INTERNATIONAL STANDARD

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Acceptance tests for CO_2-laser beam machines for high quality welding and cutting —

Part 2: Measurement of static and dynamic accuracy

Essais de réception des machines de soudage et de coupage de qualité par faisceau laser CO_2 —

Partie 2: Mesure de la précision du système de mise en œuvre du faisceau en statique et en dynamique

Reference number
ISO 15616-2:2003(E)

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this part of ISO 15616 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15616-2 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the fielsd of metal welding*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this document, read "...this European Standard..." to mean "...this International Standard...".

ISO 15616 consists of the following parts, under the general title *Acceptance tests for CO_2-laser beam machines for high quality welding and cutting*:

— *Part 1: General principles, acceptance conditions*

— *Part 2: Measurement of static and dynamic accuracy*

— *Part 3: Calibration of instruments for measurement of gas flow and pressure*

Contents

Foreword

This document (EN ISO 15616-2:2003) has been prepared by Technical Committee CEN/TC 121, "Welding", the secretariat of which is held by DS, in collaboration with ISO/TC 44 "Welding and allied processes".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2003, and conflicting national standards shall be withdrawn at the latest by September 2003.

This European Standard "*Acceptance test for CO_2 – laser beam machines for high quality welding and cutting*" consists of the following Parts:

— *Part 1: General principles, acceptance conditions.*

— *Part 2: Measurement of static and dynamic accuracy.*

— *Part 3: Calibration of instruments for gas flow and pressure measurement.*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This Part of this European Standard is applicable to the measurement of:

— the precision of the manipulation system;

— the positioning accuracy;

— the repeatability of positioning;

— the trajectory exactness,

for the acceptance testing of CO_2-laser beam machines for high quality welding and cutting in two operation directions (2D) in accordance with EN ISO 15616-1. This standard specifies the testing procedure and equipment. The scope of the examination and the grades of precision shall be stated in the technical specification for the CO_2-laser beam machine and be in accordance with the application requirements due to the diversity of the requirements to the laser system.

The work piece and/or the optics are moved during laser beam processing. The movement of the work piece and/or the optics require a certain precision in the motion system, e.g. moving working table, rotary fixture, moving laser optics, etc. to achieve producible results. This standard establishes a classification system for the motion system related to the required precision for the application being used.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN ISO 15616-1:2003, *Acceptance tests for CO_2-laser beam machines for high quality welding and cutting — Part 1: General principles, acceptance conditions (ISO 15616-1:2003)..*

3 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply.

3.1
manipulation system precision
maximum deviation from the intended path of the position of the focus (or working point) measured perpendicularly to the feeding direction X, Y or Z or the evenness and accuracy of rotation of a rotary fixture

NOTE Moreover, the manipulation system precision is characterized by any deviation from the actual fixed point focus position in any direction to the set position along the beam axis in relation to the welding or cutting position on the surface of the work piece, as long as these deviations are caused by the motion system.

3.2
positioning accuracy
precision and repeatability of positioning of the part in motion (work piece, optics, etc.) along a translation or rotation axis

NOTE The following characteristics can be distinguished in accordance with ISO 230-2:

— mean reversal value of an axis. Arithmetic mean of the reversal values at all target positions along or around the axis;

— uni-directional and bi-directional repeatability of positioning of an axis: maximum value of the repeatability of positioning at any position along or around the axis and under the conditions specified in ISO 230-2;

— bi-directional accuracy of positioning of an axis: maximum difference between the extreme values of the positional deviations regardless of the position and the direction of motion.

3.3
trajectory exactness
difference between the actual trajectory of the tool's reference point and the desired trajectory as long as this is caused by the trajectory control

4 Examination of the manipulation system precision

4.1 Extent of examination

Measurements shall be made at all relevant moving axes and in all motion directions with a load in accordance with EN ISO 15616-1:2003, 6.4.2.

4.2 Measuring devices

Measurements shall be made with calibrated measuring devices such as mechanical, optical (laser device) or inductive measuring devices, suitable for measuring in accordance with the application limits and as specified in EN ISO 15616-1:2003, Table 3.

4.3 Examination procedure

A selection of devices and procedures to measure the manipulation system precision of the moving working table, of the rotary fixture or of the moving optics is summarised in Table 1. Proposals in Table 1 are not completely covering all required measurements in accordance with EN ISO 15616-1. The extent of examination shall be defined depending on the type of laser machine, on the type of manipulation system, on the requirements on the procedure quality, etc. The axis of the manipulation system which is affecting the result shall be defined in order to select appropriate examination procedures.

The manipulation system precision of moving optics in X- and Y- direction shall be checked in Z-direction as well to prove parallelism between the XY-motion level of the optics and the XY-motion level of the moving working table. Examination of the rotary fixture with horizontal axis includes the load but the maximum torque and asymmetrical load are affecting the manipulation system precision as well.

Table 1 — Examples of how to measure the manipulation system precision of the moving working table, of the focusing head or the rotary fixture

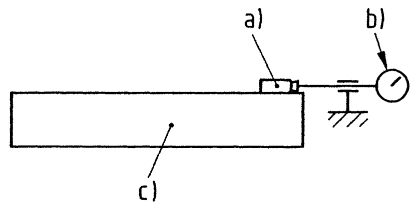
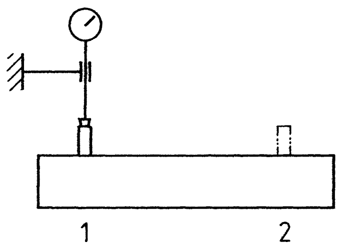
No	Object	Diagram	Equipment	Procedure
1	Straightness of X(Y) direction of working table movement in Y(X) direction	 **Key** a) Straightedge b) Dial gauge c) XY-working table	Straightedge Dial gauge	Position straightedge in X(Y) direction (e.g. by aligning it with the reference slot of working table) and attach dial gauge. Traverse working table through entire feed length in the X direction and measure deviations in Y direction, a_y. Then traverse working table through entire feed length in the Y direction and measure deviations in X direction, a_x.
2	Straightness of the X(Y) direction of working table movement in Z direction	 **Key** 1 Position 1 2 Position 2	Straightedge Dial gauge	Set straightedge at position 1 and mount dial gauge as shown. Traverse working table through entire feed length in the X(Y) direction and measure deviations in Z direction, a_z. Repeat measurement with straightedge set at position 2.

Table 1 *(continued)*

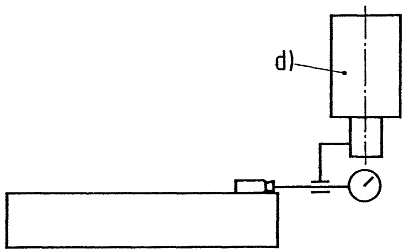
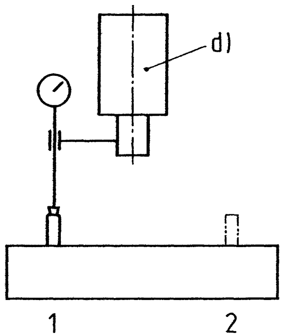
No	Object	Diagram	Equipment	Procedure
3	Straightness of the X(Y) direction of focusing head movement in Y(X)-direction (Moving optics axes only).	 **Key** d) focussing optics	Straightedge Dial gauge	Position straightedge in X(Y) direction (e.g. by aligning it with the reference slot of working table) and attach dial gauge. Traverse focusing head through entire feed length in the X direction and measure deviations in Y direction, a_y. Then traverse focusing head through entire feed length in the Y direction and measure deviations in X direction, a_x.
4	Straightness of the X(Y) direction of focusing head movement in Z direction. (Moving optics axes only).	 **Key** d) focussing optics 1 Position 1 2 Position 2	Straightedge Dial gauge	Set straightedge at position 1 and mount dial gauge as shown. Traverse focusing head through entire feed length in the X(Y) direction and measure the deviations in Z-direction, a_z. Repeat measurement with straightedge set at position 2.

Table 1 *(continued)*

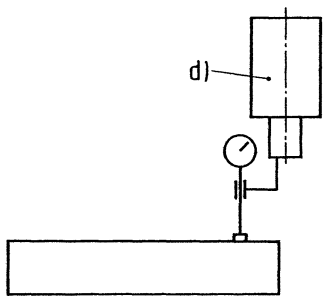
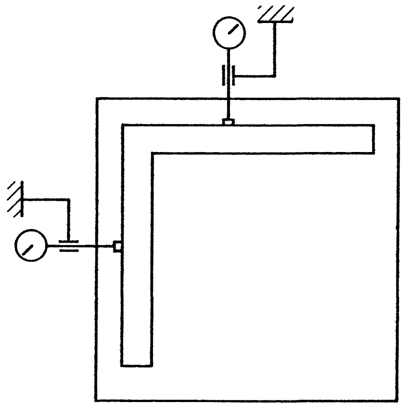
No	Object	Diagram	Equipment	Procedure
5	Parallelism of the XY-plane of focusing head movement to the XY plane of the working table movement (moving focusing head or moving working table)	 **Key** d) focussing optics	Dial gauge	Position focusing head at the 4 corner points and centre of the working table. Maintain focusing head in all positions on the same Z-coordinations and measure deviations in Z-direction, a_z.
6	Squareness of movement of working table in X and Y directions		Steel square Dial gauge	Place steel square with one leg in X direction of the working table movement. Traverse working table in Y direction and measure deviations from squareness in the X direction along the square.

Table 1 *(continued)*

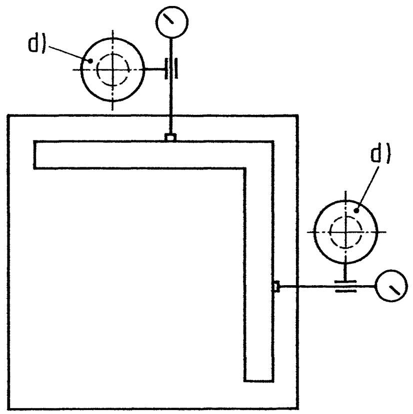
No	Object	Diagram	Equipment	Procedure
7	Squareness of focusing head movement in X and Y directions (moving focusing head)	 **Key** d) focussing optics	Steel square Dial gauge	Place steel square with one leg in X direction of the focusing head movement. Traverse in focusing head in Y direction and measure deviations from squareness in the X direction along the square.

Table 1 *(continued)*

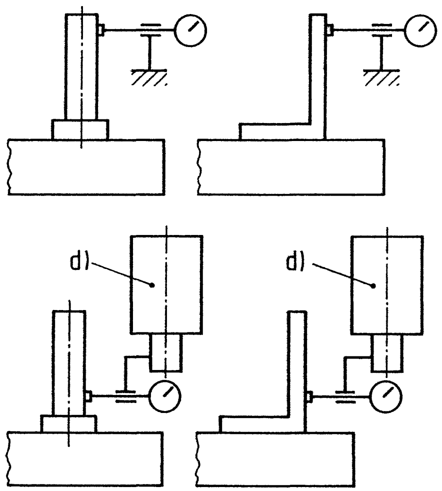
No	Object	Diagram	Equipment	Procedure
8	Squareness of working table surface to movement in Z direction	 **Key** d) focussing optics	Cylinder or steel square Dial gauge	Set up cylinder or square and traverse working table or focusing head in Z-direction. Measure deviations from squareness in X(Y) direction along the cylinder or square.

Table 1 *(continued)*

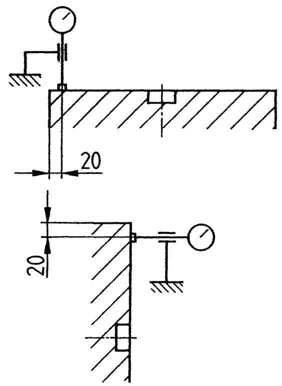
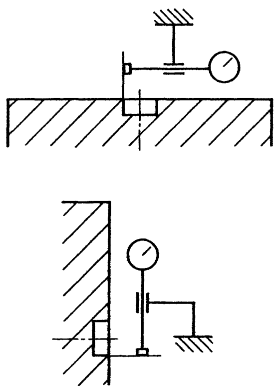
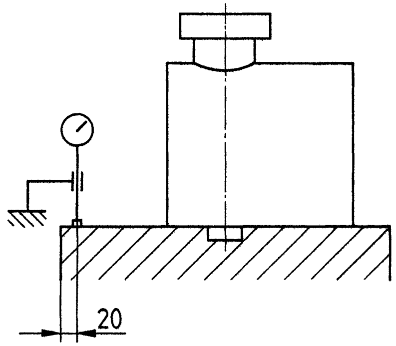
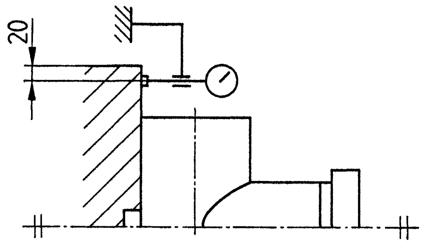
No	Object	Diagram	Equipment	Procedure
9	Axial run-out in horizontal plane or in vertical plane		Dial gauge	Position dial gauge approximately 20 mm away from the outside edge of the face plate, rotate fixture and measure deviations.
10	Radial run-out in horizontal or vertical plane		Dial gauge	Position dial gauge on the centre location hole or on the cylinder, rotate fixture and measure deviations.

Table 1 *(continued)*

No	Object	Diagram	Equipment	Procedure
11	Run-out, in horizontal plane, under load		Dial gauge	Subject rotating fixture (eccentrically) to maximum load. Position dial gauge approximately 20 mm away from the outer edge of face plate. Rotate fixture and measure deviation.
12	Axial run-out, in vertical plane, under load		Dial gauge	Subject rotating fixture to maximum load. Position dial gauge approximately 20 mm away from the outer edge of the face plate. Rotate fixture and measure deviations.

4.4 Report of the measurement results

Tables are a suitable way of reporting the results with specification of the maximum values.

5 Examination of the trajectory exactness

5.1 Extent of examination

Trajectory deviations between a program contour and a realised path shall be measured during simulated processing of three contour elements. Measurements shall be performed with and without load for machines where at least one of the axes is carrying work load. In addition the trajectory velocity is recorded. Limiting values are specified in EN ISO 15616-1:2003, Table 5.

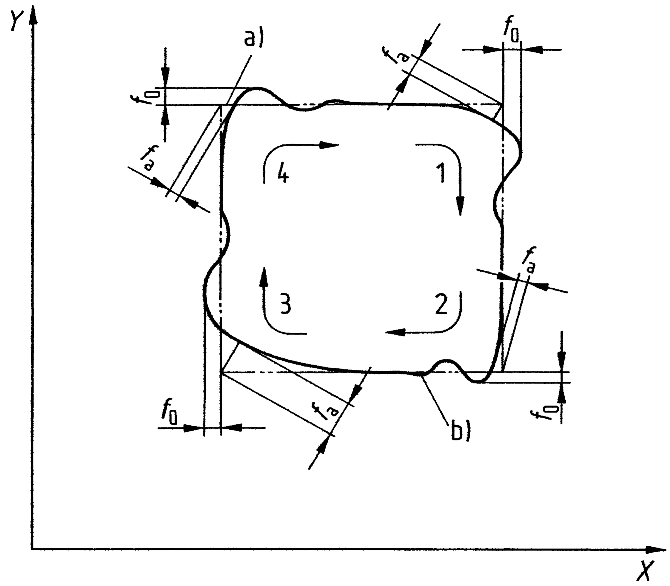
The trajectory exactness shall be checked with specified trajectory velocities.

The limiting values are specified in EN ISO 15616-1:2003, Table 5.

5.2 Definition of geometrical elements and exactness describing characteristics

At each corner of the geometrical element square (see Figure 1) the error in rounding-off f_a and the error in overshooting f_o are examined. f_a is the distance between the actual trajectory and the nominal corner. f_o is the maximum over shooting of the system in relation to the nominal side of the square.

The sides of the square are parallel to both axes of co-ordinates of the system. The length of the sides of the square is 80 mm. This value may be changed if unsuitable (to be reported in the record).



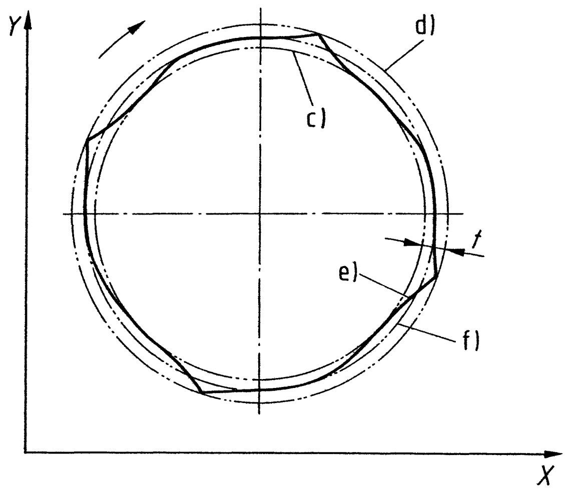
Key

f_a error in rounding-off
f_o error in overshooting
a) cut corner
b) 2nd overshooting
1, 2, 3, 4 direction of cutting

Figure 1 — Geometrical element square

The error in circularity t is examined by using the geometrical element circle (see Figure 2). t is the difference between the radius of the inscribed circle and the radius of the circumscribed circle including all deviations of the actual trajectory. The inscribed and circumscribed circles are concentric but not necessarily concentric with the nominal circle.

The nominal diameter of the test circle is 50 mm. This value may be changed if unsuitable (to be reported in the record).



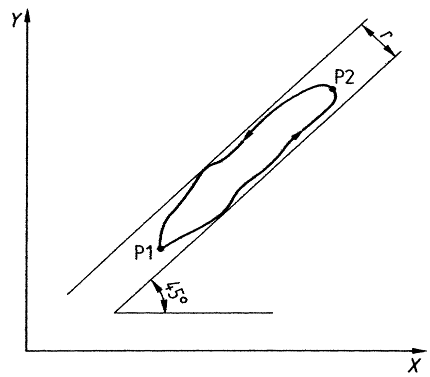
Key

c) inscribed circle
d) circumscribed circle
e) actual trajectory
f) nominal trajectory
t error in circularity

Figure 2 — Geometrical element circle

The geometrical element 45°-bevel (see Figure 3) is a straight line running 45° between the axes of the system. The straight line is limited by two end-points P1 and P2 and the test runs from one end-point to the other and the way back. The position of the bevel is characterized by the difference of the co-ordinates of P1 and P2 which is $\Delta x = \Delta y = 80$ mm. (x and y representing the 2 linear axes).

The error in reversibility r is examined at the geometrical element 45°-bevel. r is the distance between two lines parallel to the nominal trajectory including all deviations of the actual trajectory going forth and back.



Key

r error in reversibility

Figure 3 — Geometrical element 45°-bevel

5.3 Measuring devices

At least two motion pickups (one per axis of the co-ordinates) are needed to examine the trajectory exactness. Signals from the motion pickups have to be recorded for later examination. The speed belonging to the actual trajectory is calculated from the recorded signals.

To receive a correct record it shall be guaranteed that the recorded pair of values from the motion pickups belongs to the same test moment.

Other external measuring devices may be used as appropriate.

5.4 Examination procedure

The motion pickups shall be checked for orthogonality and calibration before measurements are started.

Measurements are done applying the programmed speed v_{prog} according to specifications.

For the square and the bevel the kind of motion at the corners shall be recorded (e.g. maximum speed or positive stop used by machines with speed depending power control).

As regard to the circle the CO_2-laser beam machine shall be programmed to perform one and a half circle (540 °). Calculations shall be based on the segmental arches 90 ° to 450 °, i.e. the first and the last 90° segment of the 540 ° run are not taken into account.

5.5 Test work piece

The trajectory exactness of a CO_2-laser beam machine may, as an alternative, be checked with a test work piece, if the parties agree.

Work piece geometry, material, material thickness and cutting speed as well as the limits of the specifications shall be agreed upon.

Bibliography

ISO 230-2, *Test code for machine tools — Part 2: Determination of accuracy and repeatability of positioning numerically controlled axes.*

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