

Industrial robots —

Part 4: Performance criteria and testing —

Section 4.1 Methods for comprehensive testing

The European Standard EN 29283:1992 has the status of a British Standard

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Committees responsible for this British Standard

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- Advanced Manufacturing Technology Research Institute
- British Computer Society
- British Robot Association
- Department of Trade and Industry (National Engineering Laboratory)
- Department of Trade and Industry
- ERA Technology Ltd.
- EEA (the Electronics and Business Equipment Association)
- Health and Safety Executive
- Institution of Mechanical Engineers
- Loughborough University of Technology
- Society of British Aerospace Companies Limited
- Society of Motor Manufacturers and Traders Limited
- The Welding Institute
- University of Surrey

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National foreword

This Section of BS 7228 has been prepared under the direction of the Advanced Manufacturing Technology Standards Policy Committee and is identical with ISO 9283 “*Manipulating industrial robots — Performance criteria and related testing methods*” including Amendment 1 published by the International Organization for Standardization (ISO).

In 1992 the European Committee for Standardization (CEN) accepted ISO 9283:1990 including Amendment 1:1991 as European Standard EN 29283:1992.

Amendment 1 provides a guide for the selection of essential robot tests for typical applications.

This Section of BS 7228 has been prepared as a result of international discussion in which the UK took an active part.

BS 7228 will be published in Parts and Sections. Whilst not essential, it is recommended that each Part of the standard should be read with reference to the others. The list of Parts currently published or in preparation is as follows.

- *Part 1: Glossary of terms;*
- *Part 2: Guide to definitions of coordinate systems and motions;*
- *Part 3: Specification for the presentation of characteristics by the manufacturer;*
- *Part 4: Performance criteria and testing;*
- *Section 4.1: Methods for comprehensive testing;*
- *Section 4.2: Methods for comparison testing¹⁾;*
- *Part 5: Mechanical interfaces;*
- *Section 5.1: Specification for circular form (form A);*

NOTE Further Sections of Part 5 may follow for other types of mechanical interface.

- *Part 6: Safety¹⁾.*

This International Standard has an introduction which is as follows.

“ISO 9283 is part of a series of International Standards dealing with manipulating industrial robots. Other International Standards cover such topics as safety, general characteristics, coordinate systems, terminology, and mechanical interfaces. It is noted that these International Standards are interrelated and are also related to other International Standards.

ISO 9283 is intended to facilitate understanding between users and manufacturers of robots and robot systems. It defines the important performance characteristics, describes how they shall be specified and recommends how they should be tested. An example of how the test results should be reported is included in Annex A of this International Standard. The characteristics for which test methods are given in this International Standard are those considered to affect robot performance significantly.

The selection of tests given in this International Standard is not addressed by the standard; it is intended that the user of this International Standard selects which performance characteristics are to be tested, in accordance with his own specific requirements.

The tests described in this International Standard may be applied in whole or in part, depending upon the robot type and requirements.

Future International Standards will deal with application orientated and comparison testing.

Annex A of this International Standard provides a recommended format of the test report including the minimum required information and the summary of the test results.

¹⁾ In preparation.

Cross-references

International Standard	Corresponding British Standard
	BS 7228 <i>Industrial robots</i>
ISO/TR 8373:1988	Part 1:1989 <i>Glossary of terms</i> (Identical)
ISO 9787:1990	Part 2:1991 <i>Guide to definitions of coordinate systems and motions</i> (identical)

ISO 9946, referred to in the text, is in preparation. When published, it is envisaged that it will be implemented as BS 7228-3.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, the EN title page, page 2, the ISO title page, page ii, pages 1 to 36, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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Descriptors: Mechanics, industrial robots, performance evaluation, specifications, tests, testing conditions

English version

Manipulating industrial robots — Performance criteria and related test methods

(ISO 9283:1990 including Amendment 1:1991)

Robots manipulateurs industriels — Critères de performance et méthodes d'essai correspondantes
(ISO 9283:1990 et Amendment 1:1991 inclus)

Industrieroboter — Leistungskriterien und zugehörige Testmethoden
(ISO 9283:1990 einschließlich Änderung 1:1991)

This European Standard was approved by CEN on 1992-10-15. CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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Foreword

On the proposal of the CEN Central Secretariat, the Technical Sector Board BTS2 has decided by resolutions BTS2 65/1991 and BTS2 C26/1991 to submit the International Standard ISO 9283:1990 “*Manipulating industrial robots — Performance criteria and related test methods*” including Amendment 1:1991 to the formal vote.

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 April 1993, and conflicting national standards shall be withdrawn at the latest by April 1993.

In accordance with the CEN/CENELEC Internal Regulations the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

INTERNATIONAL STANDARD

**ISO
9283**

First edition
1990-12-15

AMENDMENT 1
1991-06-15

Manipulating industrial robots — Performance criteria and related test methods

AMENDMENT 1: Guide for selection of performance criteria for typical applications

*Robots manipulateurs industriels — Critères de performance et méthodes d'essai
correspondantes*

*AMENDEMENT 1: Guide pour le choix des critères de performance pour des
applications typiques*



Reference number
ISO 9283 : 1990/Amd.1 : 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.

Amendment 1 to International Standard ISO 9283 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Sub-Committee SC 2, *Robots for manufacturing environment*.

Introduction

In the introduction to ISO 9283:1990 it is stated that the tests described may be applied in whole or in part, depending upon the robot type and requirements. The selection of tests is made by the users of ISO 9283 in accordance with their own specific requirements.

The aim of this amendment is to give guidance for the selection of essential robot tests for typical applications. Consequently the number of tests may be limited.

Table 1 on page 4 contains a list of some typical robot applications; the essential tests for the different applications have been marked with an “X”.

1 Scope

This International Standard describes methods of specifying and testing the following performance characteristics of manipulating industrial robots:

- unidirectional pose accuracy and pose repeatability;
- multi-directional pose accuracy variation;
- distance accuracy and distance repeatability;
- pose stabilization time;
- pose overshoot;
- drift of pose characteristics;
- path accuracy and path repeatability;
- cornering deviations;
- path velocity characteristics;
- minimum positioning time;
- static compliance.

This International Standard does not specify which of the above performance characteristics are to be chosen for testing a particular robot. The tests described in this International Standard are primarily intended for developing and verifying individual robot specifications, but can also be used for such purposes as prototype testing, type testing or acceptance testing.

This International Standard applies to all manipulating industrial robots as defined in ISO/TR 8373. However, for the purpose of this International Standard the term “robot” means manipulating industrial robot.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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/TR 8373:1988, *Manipulating industrial robots — Vocabulary*.

ISO 9787:1990, *Manipulating industrial robots — Coordinate systems and motions*.

ISO 9946:—, *Manipulating industrial robots — Presentation of characteristics*²⁾.

3 Definitions

For the purposes of this International Standard, the definitions given in ISO/TR 8373 and the following definitions apply.

3.1

cluster

set of attained poses, corresponding to the same command pose, used to calculate the accuracy and the repeatability characteristics (shown diagrammatically in Figure 6)

²⁾ To be published.

3.2**barycentre**

for a cluster of n points, defined by their coordinates (x_j, y_j, z_j) , the barycentre of that cluster of points is the point whose coordinates are the mean values, $\bar{x}$, $\bar{y}$ and $\bar{z}$ calculated by formulae given in 7.2.1

4 Units

Unless otherwise stated, all dimensions are as follows:

— length in millimetres	(mm)
— angle in radians or degrees	(rad) or ($^{\circ}$)
— time in seconds	(s)
— mass in kilograms	(kg)
— force in newtons	(N)
— velocity in metres per second, degrees per second or radians per second	(m/s), ($^{\circ}$ /s) or (rad/s)

5 Abbreviations and symbols

For the purpose of this International Standard, the following abbreviations and symbols apply:

5.1 Basic abbreviations

A	Accuracy
R	Repeatability
v	Variation
F	Fluctuation
d	Drift
P	Pose
D	Distance
T	Path
V	Velocity

5.2 Quantities

a, b, c	Orientation (angular components) about the x -, y -, z -axis
x, y, z	Linear coordinates along the x -, y -, z -axis
n	Number of measurement cycles
m	Number of measurement points along the path
S	Standard deviation
D	Distance between two points
l	Distance between the attained pose and the barycentre of the attained poses
v	Path velocity
AP	Unidirectional pose accuracy
RP	Unidirectional pose repeatability
vAP	Multi-directional pose accuracy variation
AD	Distance accuracy
RD	Distance repeatability
t	Pose stabilization time

dAP	Drift of pose accuracy
dRP	Drift of pose repeatability
AT	Path accuracy
RT	Path repeatability
CR	Cornering round-off error
CO	Cornering overshoot
SPL	Stabilization path length
AV	Path velocity accuracy
RV	Path velocity repeatability
FV	Path velocity fluctuation

5.3 Indices

a, b, c	Indicates an orientation characteristic about the x -, y -, z -axis
x, y, z	Indicates a positioning characteristic along the x -, y -, z -axis
c	Command
i	Indicates the i -th abscissa
j	Indicates the j -th cycle
k	Indicates the k -th direction
h	Indicates the h -th direction
1,2 ...	Indicates the pose number 1,2 ...
e	Corner point
g	Point where the robot performance falls within the specified path characteristics

5.4 Other symbols

C_1 to C_8	Corners of the test cube
E_1 to E_4	Corners of the rectangular plane for the measurement of path characteristics
G	The barycentre of a cluster of attained poses
O_c	Origin of the measurement system coordinates

NOTE 1 Further symbols are explained in the respective subclauses.

6 Performance testing conditions

6.1 Robot mounting

The robot shall be mounted in accordance with the manufacturer's recommendations.

6.2 Conditions prior to testing

The robot shall be completely assembled and fully operational. All necessary levelling operations, alignment procedures and functional tests shall be satisfactorily completed.

Prior to testing, the robot motions shall be restricted to those necessary for setting up the measuring instruments.

The tests shall be preceded by an appropriate warm-up operation, if specified by the manufacturer except for the test of drift of pose characteristics which shall start from cold condition.

If the robot has facilities for adjustment by the user that can influence any of the tested characteristics, the condition used during the test shall be specified in the test report and shall be kept constant during each test.

Table 1 — Guide for selection of performance criteria for typical applications

Criteria to be tested	Reference in ISO 9283	Applications									
		Spot welding	Handling/ loading/ unloading	Assembly		Inspection		Machining/ deburring/ polishing/ cutting	Spray- painting	Arc- welding	Adhesive/ sealing
		a	a	a	b	a	b	b	b	b	b
Unidirectional pose accuracy	7.2.1	X	X	X	X	X	X			X	
Unidirectional pose repeatability	7.2.2	X	X	X	X	X	X			X	
Multi-directional pose accuracy variation	7.2.3		X	X	X	X	X				
Distance accuracy	7.3.2	X ^c	X ^c	X ^c	X ^c	X ^c	X ^c				
Distance repeatability	7.3.3	X ^c	X ^c	X ^c	X ^c	X ^c	X ^c				
Pose stabilization time	7.4	X	X	X	X	X	X				
Pose overshoot	7.5	X	X	X	X	X	X			X	
Drift of pose characteristics	7.6	X	X	X	X	X	X			X	
Path accuracy	8.2				X		X	X	X	X	X
Path repeatability	8.3				X		X	X	X	X	X
Cornering deviations	8.4				X		X	X		X	X
Stabilization path length	8.4.2				X		X	X		X	X
Path velocity accuracy	8.5.2							X	X	X	X
Path velocity repeatability	8.5.3							X	X	X	X
Path velocity fluctuation	8.5.4							X	X	X	X
Minimum positioning time	9	X	X	X	X					X	
Static compliance	10	X	X	X	X			X			
^a Application where pose-to-pose control is normally used. ^b Application where continuous path control is normally used. ^c Only in case of explicit programming.											

6.3 Environmental and operating conditions

The performance characteristics, as specified by the manufacturer and determined by the related test methods in this International Standard, are valid only under the environmental and normal operating conditions as stipulated by the manufacturer.

6.3.1 Operating conditions

The normal operating conditions used in the tests shall be as stated by the manufacturer.

Normal operating conditions include, but are not limited to, requirements for electrical, hydraulic and pneumatic power, power fluctuations and disturbances, maximum safe operating limits (see ISO 9946).

6.3.2 Environmental conditions

6.3.2.1 General

The environmental conditions used in the tests shall be as stated by the manufacturer, subject to the requirements of 6.3.2.2.

Environmental conditions include temperature, relative humidity, electromagnetic and electrostatic fields, radio frequency interference, atmospheric contaminants, and altitude limits.

6.3.2.2 Testing temperature

Where the ambient temperature of the testing environment can be controlled; it shall be maintained at

- a) $(20 \pm 2) ^\circ\text{C}$; or
- b) $(\theta \pm 2) ^\circ\text{C}$;

where

- 1) $\theta ^\circ\text{C}$ is between $5 ^\circ\text{C}$ and $40 ^\circ\text{C}$;
- 2) $\theta ^\circ\text{C}$ is as stated by the manufacturer.

Where the ambient temperature of the testing environment is not $20 ^\circ\text{C}$ it shall be stated in the test report.

The robot and the measuring instruments shall have been in the test environment long enough (preferably overnight) so that they are in a thermally stable condition before testing. They shall be protected from draughts and external thermal radiation (e.g. sunlight, heaters).

6.4 Displacement measurement principles

The measured position and orientation data (coordinates $x_j, y_j, z_j, a_j, b_j, c_j$) shall be expressed in a coordinate system, the axes of which are parallel to those of the base coordinate system (see ISO 9787).

The measurement point shall lie at a distance from the mechanical interface as specified by the manufacturer. The position of this point in the mechanical interface coordinate system (see ISO 9787) shall be recorded (see Figure 5).

The sequence of rotation used when calculating the orientation deviation shall either be rotation about moving axes Z, Y', X'' or rotation about stationary axes X, Y, Z .

Wherever possible, a non-contact measurement method shall be used.

When a part of the measuring instrumentation is attached to the robot, its mass and position shall be considered as part of the test load.

Unless otherwise specified, the measurements shall be taken after the attained pose is stabilized.

For path characteristics measurements, the data acquisition equipment sampling rate shall be high enough to ensure that an adequate representation of the characteristics being measured is obtained.

6.5 Instrumentation

The measuring instruments used for the tests shall be calibrated and the uncertainty of measurement shall be estimated and stated in the test report. The following parameters should be taken into account: instrumentation errors including repeatability and freedom from bias; systematic errors associated with the method used; calculation errors. The total uncertainty of measurement shall not exceed 25 % of the magnitude of the characteristic under test.

6.6 Load to the mechanical interface

All tests shall be executed at 100 % of rated load conditions (mass, position of centre of gravity, moments of inertia) according to the manufacturer's specification.