electronic distance-measuring (EDM) equipment on building construction, for distances up to 150 m.

The procedure applies to those types of EDM instruments used for surveying, control and compliance measurements and also when collecting accuracy data.

Annex A gives examples of the determination of systematic errors. Annex B gives the unit lengths of various EDM instruments.

2 Normative reference

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

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

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 that 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 EDM instrument with a particular prism or combination of prisms.

The procedures assume that the particular EDM instrument and its ancillary equipment are in known and acceptable state of permanent adjustment according to methods detailed in the manufacturers' manuals.

The accuracy in use is expressed in terms of the root mean square errors.

The testing method described in this part of ISO 8322 is carried out on a building site using calibrated steel tapes. The same method can also be applied on baselines, provided that the required distances are available or can be established.

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. 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, 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 the rejection of a particular EDM equipment for a required measuring task, a second series of measurements should be carried out in accordance with clause 7, as indicated in figure 1. If the second result is similar to the first one, the equipment in question should not be used for the required task, unless further investigations in accordance with annex A can identify the main sources of systematic errors inherent in the instrument, and their values.

4 Accuracy specification of EDM instruments

The accuracy of an EDM instrument together with its associated prism is often specified by the manufacturers as the sum (in millimetres) of a constant component a and a distance-related component b:

$$\hat{s} = \pm (a + b \text{ ppm}) \qquad \ldots (1)$$

where $\hat{s}$ is the root mean square error.

EXAMPLE

A manufacturer might specify the accuracy of an instrument by

$$\hat{s} = \pm (3 + 5 \text{ ppm}) \qquad \ldots (2)$$

or

$$\hat{s} = \pm \left(3 + \frac{5}{10^6} \times d\right) \qquad \ldots (3)$$

where d is the measured distance, in millimetres.

NOTE 1 The use of parts per million (ppm) has been retained in this International Standard as this is the term which appears on most instruments and in most instruction manuals.

If the manufacturer has not specified the accuracy in the above form he should be requested to do so.

Since in common construction work distances are usually short, i.e. shorter than 150 m, the factor b in the right-hand term of formula (1) is neglected in this part of ISO 8322. For longer distances it should be taken into account (see annex A).

The term a includes:

- the so-called zero error, caused by a lack of coincidence between the mechanical and electro-optical centres of the instrument;
- the cyclic error, a systematic error occurring as a periodic function of the unit length, in general caused by electronic or optical disturbance when transmitted measuring signals are received.

It is essential before the first use of the instrument selected, and periodically thereafter, to verify that the instrument is performing within the manufacturer's specification. The test procedures given in clause 7 are designed to do this with a minimum of additional work.

5 Sources of error

The accuracy in use of an EDM instrument is affected by factors other than the inherent ones of zero, scale and cyclic error. Some of these factors are

- centring errors;
- incorrect pointing;
- insufficient voltage;
- unsuitable signal strength[1)];
- neglect of instructions given in the manufacturer's manual;
- error in meteorological data;
- incorrect setting of the meteorological switch;
- changes in the modulation frequency of the unit length;
- other unforeseen factors on site.

Many errors can be reduced by following the correct surveying or maintenance procedures. Other errors are caused by ageing of certain components in the instrument. It is therefore very important to check the instrument frequently.

1) This can be either too low because of, for example, condensation or fog, or too high because of incorrect automatic reduction of the external signal.

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)

$\hat{s}$ are the root mean square errors obtained in the field tests

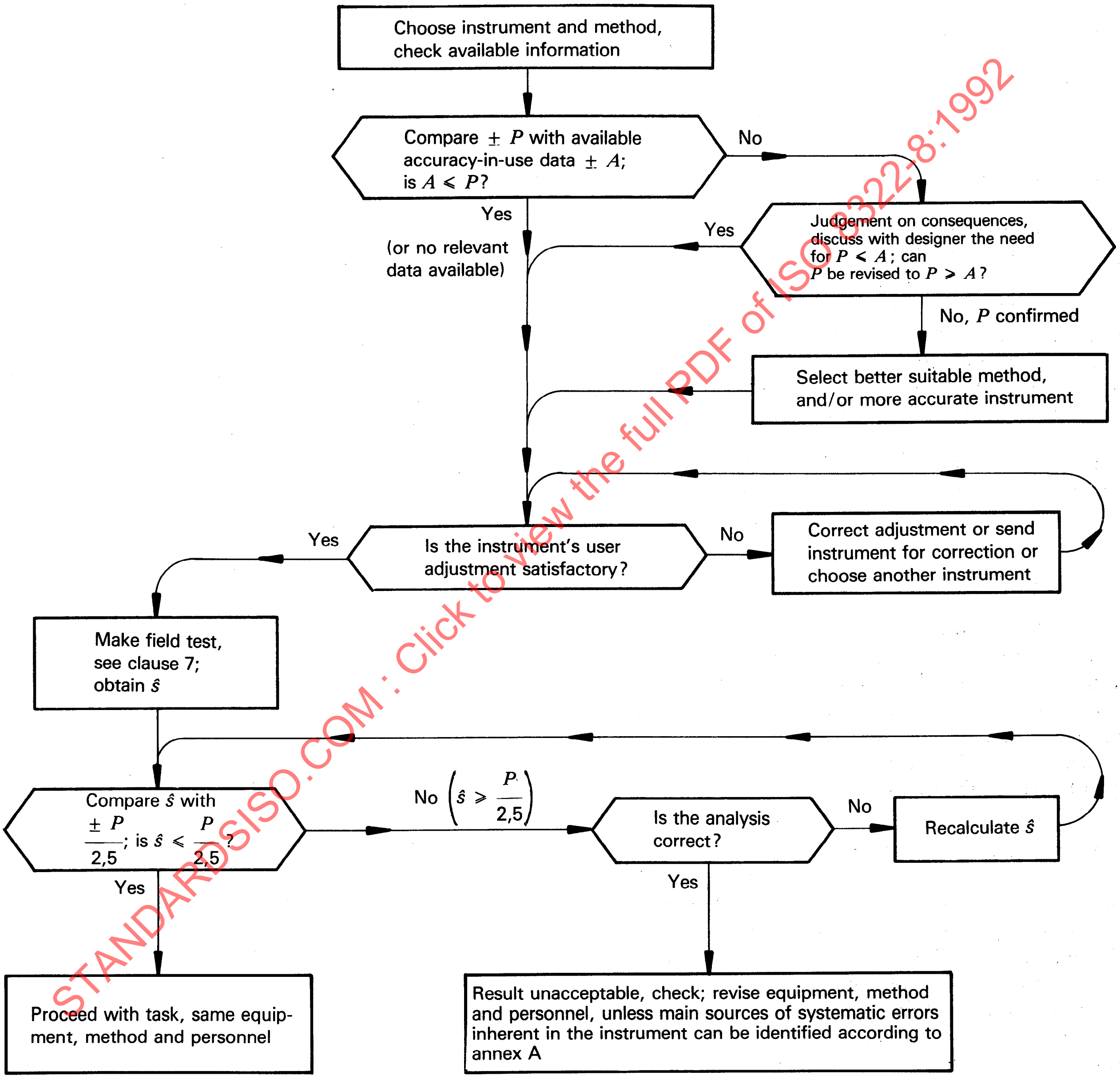

Figure 1 — Flow diagram for accuracy-in-use tests

6 State of adjustment

Before any EDM instrument is used, the requirements given in 6.1 to 6.6 should be observed.

6.1 Instruction manual

Read the instruction manual issued by the manufacturer for the particular EDM instrument.

6.2 Initial warm-up

The warming-up of the instrument shall be carried out in accordance with the instruction manual.

6.3 Frequency

A change in the modulation frequency of the unit length is a cause of change of the scale factor. Frequencies should be verified using a calibrated frequency meter in accordance with national standards prior to delivery and checked from time to time thereafter and before carrying out any field calibration procedure. The accuracy of the frequency meter should be 1×10^{-6} or better.

The determination of the scale factor using long baselines involves the risk that the results will be influenced by undetected meteorological factors.

6.4 Slope reduction

Many EDM instruments can reduce the observed slope distance to the horizontal distance without any manual calculation. The accuracy of this feature can be checked by calculating the horizontal distance using the displayed slope distance and a relevant measured vertical angle. The vertical angle should be greater than 15° (≈15 gon).

6.5 Correction for non-coaxial instruments

A vertical separation between the line of collimation of the telescope of the theodolite and that of the EDM instrument affects the reduction of a short slope distance to a horizontal one. The influence depends on the magnitude of the vertical angle and the vertical separation and should be calculated from the values for a specific set of equipment.

6.6 Meteorological corrections

Most EDM instruments have a direct input facility for meteorological data. The accuracy of this feature can be checked by measuring in the following way:

Measure a distance D (preferably about 150 m) with a random value d of the input facility. Immediately after, measure the same distance with the value $1{,}000\,006d$. Repeat the sequence with value d and value $1{,}000\,006d$ three times. The means of the sets value d and value $1{,}000\,006d$ must differ by $0{,}000\,006d$ (i.e. 9 mm for 150 m).

7 Test procedure for the accuracy in use of EDM instruments

The following test procedure shall be adopted for determining the accuracy in use for a particular instrument and its ancillary equipment [especially the prism (reflector) or combination of prisms (reflectors)] to be used before starting work. Changing prisms can introduce additional errors. When setting up EDM equipment for different series of observations, special care shall be taken when centring both the instrument and the prism over the station. Easily achievable accuracies of centring expressed in terms of standard deviation are as follows.

Optical plummet:	0,5 mm (its own state of permanent adjustment shall be checked)
Centring rod:	1 mm
Plumb line:	1 mm to 2 mm (worse in windy weather)

7.1 Measurement of distances

7.1.1 Observation procedure

7.1.1.1 Establish a straight line of points in an approximately flat area, as shown in figure 2. The points should be stable for the duration of the procedure including any repeat measurements or further investigations and should be clearly defined.

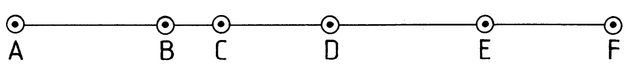

Figure 2 — Layout of measuring points

The suggested lengths are:

AB = 30,5 m; AC = 42,5 m; AD = 74,5 m;

AE = 86,5 m; AF = 158 m.[2)]

7.1.1.2 Measure each distance twice using a calibrated tape in accordance with national standards corrected for temperature, tension and slope (see table 1-A, columns 3 and 4) or using an EDM instru-

2) To obtain the influence of zero and cyclic error, the distances should be different from those used in annex A.

ment with an accuracy of ± 1 mm. Temperatures should preferably be measured using a contact thermometer.

For example, see No. 1 in column 3: 30,467 m

It is recommended that a 100 m steel tape be used. If a shorter tape is used, special care shall be taken of the reading and position error of each tape length.

7.1.1.3 Centre the instrument over A and measure in accordance with the instruction manual AB, AC, AD, AE and AF three times by keeping the same prism (reflector) or the same combination of prisms (see clause 7) over points B, C, D, E and F in succession. After each series of measurements, a new setting-up of the instrument shall be made.

See table 1-A, columns 6, 7 and 8.

For example, see No. 1, column 6: 30,483 m

7.1.1.4 Centre the instrument over F and measure FA, FB, FC, FD and FE as in 7.1.1.3.

7.1.1.5 Record the relevant measuring conditions and the time of measuring: e.g. temperature, atmospheric pressure, relative humidity.

7.1.2 Calculation procedure

A complete example of the analysis is given in table 1-A (see columns 5, 9, 10 and 11). It is recommended that this form of presentation be generally adopted.

7.1.2.1 Calculate the mean of the tape measurement for each distance AB, AC, ..., AF, in column 5.

For example, see No. 1: 30,466 m

7.1.2.2 Calculate the values for the distances FA, FB, FC from the means of AB, AC, ..., AF.

For example, see No. 8:

FC = AF − AC = 158,014 − 42,526 = 115,488 m

7.1.2.3 The values in column 5 are accepted as true values.

7.1.2.4 Calculate the mean $\hat{m}$ of the three EDM measurements reduced by the vertical angle, temperature and pressure, in column 9.

For example, see No. 1: 30,482 m

7.1.2.5 Calculate the error ε_1 (i.e. $\varepsilon_1 = \hat{m} - \bar{x}$) in column 10 for each distance as the difference: column 9 minus column 5.

For example, see No. 1:

30,482 m − 30,466 m = + 16 mm

7.1.2.6 Calculate the squares (column 11) of all values in column 10 and the overall sum of squares (column 11).

For example see No. 1: $(+16)^2 = 256$ mm^2

The overall sum of the squares = 784 mm^2

7.1.2.7 Calculate the root mean square error $\hat{s}_1$ of a distance measurement by three pointings to the prism (target) or combination of prisms as the square root of the sum of squares divided by 10 (number of observations).

For example, $\hat{s}_1 = \pm\sqrt{784/10} = \pm\sqrt{78,4} \approx 8,9$ mm

NOTE 2 In this and the following clauses and in annex A, three different root mean square errors are used:

$\hat{s}_1$ reflects the accuracy in use directly after the testing on the test line, i.e. without applying any corrections (7.1.2.7 and tables 1-A and 1-B);

$\hat{s}_2$ after applying the calculated correction for the zero error (A.1.2.4.1 and tables A.4-A and A.4-B);

$\hat{s}_3$ after applying the calculated corrections for both the zero error and the cyclic error (A.2.2 and tables A.5-A and A.5-B).

The error ε is given subscripts in the same way.

7.1.3 If the calculated root mean square error is too large for the intended task, repeat the whole procedure given in 7.1.1 and 7.1.2. If the second result is similar to the first result, the EDM equipment should not be used for the required task. The necessary steps then to be taken are either to take another instrument or to make further investigations in accordance with annex A in order to identify the main sources of systematic errors inherent in the instrument and their values.

The results of the measurements given in table 1-A indicate that there are systematic errors inherent in the instrument. All values ε_1 have the same sign.

Table 1-A — Example of field observations and calculation

Date:

Location:

Observer:

Instrument:

Conditions: temperature 15 °C, relative humidity 45 %, atmospheric pressure 1 000 mbar, time of measurement 11.30, road surface

Unit length λ of the EDM: 10 m

No.	Dis-tance	Horizontal tape measurement, corrected for temperature and tension m		Accepted as true value $\bar{x}$ m	EDM measurement reduced for vertical angle, temperature and pressure m			Mean $\hat{m}$ m	Error ε_1 mm	ε_1^2 mm²
1	2	3	4	5	6	7	8	9	10	11
1	AB	30,467	30,465	30,466	30,483	30,481	30,483	30,482	+ 16	256
2	AC	42,526	42,527	42,526	42,532	42,536	42,535	42,534	+ 8	64
3	AD	74,500	74,500	74,500	74,503	74,505	74,502	74,503	+ 3	9
4	AE	86,494	86,497	86,496	86,504	86,504	86,501	86,503	+ 7	49
5	AF	158,016	158,012	158,014	158,022	158,027	158,024	158,024	+ 10	100
6	FA			158,014	158,026	158,025	158,027	158,026	+ 12	144
7	FB			127,548	127,554	127,552	127,551	127,552	+ 4	16
8	FC			115,488	115,499	115,492	115,495	115,495	+ 7	49
9	FD			83,514	83,520	83,518	83,515	83,518	+ 4	16
10	FE			71,518	71,529	71,524	71,527	71,527	+ 9	81
										$\sum = 784$ $\hat{s}_1 = \pm$ 8,9 mm

Table 1-B — Field observations and calculation

Date:

Location:

Observer:

Instrument:

Conditions:

Unit length λ of the EDM:

No.	Dis-tance	Horizontal tape measurement, corrected for temperature and tension m		Accepted as true value $\bar{x}$ m	EDM measurement reduced for vertical angle, temperature and pressure m			Mean $\hat{m}$ m	Error ε_1 mm	ε_1^2 mm²
1	2	3	4	5	6	7	8	9	10	11
1	AB									
2	AC									
3	AD									
4	AE									
5	AF									
6	FA									
7	FB									
8	FC									
9	FD									
10	FE									
										$\Sigma =$ $\hat{s}_1 = \pm$ mm

8 Long-term stability

To obtain an indication of the long-term stability of the components of the measuring equipment, establish a stable measuring station and a stable prism (reflector) station so that the distance is between 300 m and 500 m and the distance is a multiple of the unit length of the EDM instrument plus 1/4 of the unit length. Establish a stable point for the instrument near the office. A stable prism (reflector) may be fixed to a building (chimneys or similar slender constructions should not be used because of movements caused by sunshine or wind effects). At certain intervals (at least once a month) measure and correct the distance between the established points using meteorological data and record the results. On each occasion three pointings should be made. The comparison of the results against those of earlier measurements will indicate whether the equipment is stable or if readjustment is required.

Annex A
(informative)

Systematic errors inherent in the instrument

A.1 Procedure for the investigation of systematic errors inherent in the instrument

The procedure given in this annex determines the magnitude of the systematic errors inherent in the instrument in case the user wants more information about systematic errors (zero error and cyclic error) than is achievable by the method described in clause 7. This information may enable a particular EDM instrument to be corrected to obtain an improved accuracy in use.

A.1.1 Sources of error to be determined

(The definitions of the zero error and the cyclic error are given in clause 4.)

A.1.2 Procedure for determining the zero error and the cyclic error

A.1.2.1 Establishing a test line

A.1.2.1.1 Establish a straight line of points in an approximately flat area, as shown in figure A.1. The points should be stable for the duration of the procedure including any repeat measurements or further investigations and should be clearly defined.

Figure A.1 — Test line

The suggested lengths are in relation to the unit length of the instrument (see table A.1). The unit length of various EDM instruments is given in annex B.

The distances BC and DE shall be divided into 10 sub-distances (or, if time permits, into 20 sub-distances) of equal lengths.

A.1.2.1.2 Measure the distances twice using a calibrated tape, corrected for temperature, tension and slope (see table A.2-A, columns 3 and 4).

Table A.1 — Suggested lengths

	Frequency, MHz				
	30	15	7,5	4,886	4,504
	Unit length, m				
	5	10	20	30,7	33,3
	Suggested length, m				
AB	30	30	40	30,7	33,3
AC	35	40	60	61,4	66,6
AD	130	130	140	122,8	133,2
AE	135	140	160	153,5	166,5

It is recommended to use a 100 m steel tape. If a shorter tape is used, special care should be taken of the reading and positioning error of each tape length.

A.1.2.2 Measurement

A.1.2.2.1 Centre the instrument over point A.

A.1.2.2.2 Centre the prism (reflector) or combination of prisms (see clause 7) over point B.

A.1.2.2.3 Measure the distance AB three times in accordance with the procedure given in the manufacturer's manual. For each measurement a separate pointing of the prism (reflector) should be taken (see table A.2-A, columns 6, 7 and 8).

For example, see No. 1, column 6: 30,018 m

A.1.2.2.4 Change the position of the prism (reflector) in the direction to point C about a tenth of the unit length from the position in A.1.2.2.3.

For example, for the unit length 10 m ≙ 15 MHz frequency: 1 m.

A.1.2.2.5 Repeat A.1.2.2.3 and A.1.2.2.4 up to the end of the unit length.

A.1.2.2.6 Measure the distance from A to the prism at D. Repeat the procedure in A.1.2.2.3 to A.1.2.2.5 (as a second set) for the interval DE.

A.1.2.3 Calculation of the zero error

A complete example of the analysis of the zero correction (and the cyclic correction in A.1.2.4) is given in table A.2-A (see columns 5, 9, 10, 11 and 12). It is recommended that this form of presentation be generally adopted.

A.1.2.3.1 Calculate the mean $\bar{x}$ of the tape measurements for each distance in column 5.

For example, see No. 0: 30,010 m

The values are accepted as true values.

A.1.2.3.2 Calculate the mean $\hat{m}$ of the three EDM measurements reduced by the vertical angle, temperature and pressure in column 9.

For example, see No. 0: 30,021 m

A.1.2.3.3 Calculate the error Δ (i.e. $\Delta = \hat{m} - \bar{x}$) in column 10 for each distance as the difference: column 9 minus column 5.

For example, see No. 0:

30,021 m − 30,010 m = + 11 mm

This value Δ includes the zero error, the cyclic error and any other contribution due to the inaccuracy of the measurement.

A.1.2.3.4 In this procedure the sum of the cyclic error to all points is accepted as zero (apart from rounding errors). Therefore calculate the sum of the Δ, for example 91, and divide the sum by 11.

For example, 91/11 = + 8,3 mm ≈ 8 mm

This is the value for the zero error. The zero correction has the opposite sign, in this case − 8 mm.

A.1.2.3.5 Calculate the measured values in table 1-A again (but now in table A.4-A), taking into account the zero corrections shown in table A.2-A. If the mean square error $\hat{s}_2$ is now small enough for the intended task, stop the calculation here.

A.1.2.4 Calculation of the cyclic error

A.1.2.4.1 Add the constant value of the zero correction (column 11), including its sign, to the values in column 10. The results are written down in column 12.

For example, see No. 0:

+ 11 − 8 = + 3 mm

A.1.2.4.2 The values in column 12 represent the cyclic error and other inaccuracies of the measurements. The cyclic error can be calculated either mathematically by using a Fourier series or graphically as shown in figures A.2 and A.3.

A.1.2.4.3 Plot on a sheet of graph paper the values in column 12 in relation to the parts of the unit length (see figure A.2).

A.1.2.4.4 Sketch by eye a best-fit line through the points in A.1.2.4.3.

A.1.2.4.5 Repeat A.1.2.3.1 to A.1.2.4.4 for the second set, beginning with AD.

A.1.2.4.6 The value of the zero error should be of the same order as that calculated in the first set.

A.1.2.4.7 Draw on the same sketch, as in A.1.2.4.4, the results of the cyclic error of the second set.

A.1.2.4.8 If the two lines differ significantly there are two possibilities:

a) the measurements have not been carried out with the required accuracy (see clause 6);

b) there is a length-dependent significant difference in the zero error and/or in the cyclic error.

A.1.2.4.9 If the previous clause applies, before testing other EDM equipment repeat the whole procedure to exclude the possibility that the measurements have not been carried out with the required accuracy.

A.1.2.4.10 If the lines have more or less the same form and order of magnitude, draw the mean of the two lines, as shown in figure A.3.

A.1.2.4.11 Put the numerical values of the mean line in a table (see table A.3). The values are the accepted values of the cyclic error of the measured distances in relation to the unit length.

A.2 Accuracy in use of the measured distances in clause 7, having applied the zero correction and cyclic correction

A.2.1 The mean measured distances $\hat{m}$ in 7.1.2.4, corrected by the mean of the zero correction calculated from the first and second set in A.1.2.3 (table A.5-A, column 12) and the cyclic correction calculated for the same sets (table A.5-A, column 13) have to be compared again with the values measured by the steel tape. The results are given in table A.5-A, column 15.

For example, see No. 1:

30,470 m − 30,466 m = + 4 mm

A.2.2 The remaining errors ε_3 (table A.5-A, column 15) have to be squared and added similarly to 7.1.2.7. The root mean square error $\hat{s}_3$ for the measured distances, having applied the zero correction and the cyclic correction, is

$$\hat{s}_3 = \pm \sqrt{\frac{\varepsilon_3^2}{n}}$$

For example,

$$\hat{s}_3 = \pm \sqrt{77/10} = \pm \sqrt{7,7} = \pm 2,8 \text{ mm}$$

A.2.3 The site surveyor in charge should now decide whether this accuracy is sufficient for the intended task.

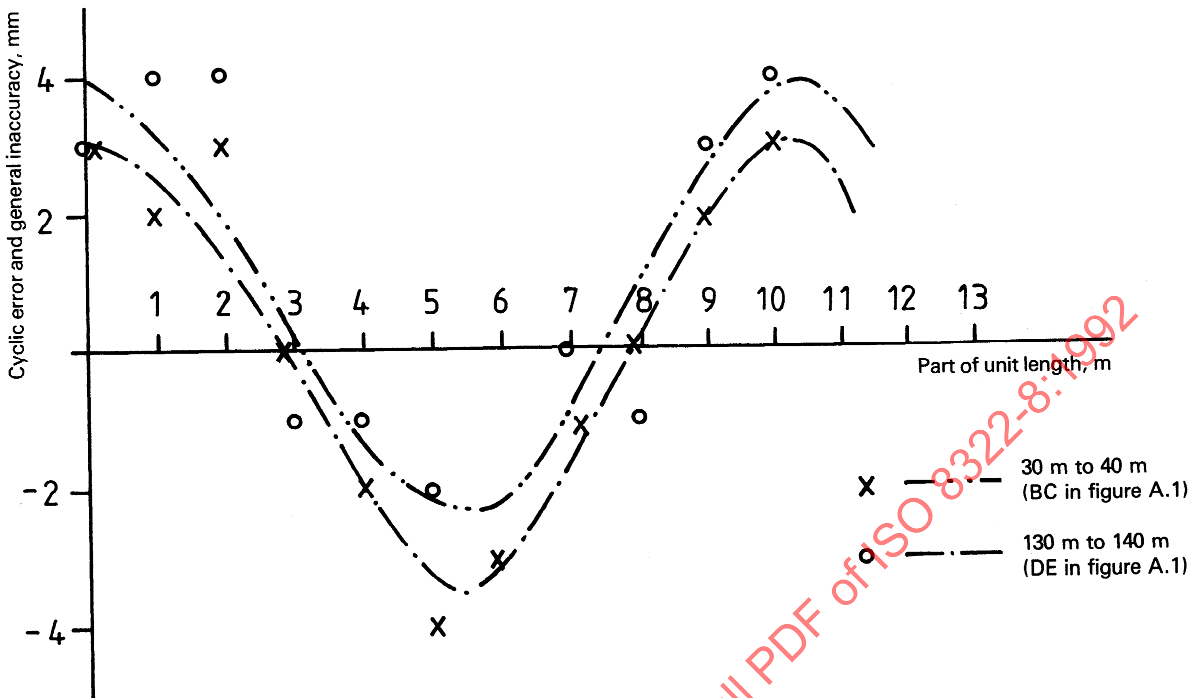

Figure A.2 — Graphical representation of cyclic error

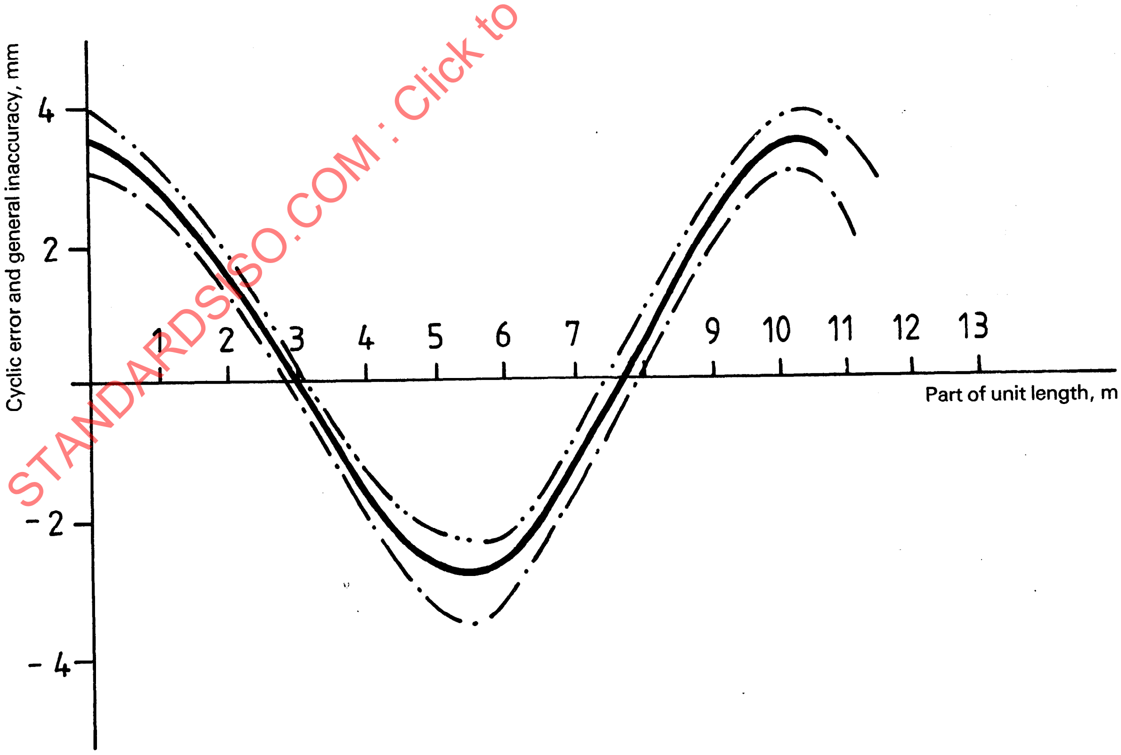

Figure A.3 — Mean of the lines shown in figure A.2

Table A.2-A — Example of field observations and calculation — Zero correction and cyclic correction

Date:

Location:

Observer:

Instrument:

Conditions: temperature 15 °C, relative humidity 45 %, atmospheric pressure 1 000 mbar, time of measurement 11.30, road surface

Unit length λ of the EDM: 10 m

No.	Distance	Horizontal tape measurement corrected for temperature and tension m		Accepted as true value $\bar{x}$ m	EDM measurement reduced for vertical angle, temperature and pressure m			Mean $\hat{m}$ m	Error Δ mm	Zero correction[1)] mm	Cyclic error and general inaccuracy mm
1	2	3	4	5	6	7	8	9	10	11	12
0	AB	30,009	30,010	30,010	30,018	30,022	30,022	30,021	+ 11		+ 3
1	AB + 0,1λ	31,002	31,002	31,002	31,014	31,011	31,010	31,012	+ 10		+ 2
2	AB + 0,2λ	31,999	31,999	31,999	32,010	32,010	32,009	32,010	+ 11		+ 3
3	AB + 0,3λ	33,000	33,003	33,002	33,008	33,010	33,012	33,010	+ 8		0
4	AB + 0,4λ	34,002	34,002	34,002	34,010	34,006	34,008	34,008	+ 6		− 2
5	AB + 0,5λ	35,011	35,008	35,010	35,013	35,014	35,015	35,014	+ 4	− 8	− 4
6	AB + 0,6λ	35,998	36,001	36,000	36,005	36,006	36,004	36,005	+ 5		− 3
7	AB + 0,7λ	37,000	36,997	36,998	37,003	37,006	37,006	37,005	+ 7		− 1
8	AB + 0,8λ	38,003	38,001	38,002	38,013	38,009	38,008	38,010	+ 8		0
9	AB + 0,9λ	39,005	39,005	39,005	39,015	39,016	39,015	39,015	+ 10		+ 2
10	AC	40,000	40,000	40,000	40,010	40,011	40,012	40,011	+ 11		+ 3
									$\sum \Delta = 91$		

1) Zero error $= \frac{\sum \Delta}{10} = \frac{+91}{11} = +8,3$ mm

Zero correction ≈ -8 mm

Table A.2-B — Field observations and calculation — Zero correction and cyclic correction

Date:

Location:

Observer:

Instrument:

Conditions:

Unit length λ of the EDM:

No.	Distance	Horizontal tape measurement corrected for temperature and tension m		Accepted as true value $\bar{x}$ m	EDM measurement reduced for vertical angle, temperature and pressure m			Mean $\hat{m}$ m	Error Δ mm	Zero correction[1)] mm	Cyclic error and general inaccuracy mm
1	2	3	4	5	6	7	8	9	10	11	12
0	AB										
1	AB + 0,1λ										
2	AB + 0,2λ										
3	AB + 0,3λ										
4	AB + 0,4λ										
5	AB + 0,5λ										
6	AB + 0,6λ										
7	AB + 0,7λ										
8	AB + 0,8λ										
9	AB + 0,9λ										
10	AC										
									$\sum \Delta =$		

1) Zero correction $= \frac{-\sum\Delta}{11} =$

Table A.3 — Accepted values of the cyclic error of the measured distances

Part of unit length m	Error mm	Correction mm
0	+ 4	− 4
1	+ 3	− 3
2	+ 2	− 2
3	0	0
4	− 2	+ 2
5	− 3	+ 3
6	− 2	+ 2
7	− 2	+ 2
8	0	0
9	+ 2	− 2
10	+ 4	− 4

Table A.4-A — Example of field observations and calculation, with zero correction

Date:

Location:

Observer:

Instrument:

Conditions: temperature 15 °C, relative humidity 45 %, atmospheric pressure 1 000 mbar, time of measurement 11.30, road surface

Unit length λ of the EDM: 10 m

No.	Distance	Horizontal tape measurement, corrected for temperature and tension m		Accepted as true value $\bar{x}$ m	EDM measurement reduced for vertical angle, temperature and pressure m			Mean $\hat{m}$ m	Error ε_1 mm	ε_1^2 mm²	Zero correction mm	Corrected EDM measurement m	Error ε_2 after zero correction mm	ε_2^2 mm²
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	AB	30,467	30,465	30,466	30,483	30,481	30,483	30,482	+ 16	256		30,474	+ 8	64
2	AC	42,526	42,527	42,526	42,532	42,536	42,535	42,534	+ 8	64		42,526	0	0
3	AD	74,500	74,500	74,500	74,503	74,505	74,502	74,503	+ 3	9		74,495	− 5	25
4	AE	86,494	86,497	86,496	86,504	86,504	86,501	86,503	+ 7	49		86,495	− 1	1
5	AF	158,016	158,012	158,014	158,022	158,027	158,024	158,024	+ 10	100	− 8	158,016	+ 2	4
6	FA			158,014	158,026	158,025	158,027	158,026	+ 12	144		158,018	+ 4	16
7	FB			127,548	127,554	127,552	127,551	127,552	+ 4	16		127,544	− 4	16
8	FC			115,488	115,499	115,492	115,495	115,495	+ 7	49		115,487	− 1	1
9	FD			83,514	83,520	83,518	83,515	83,518	+ 4	16		83,510	− 4	16
10	FE			71,518	71,529	71,524	71,527	71,527	+ 9	81		71,519	+ 1	1
										$\sum = 784$ $\hat{s}_1 = 8,9$ mm	Mean correction = − 8		$\sum = 0$ to be used as a check	$\sum = 144$ $\hat{s}_2 = 3,8$ mm

Table A.4-B — Field observations and calculation, with zero correction

Date:

Location:

Observer:

Instrument:

Conditions:

Unit length λ of the EDM:

No.	Distance	Horizontal tape measurement, corrected for temperature and tension (m)		Accepted as true value $\bar{x}$ (m)	EDM measurement reduced for vertical angle, temperature and pressure (m)			Mean $\hat{m}$ (m)	Error ε_1 (mm)	ε_1^2 (mm²)	Zero correction (mm)	Corrected EDM measurement (m)	Error ε_2 after zero correction (mm)	ε_2^2 (mm²)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	AB													
2	AC													
3	AD													
4	AE													
5	AF													
6	FA													
7	FB													
8	FC													
9	FD													
10	FE													
										$\Sigma =$ $\hat{s}_1 =$ mm	Mean correction =		$\Sigma =$ to be used as a check	$\Sigma =$ $\hat{s}_2 =$ mm

Table A.5-A — Example of field observations and calculation, with zero correction and cyclic correction

Date:

Location:

Observer:

Instrument:

Conditions: temperature 15 °C, relative humidity 45 %, atmospheric pressure 1 000 mbar, time of measurement 11.30, road surface

Unit length λ of the EDM: 10 m

No.	Distance	Horizontal tape measurement, corrected for temperature and tension (m)		Accepted as true value $\bar{x}$ (m)	EDM measurement reduced for vertical angle, temperature and pressure (m)			Mean $\hat{m}$ (m)	Error ε_1 (mm)	ε_1^2 (mm²)	Zero correction in accordance with A.1.2.3.4 (mm)	Cyclic correction in accordance with A.1.2.4.9 (mm)	Corrected EDM measurement (m)	Remaining errors ε_3 (mm)	ε_3^2 (mm²)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	AB	30,467	30,465	30,466	30,483	30,481	30,483	30,482	+ 16	256		− 4	30,470	+ 4	16
2	AC	42,526	42,527	42,526	42,532	42,536	42,535	42,534	+ 8	64		− 1	42,525	− 1	1
3	AD	74,500	74,500	74,500	74,503	74,505	74,502	74,503	+ 3	9		+ 2	74,497	− 3	9
4	AE	86,494	86,497	86,496	86,504	86,504	86,501	86,503	+ 7	49		+ 2	86,497	+ 1	1
5	AF	158,016	158,012	158,014	158,022	158,027	158,024	158,024	+ 10	100	− 8	0	158,016	+ 2	4
6	FA			158,014	158,026	158,025	158,027	158,026	+ 12	144		0	158,018	+ 4	16
7	FB			127,548	127,554	127,552	127,551	127,552	+ 4	16		0	127,544	− 4	16
8	FC			115,488	115,499	115,492	115,495	115,495	+ 7	49		+ 3	115,490	+ 2	4
9	FD			83,514	83,520	83,518	83,515	83,518	+ 4	16		+ 1	83,511	− 3	9
10	FE			71,518	71,529	71,524	71,527	71,527	+ 9	81		− 2	71,517	− 1	1
										$\sum = 784$ $\hat{s}_1 = \pm 8{,}9$ mm					$\sum = 77$ $\hat{s}_3 = \pm 2{,}8$ mm

Table A.5-B — Field observations and calculation, with zero correction and cyclic correction

Date:

Location:

Observer:

Instrument:

Conditions:

Unit length λ of the EDM:

No.	Dis-tance	Horizontal tape measurement, corrected for temperature and tension m		Ac-cepted as true value $\bar{x}$ m	EDM measurement reduced for vertical angle, temperature and pressure m			Mean $\hat{m}$ m	Error ε_1 mm	ε_1^2 mm²	Zero correc-tion in accord-ance with A.1.2.3.4 mm	Cyclic correction in accord-ance with A.1.2.4.9 mm	Corrected EDM measure-ment m	Remain-ing errors ε_3 mm	ε_3^2 mm²
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	AB														
2	AC														
3	AD														
4	AE														
5	AF														
6	FA														
7	FB														
8	FC														
9	FD														
10	FE														
										$\Sigma =$ $\hat{s}_1 =$ mm					$\Sigma =$ $\hat{s}_3 = \pm$ mm

Annex B
(informative)

Various EDM instruments and their unit lengths

Manufacturer	EDM instrument	Unit length, m
Com-Rad	Geomensor	0,3
Geotronics (previously AGA)	Geodimeter 6A	5
	Geodimeter 6B	5
	Geodimeter 6BL	5
	Geodimeter 8	5
	Geodimeter 10	10
	Geodimeter 12	10
	Geodimeter 12A	10
	Geodimeter 14	10
	Geodimeter 14A	10
	Geodimeter Series 100	10
	Geodimeter 210	10
	Geodimeter 216	10
	Geodimeter 220	10
	Geodimeter Series 400	10
	Geodimeter 600	5
	Geodimeter 700	5
	Geodimeter 710	5
	Geodimeter 6000	10
Hewlett-Packard	HP 3800 B	10
	HP 3805 A	10
	HP 3808 A	10
	HP 3810 A	10
	HP 3810 B	10
	HP 3820 A	10
	HP 3850 A	10
Kern, now **Leica**	DM 102	10
	DM 104	10
	DM 150	10
	DM 500	10
	DM 501	10
	DM 502	10
	DM 504	10
	DM 550	10
	DM 1000	10
	DM 2000	10
	ME 3000	0,3
	ME 5000	0,3