International Standard ISO 230/1

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Acceptance code for machine tools — Part 1 : Geometric accuracy of machines operating under no-load or finishing conditions

Code de réception des machines-outils — Partie 1 : Précision géométrique des machines fonctionnant à vide ou dans des conditions de finition

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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.

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 230/1 was prepared by Technical Committee ISO/TC 39, *Machine tools.*

It cancels and replaces ISO Recommendation R 230-1961, of which it constitutes a minor revision.

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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Acceptance code for machine tools — Part 1: Geometric accuracy of machines operating under no-load or finishing conditions

0 Introduction

The purpose of ISO 230 is to standardize methods of testing the accuracy of machine tools, excluding portable machine tools: it consists of the following parts:

Part 1: Geometric accuracy of machines operating under no-load or finishing conditions.

Part 2: Determination of accuracy and repeatabiity of positioning of numerically controlled machine tools.[1]

Part 3: Accuracy of machines operating under load.[2]

Part 4: Vibration.[2]

Part 5: Sound level.[1]

Part 6: Safety.[2]

1 Scope and field of application

The aim of this part of ISO 230 is to standardize methods of testing the geometric accuracy of machine tools, operating either under no-load or under finishing conditions, by means of geometrical and practical tests.

A *machine tool* is a power-driven machine, not portable by hand while working, which can be used for machining metal, wood, etc., by removal of chips or swarf or by plastic deformation.

This part of ISO 230 generally relates only to machines which cut metal by removing chips or swarf. In particular, special methods necessary for testing wood-working machines and machines which operate by plastic deformation are not included.

By *geometrical checks* is meant the checking of dimensions, forms and positions of components, as well as the checking of their displacement relative to one another. They comprise all the operations which affect the components of the machine (surface flatness, coincidence and intersection of axes, parallelism and perpendicularity of straight lines to straight lines, of flat surfaces to flat surfaces or of each to the other). They concern only sizes, forms positions and relative movements which may affect the accuracy of working of the machine.

By *practical test* is meant the machining of test pieces appropriate to the fundamental purposes for which the machine has been designed, and having predetermined limits and tolerances.

NOTE — This part of ISO 230 relates only to the checking of the accuracy itself. In particular, it deals neither with the checking of the running of the machine tool (vibrations, abnormal noises, stick-slip motion of components, etc., nor with the checking of characteristics (speeds, feeds), as these checks should normally be carried out before checking the accuracy of the machine tool.

After general considerations on definitions, test methods, use of checking instruments and tolerances, this part of ISO 230 deals more thoroughly with preliminary checking operations, practical tests and geometrical checks, and some special checks. An annex deals with the accuracy of instruments used for testing machine tools.

NOTE — This part of ISO 230 gives essentially a recommended selection of test methods by means of geometrical checks. Attention is drawn to the fact that, while geometrical checks are explained at length, the practical tests are not, as the problems of the inspection of components regarding position, dimensions and forms are properly dealt with in most technical books on metrology.

2 General considerations

2.1 Definitions relating to geometrical checks

A distinction should be made between geometrical definitions and those designated in this part of ISO 230 as metrological definitions.

Geometrical definitions are abstract and relate only to imaginary lines and surfaces. From this it follows that geometrical definitions sometimes cannot be applied in practice. They take no account of the realities of construction or the possibility of checking.

Metrological definitions are concrete, as they take account of real lines and surfaces accessible to measurement. They cover in a single result all micro- and macro-geometrical errors. They allow a result to be reached covering all causes of error, without distinguishing them from one another. The distinction should be left to the manufacturers.

1) At present at the stage of draft.

2) In preparation.

Nevertheless, in some cases, geometrical definitions (e.g. definitions of out-of-true running, periodic axial slip, etc.) have been retained in this part of ISO 230, in order to eliminate any confusion and to clarify the language used, but, when describing test methods, measuring instruments and tolerances, metrological definitions are taken as a basis.

2.2 Test methods and use of checking instruments

During the testing of a machine tool, if the methods of measurement only allow verification that the tolerances are not exceeded (e.g. limit gauges) or if the actual deviations could only be determined by high-precision measurements for which a great amount of time would be required, it is sufficient, instead of measuring, to ensure that the limits of the tolerance are not exceeded.

It should be emphasized that errors of measurement due to the instruments, as well as to the methods used, are to be taken into consideration during the tests. The measuring instrument should not give any error of measurement exceeding a given fraction of the tolerance to be verified. Since the accuracy of the devices used are very variable from one laboratory to another, a calibration sheet should be supplied with each instrument.

Test operations should be protected from draughts and from disturbing light or heat radiation (sunlight, electric lamps too close, etc.) and the temperature of the measuring instruments should be stabilized before measuring. The machine itself shall be suitably protected from the effects of external heat.

A given test should preferably be repeated, the result of the test being obtained by taking the average of the measurements. However, the various measurements should not show too great deviations from one another. If they do, the cause should be looked for either in the method or the checking instrument or the machine tool itself.

2.3 Tolerances

2.31 Tolerances on measurements when testing machine tools

Tolerances, which limit deviations to values which are not to be exceeded, relate to the sizes, forms, positions and movements which are essential to the accuracy of working and to the mounting of tools, important components and accessories.

There are also tolerances which apply only to test pieces.

2.311 Units of measurement, measuring ranges

When establishing tolerances, it is necessary to indicate:

a) the unit of measurement used;

b) the reference base and the value of the tolerance and its location to the reference base;

c) the range over which measurement is made.

The tolerance and the measuring range shall be expressed in the same unit system. Tolerances, particularly tolerances on sizes, shall be indicated only when it is impossible to define them by simple reference to International Standards for the components of the machine. Those relating to angles shall be expressed either in units of angle: degree, minute, second (one revolution = 360°), or as tangents (micrometres or millimetres per metre for countries using the metric system or inch per 10 in or inch per foot for countries using the inch-foot system).

When the tolerance is known for a given range, the tolerance for another range comparable to the first one shall be determined by means of the law of proportionality. For ranges greatly different from the reference range, the law of proportionality cannot be applied: tolerances shall be wider for small ranges and smaller for large ranges than those which would result from the application of this law.

2.312 Rules concerning tolerances

Tolerances include errors inherent in the measuring instruments and test methods used. Errors of measurement should consequently be included in the permitted tolerances (see 2.2).

Example:

Tolerance of run-out: X µm

Inaccuracy of instruments, errors of measurement: Y µm

Maximum permissible difference in the readings during the test $(X - Y)$ µm

Errors to be ignored are those of block gauges, reference discs, etc., inaccuracies arising from comparative laboratory measurements, inaccuracies of form of machine part used as reference surfaces, including surfaces masked by plungers or by support points of measuring instruments.

The actual deviation should be the arithmetical mean of several readings taken, ignoring the above causes of error.

Lines or surfaces chosen as *reference bases* should be directly related to the machine tool (e.g. line between centres of a lathe, spindle of a boring machine, slideways of a planing machine, etc.). The direction of the tolerance shall be defined according to the rules given in 2.325.

2.32 Subdivisions of tolerances

2.321 Tolerances applicable to test pieces and to fixed parts of machine tools

2.321.1 Tolerances of dimensions

The tolerances of dimensions indicated in this part of ISO 230 relate exclusively to the dimensions of test pieces for practical tests and to the fitting and to the fitting dimensions of cutting tools and of checking instruments which may be mounted on the machine tool (spindle taper, turret bores). They are the limits of permissible deviation from the nominal dimensions. They shall be expressed in length units (e.g. deviations of bearings and bore diameters, for the setting up and the centring of tools).

For internal and external dimensions of cylindrical and parallelepipedic parts, tolerances shall be given in compliance with the rules prepared by Technical Committee ISO/TC 10, *Technical drawings.* In particular, deviations should be indicated or the ISO symbols used.

Example:

$80 \begin{smallmatrix} +0,012 \\ -0,007 \end{smallmatrix}$ or 80 j6

2.321.2 Tolerances of form

Tolerances of form limit the permissible deviations from the theoretical geometric form (e.g. deviations relative to a plane, to a straight line, to a revolving cylinder, to the profile of thread or of tooth). The shall be expressed in units of length or of angle. Because of the dimensions of the plunger surface or of the support surface, only part of the error of form is detected. Therefore where extreme accuracy is required, the area of the surface covered by the plunger or support shall be stated.

In a general way, the plunger surface should be proportional to the precision and to the dimension of the surface to be checked (a surface plate and the table of a heavy planing machine are not checked from the same plunger surface).

2.321.3 Tolerances of position

Tolerances of position limit the permissible deviations concerning the position of a component relative to a line, to a plane, or to another component of the machine (e.g. deviation of parallelism, of perpendicularity, of alignment, etc.). They shall be expressed in units of length or angle.

When a tolerance of position is defined by two measurements taken in two different planes, the tolerance should be fixed in each plane, when the deviations from those two planes do not affect the working accuracy of the machine tool in the same way.

NOTE — When a position is determined in relation to surfaces showing errors of form, these errors of form should be taken into account when fixing the tolerance of position.

2.321.4 Rules for the influence of defects of form in determining positional errors

When positional errors of two surfaces or of two lines (see figure 1, lines XY and ZT) are being determined, the readings of the measuring instrument automatically include some errors of form. It shall be laid down, as a principle, that checking shall apply only to the total error, including the errors of form of the two surfaces or of the two lines. Consequently, the tolerance shall take into account the tolerance of form of the surfaces involved. (If thought useful, preliminary checks may ascertain defects of form of lines and of surfaces, of which the relative positions are to be determined.)

When setting out on a graph (see figure 1) the different readings mn of the checking instrument, a curve, such as AB, is obtained. It is to be accepted, when there is no contradictory stipulation, that the error is to be determined by using, instead of this curve, a line calculated from the minimun squared deviation.

2.322 Tolerances applicable to the displacement of a component of a machine tool

2.322.1 Tolerances of dimensions

Tolerances of dimensions limit the permissible deviation of the position reached by a point on the moving part from that which it should have reached after moving.

Examples

1 Deviation *d*, at the end of the travel, of the position of a lathe cross slide from the position which it should have reached under the action of the lead screw (see figure 2).

2 Angle of rotation of a spindle relative to the angular displacement of a dividing plate coupled to it.

2.322.2 Tolerances of form

These limit the deviation of the actual trajectory of a point relative to the theoretical trajectory (see figure 3). They shall be stated in units of length.

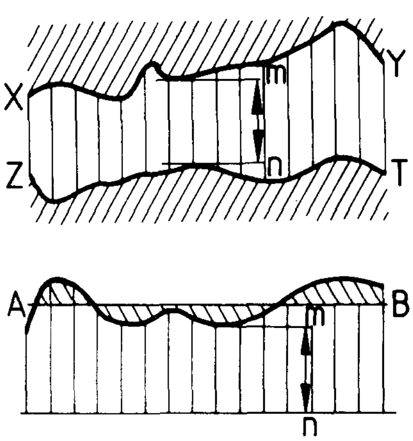

Figure 1

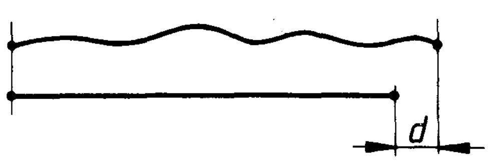

Figure 2

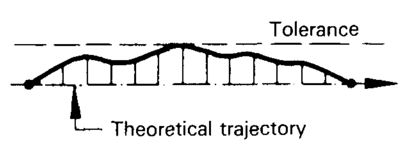

Figure 3

2.322.3 Tolerances of position

Tolerances of position limit the permissible deviation between the trajectory of a point on the moving part and the trajectory laid down (e.g. deviation of parallelism between the trajectory and a straight line or a surface) (see figure 4). They shall be expressed in units of angle or preferably as successive tangents over a given measurement of length.

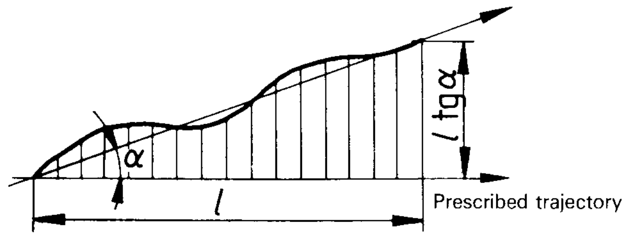

Figure 4

2.322.4 Local tolerances

Tolerances of form and position are usually relative to the form or position as a whole, e.g. 0,03/1 000 for a straightness or flatness. It should be observed that checking can show up a deviation (see figure 5) which is not spread over the whole of the form or position, but is concentrated on a short length of the former (e.g. 200 mm). If such defects, seldom met with in practice, are to be avoided, the overall tolerance may be accompanied by a statement of a local tolerance; or it may be simply agreed that the local tolerance, provided that it does not fall below a minimum to be stated (e.g. 0,01 or 0,005 mm) should be proportional to the overall tolerance. In the case under consideration, relating for example to straightness, the local error shall not in these conditions exceed:

$$\frac{0,03}{1\ 000} \times 200 = 0,006 \text{ mm}$$

If 0,01 mm is accepted as a minimum for any given machine, it is sufficient to check that the local error does not exceed this value.

In practice, local defects are generally imperceptible, as they are covered by the supporting or the feeling surfaces of the measuring instruments. However when the feeling surfaces are relatively small (plungers of dial gauges or micro-indicators), the measuring device should be such that the plungers follow a surface of high grade finish (straightedge, test mandrel, etc.).

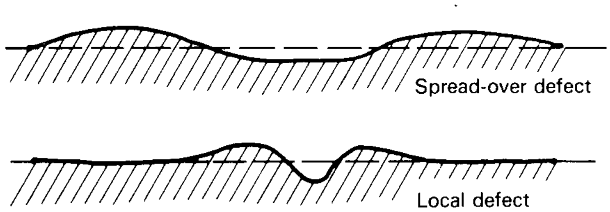

Figure 5

2.323 Cumulative or inclusive tolerances

The cumulative tolerances are the resultant of several deviations and may be determined by a single measurement, without it being necessary to know each deviation.

Example (see figure 6) : The tolerance for the run-out of a shaft is the sum of the tolerance of form (out-of-round of the circumference ab on which the plunger is in contact), the tolerance of position (the geometrical axis and the rotating axis of the shaft do not coincide) and the tolerance of out-of round of the bore of the bearing.

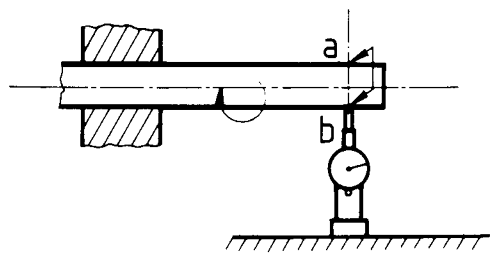

Figure 6

2.324 Symbols and positions of tolerances for relative angular positions of axes, slideways, etc.

When the position of the tolerance in relation to the nominal position is symmetrical, the sign ± may be used. If the position is asymmetrical it shall be stated precisely, in words,

— either in relation to the machine or to one of the components of the machine, or

— in relation to the operator in his conventional position.

2.325 Conventional position of the operator

For each type of machine a conventional position of the operator shall be defined. The *front* of a machine shall be the part which faces the operator. The *right* of a machine shall be the part which is at his right. The *rear* and the *left* of a machine shall be the parts respectively opposite to those already defined.

3 Preliminary checking operations

3.1 Installation of the machine before test

Before proceeding to test a machine tool, it is essential to fix the machine upon suitable foundations and to level it in accordance with the instructions of the manufacturer.

3.11 Levelling

The preliminary operation of installing the machine shall involve (see 3.1) precise levelling and is essentially determined by the particular machine concerned.

In the case of a lathe, the plane of the slides (front and rear) shall be laid horizontally or with a suitable slope. The cross slide shall be placed in the middle of the bed. When jacks and fixing bolts are used, the extreme ends of the slideways shall be placed horizontally and the twisting of the bed shall be remedied if necessary. For this purpose, the level shall be placed in succession (see figure 7) on the longitudinal positions a, b, c and d, and the transverse positions e and f.

After the first installation, checking of the straightness of the slideways (or straightness of the movement of the slide) may be made. It should be noted that this checking is not distinguishable from the setting out of the machine, particularly in the case of large-sized beds. Jacks are often spaced along the bed to effect local corrections as the checking of the slideways progresses.

When installing milling machines, the table of the machine shall be set approximately horizontal; the purpose of this is to facilitate the test operations.

Generally, it is desirable to follow the manufacturer's instructions for the proper setting-out of the machine and for the provision of suitable foundations which, in certain cases, are indispensable.

3.2 Condition of the machine before test

3.21 Dismantling of certain components

As the tests are carried out, in principle, on a completely finished machine, dismantling of certain components should only be carried out in exceptional circumstances, in accordance with the instructions of the manufacturer (e.g. dismantling of a grinding machine table in order to check the slideways).

3.22 Temperature conditions of certain components before test

The aim is to check the accuracy of the machine under conditions as near as possible to those of normal functioning as regards lubrication and warming up. During the geometrical and practical tests, components, e.g. spindles, which are liable to warm up and consequently to change position or shape, shall be brought to the correct temperature by running the machine idle in accordance with the conditions of use and the instructions of the manufacturer.

3.23 Functioning and loading

Geometrical checks shall be made either when the machine is at a standstill or when it is running idle. When the manufacturer specifies it, for example, as in the case of heavy-duty machines, the machine shall be loaded with one or more test pieces.

4 Practical tests

4.1 Testing

Practical tests shall be carried out on pieces the making of which does not require operations other than those for which the machine has been built. Practical tests to ascertain the precision of a machine tool shall be the finishing operations for which the machine has been designed. (It is of primary importance that such tests should be carried out in good faith.)

The number of workpieces or, as the case may be, the number of cuts to be made on a given workpiece, shall be such as to make it possible to determine the average precision of working. If necessary, wear on the cutting tool used should be taken into account.

The nature of the workpieces to be made, their dimensions, their material and the degree of accuracy to be obtained and the cutting conditions shall be settled by agreement between the manufacturer and the user, unless ISO specifications already exist.

4.2 Checking of workpieces in practical tests

Checking of workpieces in practical tests shall be done by measuring instruments selected for the kind of measurement to be made and the degree of accuracy required.

The tolerances indicated in 2.321, particularly in 2.321.1 and 2.321.2, are to be used for these checks.

4.3 Importance of practical tests

The results of practical tests and geometrical checks can be compared only insofar as these two kinds of tests have the same object. There are cases moreover when, on account of expense or technical difficulties in conducting the tests, the accuracy of a machine is checked only by geometrical checks or only by practical tests.

If the tests by means of geometrical checks and practical tests having the same object do not give the same results, those results obtained by making practical tests should be accepted as the only valid ones.

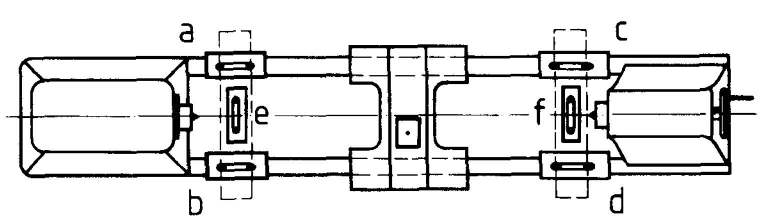

Figure 7

5 Geometrical checks

5.1 General

For each geometrical check of a given characteristic of shape, position or displacement of lines or surfaces of the machine:

- straightness (see 5.2),
- flatness (see 5.3),
- parallelism, equidistance and coincidence (see 5.4),
- squareness (see 5.5),
- rotation (see 5.6),

a definition [1], a method of measurement and the way of determining the tolerance are given.

For each test, at least one method of measurement has been indicated, and only the principles and apparatus used have been shown.

When other methods of measurement are used, their accuracy shall be at least equal to the accuracy of those in this part of ISO 230.

Although, for the sake of simplicity, the methods of measurement have been chosen systematically from those which employ only the elementary test instruments most frequently used in engineering workshops, such as straightedges, squares, mandrels, measuring cylinders, spirit levels and dial gauges, it should be observed that other methods, notably those using optical devices, are in fact generally used in machine tool building and in inspection departments. Testing of machine tool parts of large dimensions often requires the use of special devices for convenience and speed.

5.2 Straightness

Geometrical checks covering straightness are the following:

- straightness of a line in two planes, see 5.21;
- straightness of components, see 5.22;
- straight line motion, see 5.23.

5.21 Straightness of a line in two planes

5.211 Definition

A line is deemed to be straight over a given length when the variation of the distance of its points from two planes perpendicular to each other and parallel to the general direction of the line remains below a given value for each plane.

Reference planes shall be chosen so that their intersection is parallel to the straight line joining two points suitably located on the line to be tested. The two points should be close to the ends of the length to be measured.

1) See also 2.1.

5.212 Methods of measurement

It is recommended to use:

a) for lengths below 1 600 mm or 63 in:

a spirit level or straightedge conforming to International or national Standards, as the case may be,

b) for lengths above 1 600 mm or 63 in:

the methods of measurement by means of a spirit-level, or of optical devices (the autocollimation method, the microscope and taut wire).

5.212.1 Straightedge method

The straightedge should be placed on two blocks, located, if possible, at the points corresponding to the minimum deflection.

The measurement shall be made by moving along the straightedge a rider of which one point rests on the surface to be measured and the other carries a dial gauge, the plunger of which is in contact with the straightedge (see figure 8).

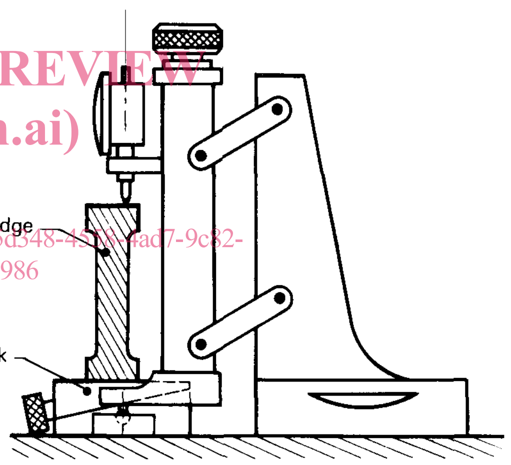

Figure 8

The straightedge is set to give identical readings at both ends of the line (e.g. by means of adjustable blocks); errors in the line AMB relative to the straight line AB joining the two extremes may be read off directly [see figure 9a)].

The straightedge may also be set without aiming at identical readings at both ends of the line; the readings are then plotted graphically and the errors checked in relation to the straight line AB [see figure 9b)].

5.212.2 Spirit-level method or autocollimation method

In the spirit-level method, the reference plane is the horizontal plane, as defined by the level.

In the autocollimation method, the reference line is a light beam.

Measurements shall be taken at successive equidistant points. These shall then be set out on a chart of the angles and the general direction XY in relation to the line AB checked (see figure 10).

Deviations MN perpendicular to this line shall not exceed the specified tolerance.

5.212.21 Spirit-level method

1) The line is reasonably horizontal

The initial straight line of reference is constituted by the straight line omx, o and m being two points on the line to be checked (see figure 11).

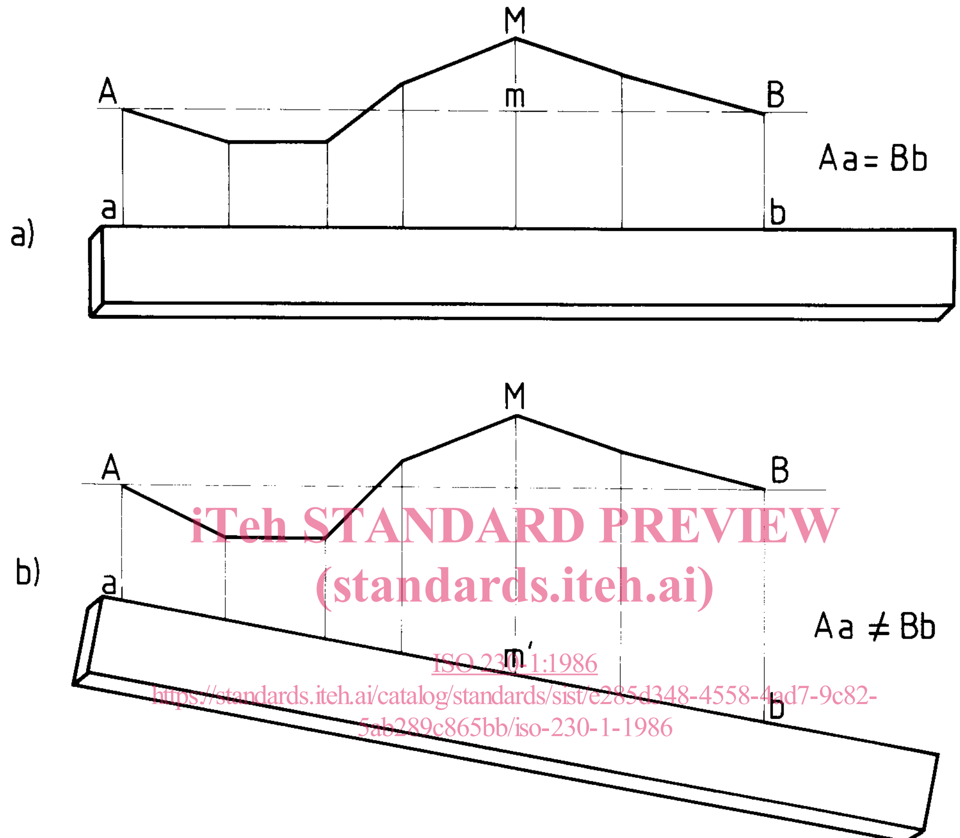

Figure 9

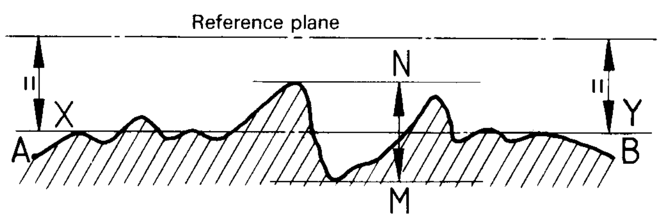

Figure 10

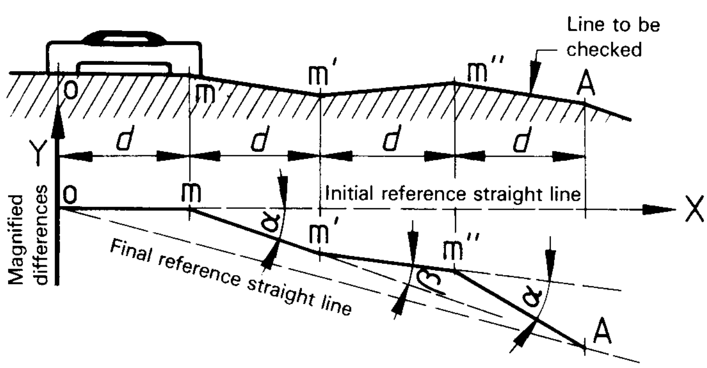

Figure 11