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Manipulating industrial robots — EMC test methods and performance evaluation criteria — Guidelines

Robots manipulateurs industriels — Méthodes d'essai EMC et critères d'évaluation de performance — Lignes directrices

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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 members 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.

The main task of technical committees is to prepare International Standards. In exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful

ISO/TR 11062, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 2, *Robots for manufacturing environment*

This document is being issued in the type 2 Technical Report series of publications (according to subclause G.4.2.2 of part 1 of the ISO/IEC Directives, 1992) as a "prospective standard for provisional application" in the field of electromagnetic compatibility applied to robots because there is an urgent need for guidance on how standards in this field should be used to meet an identified need.

This document is not to be regarded as an "International Standard". It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the ISO Central Secretariat.

A review of this type 2 Technical Report will be carried out not later than two years after its publication with the options of: extension for another two years; conversion into an International Standard; or withdrawal.

Annex A forms an integral part of this Technical Report.

Annexes B, C and D are for information only.

Introduction

In the past, electromechanical devices and systems were generally not sensitive to electromagnetic disturbances (i.e. conducted electric, electrostatic and radiated electromagnetic disturbances).

The electronic components and equipment now in use are much more sensitive to these disturbances, particularly "high frequency" and "transient" phenomena.

In addition, electronic components and equipment are themselves source of electromagnetic interferences.

The increasing occurrence of malfunctions or damage caused by electromagnetic disturbances is typically correlated to the increasing usage of the electronic devices.

These guidelines deal with the selection of appropriate electromagnetic compatibility (EMC) tests applicable to manipulating industrial robots, which are complex and sophisticated electronic devices with several degrees of freedom.

Some basic performance criteria defined in ISO 9283 are applied to evaluate the EMC behaviour of the robot. The robot control check is also included to evaluate the electrical characteristics of the robot control system.

This Technical Report is also related to ISO 10218 because some safety aspects are very close to EMC.

Manipulating industrial robots — EMC test methods and performance evaluation criteria — Guidelines

1 Scope

This Technical Report provides guidelines on how to apply the already existing Electromagnetic Compatibility (EMC) International Standards for testing electromagnetic influences on the performance of manipulating industrial robots.

The existing EMC Standards do not specifically address test methods for robots and the intention of this Technical Report is to define appropriate testing procedures for robots in their normal working environment and applications and to provide guidance for the evaluation of the test results.

In addition, these guidelines are useful for evaluating the safety of manipulating industrial robots affected by electromagnetic disturbances.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report 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 8373:1994, *Manipulating industrial robots — Vocabulary.*

ISO 9283:1990, *Manipulating industrial robots — Performance criteria and related testing methods.*

ISO 9283:1990/Amd.1:1991, *Manipulating industrial robots — Performance criteria and related testing methods — Amendment 1: Guide for selection of the performance criteria for typical robotic applications.*

IEC 1000-1-1:1992, *Electromagnetic compatibility (EMC) — Part 1. General — Section 1: Application and interpretation of fundamental definitions and terms.*

IEC 1000-4-1:1992, *Electromagnetic compatibility (EMC) — Part 4: Testing and measuring techniques — Section 1: Overview of immunity tests.*

IEC CISPR Publication 11:1990, *Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment.*

IEC CISPR Publication 22:1985, *Limits and methods of measurement of radio interference characteristics of information technology equipment.*

3 Definitions

For the purposes of this Technical Report, the definitions given in ISO/TR 8373 and IEC 1000-1-1, and the following definitions, apply.

3.1 manipulating industrial robot; robot: Automatically controlled, reprogrammable, multi-purpose, manipulative machine with several degrees of freedom, which may be either fixed in place or mobile for use in industrial automation applications.

3.2 electromagnetic environment: Totality of electromagnetic phenomena existing at a given location.

3.3 electromagnetic disturbance: Any electromagnetic phenomenon which may degrade the performance of a device, equipment or system.

3.4 electromagnetic interference; EMI: Degradation of the performance of a device, transmission channel or system caused by an electromagnetic disturbance.

NOTE 1 Disturbance and interference are respectively cause and effect

3.5 electromagnetic compatibility; EMC: Ability of equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances to anything in that environment.

3.6 (electromagnetic) compatibility level: Specified maximum electromagnetic disturbance level expected to be impressed on a device, equipment or system operating in particular conditions.

NOTE 2 In practice the electromagnetic compatibility level is not an absolute maximum level but may be exceeded by a small probability.

3.7 (electromagnetic) emission: Phenomenon by which electromagnetic energy emanates from a source.

3.8 immunity (to a disturbance): Ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

3.9 (electromagnetic) susceptibility: Inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

NOTE 3 Susceptibility is a lack of immunity.

4 Units of measurement

The units of measurement adopted in this Technical Report are in accordance with ISO 9283 and ISO 9946.

In addition, unless otherwise stated, all quantities in EMC are given in SI units, their decimal multiples or submultiples.

NOTE 4 The level difference of a field is defined as 1 dB (decibel) when $10 \lg \frac{W_1}{W_2} = 1$ where W_1 and W_2 are amplitudes of that field.

If W_1 and W_2 are electrical power levels, a level difference of 1 dB may also be defined as when $20 \lg \frac{V_1}{V_2} = 1$ or $20 \lg \frac{A_1}{A_2} = 1$ where V_1 and V_2 are voltages measured over the same impedance and A_1 and A_2 are currents measured over the same impedance.

5 Requirements for the testing conditions

5.1 Environmental conditions

The environmental conditions adopted as reference for testing activities shall be reported. Any changes of settled environmental parameters shall be made in accordance with the manufacturer and included in the test report.

The recommended values of the typical environmental parameters controlled in a laboratory (temperature, atmospherical pressure and relative humidity) are based on IEC 801.

The climatic conditions shall be maintained at the following values during EMC tests:

a) ambient temperature of between 15 °C and 35 °C;

b) relative humidity of between 10 % and 75 % (between 30 % and 60 % during the electrostatic discharge test);

c) atmospheric pressure of between 86 kPa and 106 kPa (between 860 mbar and 1 060 mbar).

Electromagnetic environment conditions shall not influence the test results.

Electromagnetic emission measurements, particularly those ones related to the radiated field emitted by the robot (radiated emission tests), are normally performed in electromagnetically screened anechoic rooms in accordance with the standard requirements regarding the usage of a test site free from objects reflecting the electromagnetic field in the measurement frequency range.

Proper broadband pyramidal absorbers mounted on nearly all the surfaces of a screened room can ensure that reflections and resonances are controlled from very low frequencies (i.e. 30 MHz) in such a screened and also anechoic room.

Conducted emission tests that measure the currents generated by the robot on its cables (mains, signal or control cables) are normally performed in a screened or anechoic room.

Screened rooms are used to protect the test site from the electromagnetic field outside, that is the field generated by sources located out of the test room and whose contribution, when it is not eliminated, makes the measurement incorrect and unrepeatable.

For this reason, before each emission test, IEC CISPR Publications require that a preliminary "environmental noise" measurement be carried out that is lower than the CISPR limits.

In addition, during radiated emission tests it is necessary to carefully determine the robot configuration and its operating state that are related to the robot maximum radiated and conducted electromagnetic emission.

Radiated immunity tests that measure the effect of fields on the correct operation of the robot are performed in test sites where the required field uniformity shall be achieved at all measurement frequencies.

For the safety of the test operators, who must be protected from the high frequency and high intensity electromagnetic fields generated inside the test site, at least a screened room is necessary, even if open sites are acceptable in less populated sections of the country, providing legal limits are met.

In partially lined screened rooms, which are screened rooms modified with a quantity of radio frequency (RF) absorbing material employed to damp typical resonances in unlined rooms, performing radiated immunity tests is allowed, provided that a uniform field can be established.

On the other hand, considering the size of a robot, to reach a better field uniformity during radiated immunity tests on robots the use of a screened anechoic room is recommended, even if partially lined screened rooms are less expansive than the anechoic rooms.

Figure 1 shows the layout of a screened anechoic room suitable for performing EMC tests on robots. Besides an anechoic room, some contiguous screened rooms are usually used to leave the test instrumentation and the equipment interacting with the robot during the radiated immunity tests.

In addition, the uniformity of the generated electromagnetic field is improved using proper antennas (i.e. a multiwire transmission line) and adopting an appropriate test setup.

5.2 Robot operating conditions

The robot shall be correctly installed (electric and mechanical installation) and fully operational (starting up and functional tests) in accordance with the manufacturer's recommendations.

Before each EMC test, it is very important to define the configuration of the robot specifying the I/O states, its possible connection with some external equipment or any information useful in better identifying the robot.

In this way, during EMC tests it is possible to evaluate the behaviour of a robot in its "basic configuration", i.e. the simplest and the most reproducible configuration.

6 Test methods

6.1 Robot characterization without electromagnetic disturbances

Carry out path repeatability or pose repeatability tests in accordance with ISO 9283 to characterize the robot without EMC disturbances.

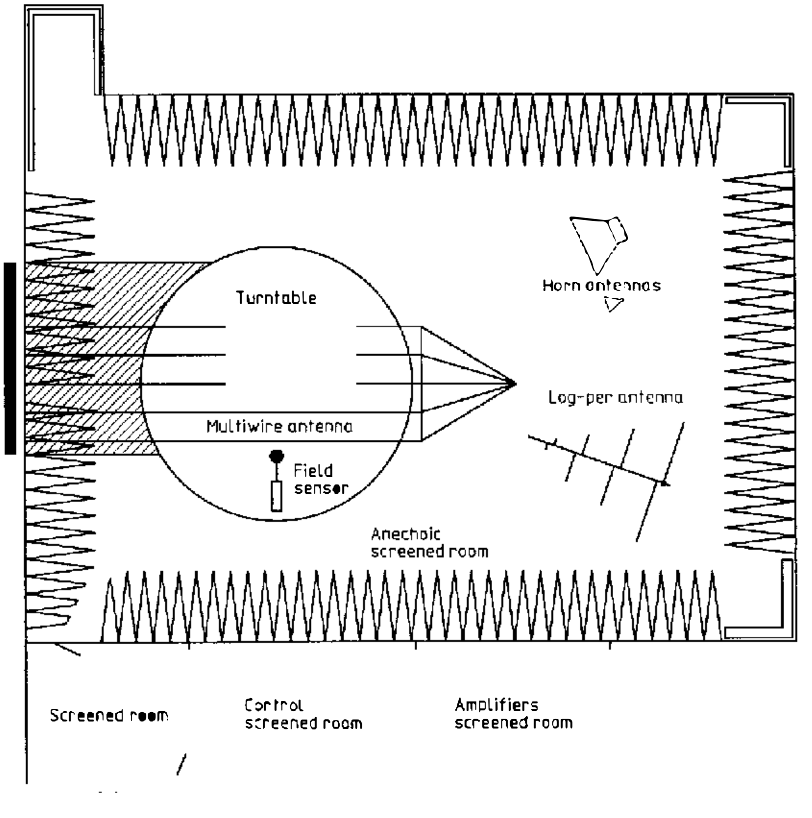


Figure 1 — Layout of a screened anechoic room

Tests shall be performed at nominal load and at *maximum* velocity.

The results of these tests give the robot performance reference values when it is working according to the manufacturer's technical specifications. It is possible to evaluate the EMC test results by comparing these results with those obtained in the same configuration during EMC tests.

6.2 Electromagnetic compatibility tests on robots: evaluation criteria

During EMC tests, the robot is configured in several "operating states" to obtain the greatest quantity of information about the behaviour of the robot subjected to electromagnetic influences.

Tests shall be performed at least in the states given in table 1.

Table 1

Operating state	Definition
1	Control system switched on, with the robot arm power off
2	Robot arm power on and stopped in the automatic mode
3	Robot arm power on, operating under the path control and returning into a programmed point in the teach programming mode
4	Robot arm power on, operating under the path control and returning into a programmed point in the automatic mode

Consequently, during the EMC tests on the robot operating in each of the above-mentioned states, the following robot performance shall be checked:

a) robot motion check in accordance with the criteria established in 6.1;

b) robot control check (serial lines, monitor and/or display, system I/O, user I/O).

In the IEC Standards relating to immunity tests, some definitions are given about the malfunction evaluation criteria.

Nevertheless, these criteria can be substituted by those established in the robot manufacturer's specification.

Test evaluation criteria, in accordance with the IEC classification and applicable to robots, are given in table 2.

During the execution of each EMC test, it is useful to report the possible malfunctions that have been found in two tables (from the least to the most serious, as listed in table 2) in each "operating state" of the robot (as defined in table 1). Examples of suitable tables are given as tables B.1 and B.2.

Table 2

Malfunction criterion	Definition
a	Normal performance within the specification limits (no fault)
b	Temporary acceptable loss of one or more functions (minor fault)
c	Temporary degradation or loss of function or performance that the robot under test is able to self-recover (greater fault)
d	Temporary degradation or loss of function or performance which requires operator intervention at least to switch off and start up the robot (critical fault)
e	Degradation or permanent loss of function or performance that the robot is unable to recover due to both hardware and software damages (damage)

The final test result is determined by the most serious malfunction that happened in a state, considering both tables.

Maintenance of robot performance during both the EMC test and the robot performance check after the EMC test constitutes a successful test. This procedure is mandatory for the EMC test result evaluation.

The main robot malfunctions that can occur are the following:

— incorrect displacements (velocities higher or lower than the imposed ones, including abnormal stop; execution of unprogrammed paths; positioning errors);

— communication errors;

— incorrect robot I/O state;

— errors on programming terminal display (but if errors consist only of "flickering" and do not cause difficulties in practical use of the terminal they are considered acceptable).

6.3 List of possible electromagnetic compatibility tests on robots

Possible EMC tests for robots are as follows:

a) Electrostatic discharge immunity tests

Tests concerning contact and air electrostatic disturbances in accordance with IEC 801-2.

b) Radiated/conducted electromagnetic fields immunity tests

Tests concerning electromagnetic fields generated in the frequency range 80 MHz to 1 GHz (80 % amplitude, 1 kHz sinusoidal modulation) in accordance with IEC 1000-4-3. For lower frequencies (up to 9 kHz), conducted immunity tests are preferred to radiated tests (see IEC 801-6).

c) Electrical fast transient/bursts immunity tests

Tests concerning short rise time (5 ns), spike duration 50 ns, low energy and high repetition rate transients, due to interruption of inductive loads or relay contacts bounce, conducted in accordance with IEC 801-4.

d) Surge immunity tests

Tests concerning induced voltage surge (1,2 µs/50 µs) caused by switching phenomena or faults in the power network and lightning stroke, conducted in accordance with IEC 1000-4-5.

e) Harmonics immunity tests

Tests concerning network frequency harmonics conducted in accordance with IEC 1000-4-1 (see IEC 1000-2-1 and IEC 1000-2-2 for the definition and the compatibility levels).

f) Ring wave immunity tests

Tests concerning oscillatory transients (100 kHz/0,5 µs) conducted in accordance with IEC 1000-4-1. This test is complementary to the surge test.

g) Damped oscillatory waves immunity tests

Tests concerning 0,1 MHz and 1 MHz damped oscillatory transients (the rise time of both waves is 75 ns) conducted in accordance with IEC 1000-4-1. The 100 kHz damped oscillatory wave test is complementary to the surge test, but it is similar to the ring wave test with only a shorter rise time. Therefore ring wave is an alternative to the 100 KHz damped oscillatory wave with less severe requirements.

h) High frequency induced continuous waves voltages immunity tests

Tests concerning high frequency induced voltages in the frequency range 0,01 MHz to 1 MHz conducted in accordance with IEC 1000-4-1.

i) Voltage dips and short interruptions immunity tests

Immunity tests concerning power supply voltage dips and short interruptions conducted in accordance with IEC 1000-4-1 (see IEC 1000-2-1 and IEC 1000-2-2 for the definition and the compatibility levels).

j) Conducted emission measurements

Measurements in the frequency range 0,15 MHz to 30 MHz in accordance with CISPR 11 and CISPR 22.

k) Radiated emission measurements

Measurements in the frequency range 30 MHz to 1 GHz in accordance with CISPR 11 and CISPR 22.

All the above-mentioned conducted immunity tests are applicable to the robot control system power supply lines. In addition, fast transients immunity tests can be performed on the input/output control circuit and signal lines.

Electrostatic discharge immunity tests are applicable only outside the robot working space.

The whole robot, manipulator inclusive of the control system, has to be tested during electromagnetic fields immunity tests and radiated emission measurements.

Among the above-mentioned tests, some of them can be considered essential to a preliminary EMC characterization of the robot.

On the basis of testing experience, the following EMC tests shall be considered as mandatory for a robot:

— electrostatic discharges immunity tests;

— electrical fast transients/bursts immunity tests;

— voltage dips and short interruptions immunity tests;

— surge immunity tests.

If these tests are successfully passed, it means that the correct performance maintenance of the robot subjected to some of the most common and dangerous electromagnetic disturbances has been proved and the occurrence of possible malfunctions during its normal working is drastically decreased.

Further EMC test requirements shall be in agreement with the manufacturer, who shall take into account both the typology of the typical robot application and the electromagnetic environment where the robot under test is foreseen to work.

More details are given about the above-mentioned EMC tests in annex A.

6.4 Suggested levels of electromagnetic compatibility tests on robots

EMC test levels (severity levels) shall be selected on the basis of the electromagnetic environment where the robot under test is destined to operate.

The definition of electromagnetic environment (see 3.2) is discussed in IEC 1000-1-1. It is pointed out that "the totality of electromagnetic phenomena existing at a given location" means that "an" environment is considered instead of "every" environment.

As a consequence, if a device has the property of being electromagnetically compatible in a particular environment it does not mean that it will be electromagnetically compatible in another environment.

In most cases the properties of the electromagnetic environment are never 100 % predictable because they are location-dependent and time-dependent.

This is a very critical point because it requires at least to identify which kind of electromagnetic fields and disturbances are generated by equipment or devices inside the environment under consideration. Only after this check is it possible to identify in which electromagnetic environment the robot is really working.

Therefore, collecting data and information about the environment is necessary, but if data are insufficient, an experimental investigation, normally rather expensive, is performed.

In addition, the definition of EMC (see 3.5) refers to "the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances to anything in that environment".

This means that not only equipment, devices or systems are involved, but also living creatures: this is an important aspect when emission limits are set to electromagnetic fields, to achieve EMC.

On the other hand, well known and defined environmental characteristics can become a guide for designing robots that are immune from EMC disturbances regarding the actual environment and, at the same time, are unable to introduce disturbances in their operating environment.

In addition to the environmental conditions, the proper choice of EMC test levels depends on numerous factors, mainly:

- kinds of disturbances affecting the equipment;
- required reliability and behaviour;
- economical constraints.

These factors are connected together because, for example, very high reliability requirements are normally contrary to economical constraints.

Recently, some electromagnetic environments models have been defined by IEC 1000 in order to apply the same EMC requirements to all the equipment working in similar places and to provide the data necessary to identify the environment from an electromagnetic point of view.

The typical working environment of a manipulating industrial robot is light or heavy industry, where power is distributed by an industrial low-voltage distribution network with a dedicated distribution transformer usually located near or inside the plant. Low-voltage a.c. distribution systems are characterized by a nominal voltage up to 240 V single-phase, or up to 415 V three-phase, and a nominal frequency of 50 Hz or 60 Hz. In heavy industrial environments low voltage a.c. distribution systems can reach 1 kV.

According to IEC 1000, the major contributors to the industrial environment are the presence of one or more of the following conditions:

- industrial, scientific and medical (ISM) apparatus, e.g. welding machines, are present;
- heavy inductive or capacitive loads are frequently switched;
- currents and associated magnetic fields are high.

In addition to the industrial environment, a robot could even work in hostile electromagnetic environments such as high voltage substations.

In this situation it is necessary to know or to measure the level of the electromagnetic disturbances generated by the hostile environment because there are no suitable reference models which can describe the so-called "special" environments.

As the EMC test level is related to the environmental class level, IEC 1000-4-1 indicates that:

- the values of the EMC disturbances to apply to the robot under test shall be selected among those that are typical of the industrial environment, that are related to test level 3;
- test level 4 shall be applied only in particular critical situations;
- the special level X shall be applied only if robots are destined to very hostile environments.

The test level value can be reduced if it is declared that the environment where the robot will work is less critical than the industrial environment model.

6.5 Recommended tests related to some robotic applications

Table 3 gives a correlation between the main robot applications and the applicable EMC tests selection criteria.

Moreover, it gives some indications on the chosen values of each EMC test according to the suitable electromagnetic environmental model.

Table 3

	Robot applications						
	Spot welding	Handling, loading, unloading	Assembly, inspection	Machining, deburring, polishing, cutting	Spray painting	Arc welding	Adhesive sealant
Subclause in ISO 9283:1990	7.2.2	7.2.2	7.2.2 and 8.3	8.3	8.3	8.3	8.3
	EMC test level values recommended						
Electrostatic discharges, kV[1]:							
— contact discharge	6	6	6	6	—	6	6
— air discharge	8	8	8	8		8	8
Electromagnetic radiated fields, V/m	10	—[2]	—[2]	10	10	10	10
Fast transient, kV:							
— power supply	2	2	2	2	2	2	2
— continuous and signal	1	1	1	1	1	1	1
Induced voltage surge, kV[3]	2 to 4	2 to 4	2 to 4	2 to 4	2 to 4	2 to 4	2 to 4
Harmonics THD, %	10	10	10	10	10	10	10
Ring wave, kV	2	2	2	2	2	2	2
Damped oscillatory wave, kV	2	2	2	2	2	2	2
HF induced continuous waves voltage,V	50	50	50	50	50	50	50
Voltage, ms[4]:							
— dips (−20 %)	50	50	50	50	50	50	50
— short interruptions (−100 %)	20	20	20	20	20	20	20

1) Test values reported are equal to test level 3; remember to check the relative humidity value and the presence or the absence of synthetic materials to increase, if necessary, the test level.

2) When in the environment a moderate electromagnetic radiation is present, that is when low power (less than 1 W rating) portable transceivers are used but with restrictions on their use in close proximity to the robot, it is advisable to perform the test at a field level value of 3 V/m (that means at the test level 2).

3) The recommended test levels are located between level 3 and level 4 established in IEC 1000-4-1.

The test level selection depends greatly on the type of connection between the robot and the outdoor environment. For example, interconnecting cables running as outdoor cables can be subjected to interference voltages generated by lightning if the outdoor environment is insufficiently protected.

It is suggested to apply test level 4 (4 kV) if the installed robot is insufficiently protected from lightning.

4) The reported test levels are applicable to electrical and electronic parts of the robot whose rated current is up to 16 A per phase. Higher currents robots shall be tested, reducing the duration of the power voltage short interruption (for example 10 ms).

Main robot applications included in table 3 come from ISO 9283:1990/Amd.1, which contains the requirements for robot performance assessment and gives criteria to select essential robot performance tests for some typical robot applications.

It specifies two robot applications classes, i.e.

— if the application normally requires a pose-to-pose control, it is necessary to perform at least pose repeatability tests (see ISO 9283:1990, subclause 7.2.2);

— if the application normally requires a continuous path control, it is necessary to perform at least path repeatability tests (see ISO 9283:1990, subclause 8.3).

The advantage of this method is that it reduces the quantity of tests that are necessary to characterize the robot performance for specific applications. In addition, this method allows to select which robot performance verification is better to apply to evaluate the EMC tests.

The recommended EMC test levels in table 3, which are almost all equal to the test level 3, are given as voltage peak values unless otherwise stated.

Table 3 is a guide for selection of EMC tests in relation to the main robot applications, with some indications about test levels.

Table 4 refers to both conducted and radiated emission tests appicable to robots. Test levels shall be selected taking into consideration whether devices or living creatures near the robot are protected or not from electromagnetic disturbances generated by the robot. Emission levels are chosen in accordance with IEC/CISPR 11 indications. The main robot applications in table 4 are classified into four relevant areas: RF excited arc welding; non RF excited arc welding; spot welding; others.

It is important to note that some values given in table 4 are still under consideration; e.g. there are two types of arc welding applications, TIG and MIG, which should be further analysed.

Further experimental verifications will be done to update tables 3 and 4.

Table 4

	Robot applications					
	RF excited arc welding	Non-RF excited arc welding	Spot welding	Others[1)]	Spray painting	Adhesive sealant
Subclause in ISO 9283:1990	8.3	8.3	7.2.2	7.2.2 and 8.3	8.3	8.3
	EMC test level values recommended					
Conducted emissions	ISM Group 2 class A too restrictive. Limits are under consideration.	ISM Group 2 class A	ISM Group 2 class A	ISM Group 1 class A	ISM Group 2 class A	ISM Group 2 class A
Radiated emissions	ISM Group 2 class A too restrictive Limits are under consideration.	ISM Group 2 class A	ISM Group 2 class A	ISM Group 1 class A	ISM Group 2 class A	ISM Group 2 class A

1) "Others" means Handling, Loading, Unloading, Assembly, Inspection, Machining, Deburring, Polishing, Cutting robots. These robots are classified in the ISM group 1 class A unless some specific applications are proved to be included in the ISM group 2 class A as reported in IEC CISPR Publication 11, annex A detailed list.

Annex A
(normative)

Suggestion for EMC tests execution on robots

In this annex, the EMC tests reported in 6.3 are discussed. In addition, mandatory tests like electrostatic discharges, fast transients voltage dips and short interruptions and surge are thoroughly considered.

A.1 Immunity tests concerning electrostatic discharges

Electrostatic discharges (ESD) can influence the operation of the robot or damage its electronic circuit either by a direct effect or indirectly by inductive coupling or radiation.

ESD shall be applied only to such points and surfaces of the robot which are normally accessible to the test operator and which are outside the robot working space.

In addition, tests shall be also carried out on connectors, serial and I/O ports located on the control system, provided that they are accessible outside the control system.

Direct application of discharges consists of single discharges applied between the selected test points and earth.

To perform the test, at least 10 discharges (positive and negative) with intervals of at least 1 s between successive discharges are applied.

The points to which discharges are to be applied may be selected by an exploration with 20 discharges per second.

To simulate discharges between objects in the proximity of the robot, the discharge is applied to the ground plane or to a metal plate 50 cm x 50 cm around the robot (located 10 cm from it).

Figures A.1 and A.2 show the typical ESD waveform and generator diagram.

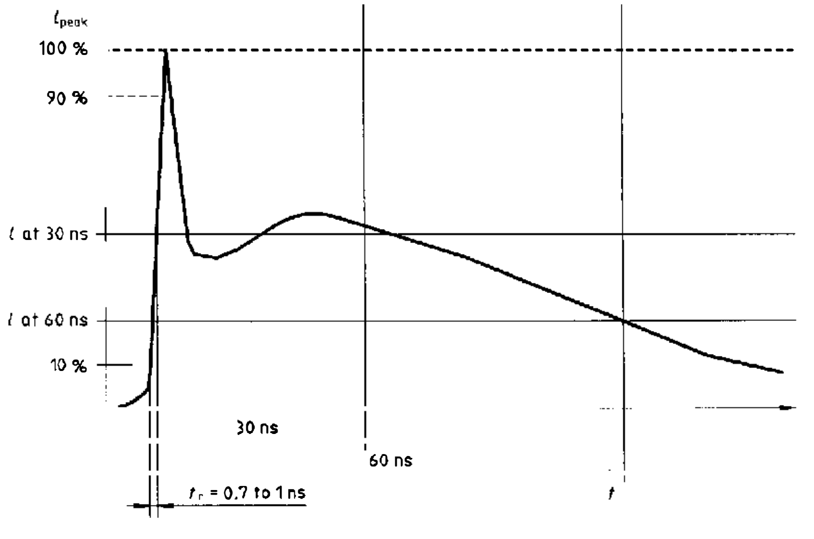
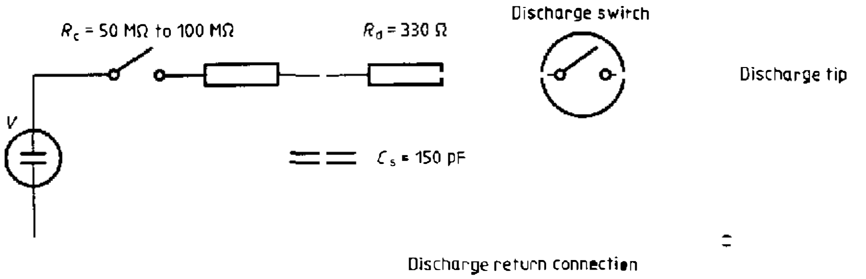


Figure A.1 — Typical waveform of the output current of the ESD generator



V	is the high-voltage source	(16,5 kV)
R_c	is the charging resistor	(50 MΩ to 100 MΩ)
C_s	is the energy storage capacitor	(150 pF)
R_d	is the discharge resistor	(330 Ω)

Figure A.2 — Simplified diagram of the ESD generator

A.2 Immunity tests concerning electromagnetic fields

Radio transmitters or any other device emitting continuous wave-radiated electromagnetic energy generate electromagnetic fields.

Even if the immunity of robots to the radiation of hand-held transceivers (walkie-talkies) is one of the main concerns, other sources of electromagnetic fields, such as fixed-station, radio and transmitters, vehicle radio transmitters and various industrial electromagnetic sources or intermittent sources are to be considered.

In order to obtain reproducible results, tests shall be carried out in a suitable test site (see 5.1).

The choice of the robot performance measurement system is a critical point; the susceptibility of the measuring system shall also be verified.

A.3 Immunity tests concerning conducted disturbances

Surge withstand tests, in addition to dielectric strength and insulation resistance tests, shall be carried out for safety purposes and performed before any other immunity test on the unenergized robot.

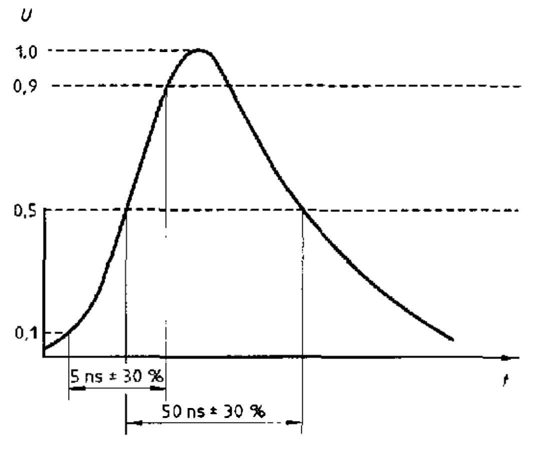
Low- and high-frequency conducted immunity tests are recommended to be performed using both a pulse generator and a robot performance measurement system equipped with a trigger to monitor the synchronism of the events.

Fast transients, voltage dips and short interruptions, and surge immunity tests, from the list of conducted immunity tests listed in 6.3, are discussed in detail in this clause because they are considered mandatory.

A.3.1 Fast transients

The significant characteristics of these transients are the fast rise time (5 ns), short duration (50 % pulse duration is 50 ns) and low energy but high repetition rate (5 kHz or 2,5 kHz).

The test is performed with repetitive bursts of short pulses as shown in figures A.3 and A.4.



NOTE — 1 = 100 %

Figure A.3 — Waveform of a single spike into 50 Ω load

A schematic representation of the test generator is shown in figure A.5.

The test voltage shall be applied to:

— power supply lines (in common mode between each of the power supply terminals and the nearest protective earth point or reference ground plane);

— control and signal lines and communications lines (in common mode preferably with the capacitive coupling clamp).

The minimum duration of the test is 1 min.

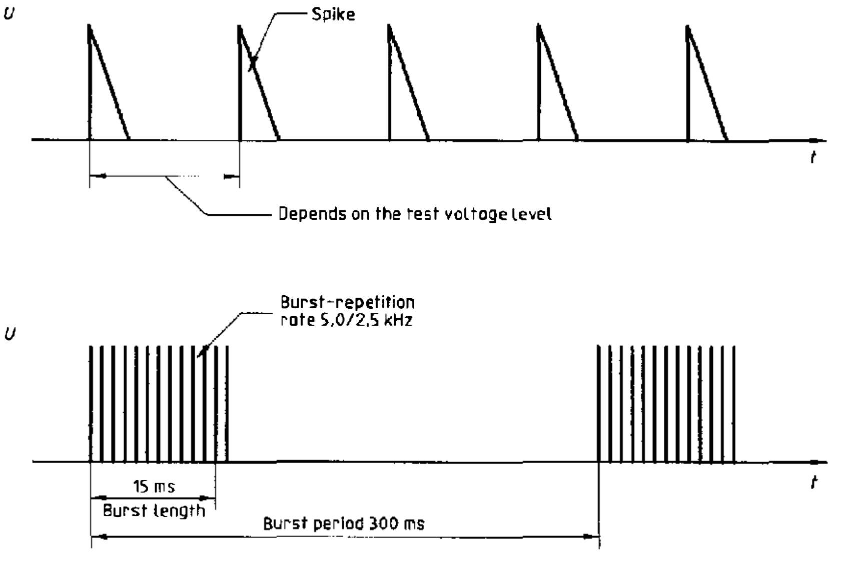
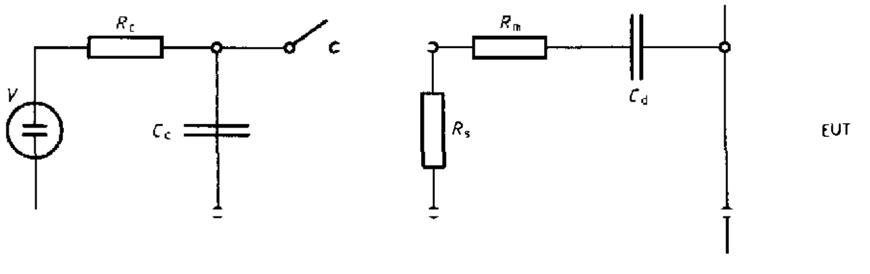


Figure A.4 — General graph of a fast transient



V is the high-voltage source

R_c is the charging resistor

C_c is the energy storage capacitor

R_s is the pulse duration shaping resistor

R_m is the impedance matching resistor

C_d is the d.c. blocking capacitor

Figure A.5 — Fast transient generator

A.3.2 Voltage dips and short interruptions

The purpose of the test is to verify the immunity of the robot to voltage dips and short interruptions caused by faults in low-voltage, medium-voltage and high-voltage networks (short circuits or ground faults) or by faults switching rapid reclosure.

The robot is initially in operation at its rated voltage and then is subjected to voltage dips or interruption in accordance with figure A.6.

In order to simulate the conditions in certain networks, a test with a cycle of two consecutive dips/interruptions with variable time interval may also be considered.

A robot is normally a three-phase device; in this situation voltage dips shall be applied either on all the three phases simultaneously or on one or two phases only.

A.3.3 Surge

The induced voltage surge, which is caused by switching phenomena or faults in power networks or by lightning strokes, can produce different effects depending on the relative impedance of the source and of the robot (robot impedance higher than the source ones means induced voltage pulse; the opposite situation means an induced current).

Therefore, the test surges should have the following basic characteristics:

— a voltage pulse 1,2/50μs for open circuit generators (see Figure A.7);

— a current pulse 8/20μs for short-circuited generators.

The test generator shall be capable of delivering, in open circuit, a voltage pulse, as well as, in short circuit, a current pulse of the specified forms and magnitudes.

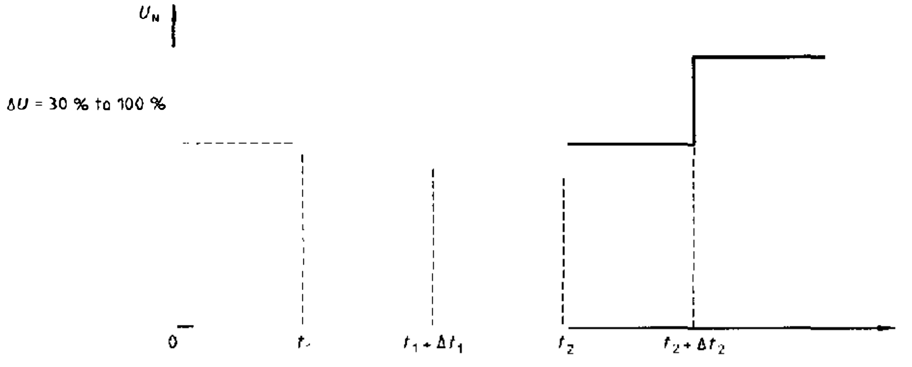
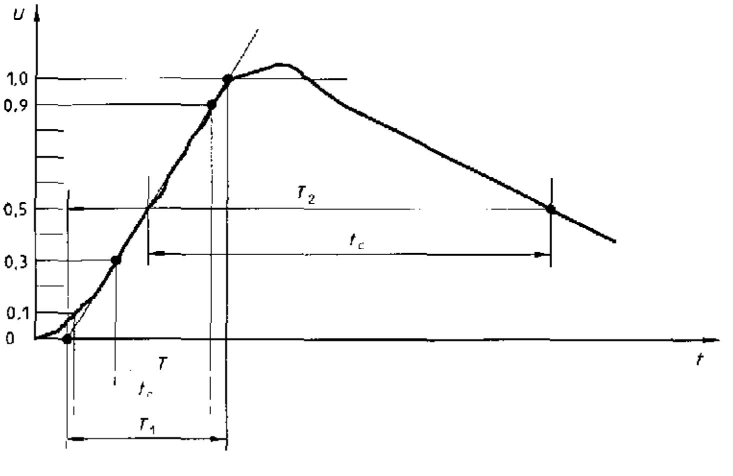


Figure A.6 — Example of a test cycle with two voltage dips



Front time:

T_1 = 1,67 × T = 1,2 μs ± 30 %

Time to half value:

T_2 = 50 μs ± 20 %
T = 0,72μs ± 30 %
t_d = 50 μs ± 20 %
t_r = 1 μs ± 20 %

NOTE — 1 = 100 %

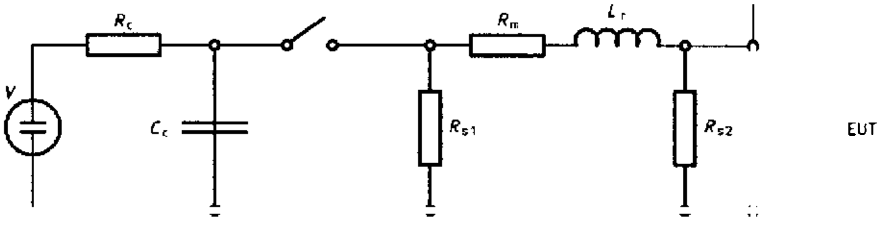
Figure A.7 — Open-circuit voltage waveform

Figure A.8 is a schematic representation of such a "hybrid" circuit.

The test shall be carried out at least five times with each polarity, if possible each time at a different position of the mains voltage wave. The time between two surges depends on the recovery time (built-in) protection (for example repetition rate: one per minute).

A.4 Conducted and radiated emission measurements

To perform these tests on robots, it shall be necessary to determine the robot operating states corresponding to the maximum conducted or radiated emissions.



V is the high-voltage source
R_c is the charging resistor
C_c is the energy storage capacitor
R_s is the pulse duration shaping resistor
R_m is the impedance matching resistor
L_r is the impedance matching inductor

Figure A.8 — Combination wave generator

Annex B
(informative)

Suggestions for the layout of the test report

Tables B.1 and B.2 are suggested layouts for the presentation of EMC test results.

The coding for the operating states is as follows:

1 control system switched on, with the robot arm power off

2 robot arm power on and stopped in the automatic mode

3 robot arm power on, operating under the path control and returning into a programmed point in the teach programming mode

4 robot arm power on, operating under the path control and returning into a programmed point in the automatic mode

The coding for the malfunction criteria is as follows:

a no fault

b minor fault

c greater fault

d critical fault

e damage

Table B.1 — Robot motion check in accordance with the criteria established in 6.1

Robot motion evaluation EMC test:					
Operating states	Malfunction criteria				
	a	b	c	d	e
1	Not applicable				
2					
3					
4					

Table B.2 — Robot control check (serial lines, monitor and/or display, system I/O, user I/O) in accordance with the manufacturer's specification

Robot control evaluation EMC test:					
Operating states	Malfunction criteria				
	a	b	c	d	e
1					
2					
3					
4					

Annex C
(informative)

Some considerations about the EC Directive (89/336/EEC)

During the drawing up of this Technical Report the EC Directive (89/336/EEC) regarding electromagnetic compatibility was published.

In this Technical Report it has been considered opportune to provide information about some data and indications included in the Basic and Generic Standards, European Standard Projects designed to meet the EC Directive Requirements.

European Committee TC 110 CENELEC is collaborating closely with International Technical Committees, especially IEC, to draft Basic Standards, which are essential rules making up the fundamental basis of the EMC set of applicable rules.

Basic Standards are not applicable to any particular product, and test levels and acceptance criteria are not specified in these rules.

Basic Standards include test methodology, test instrumentation and basis test configuration for each EMC disturbance examined.

In particular, some Basic Standards are similar to the IEC 801 and IEC 1000 documents, except for some editorial modifications or for some minor adjustments.

Reference EMC standards published both as IEC and as Basic Standards is given in table C.1.

Table C.1 — Relevant immunity Basic Standards

Basic EMC immunity tests	CENELEC pr ENV	IEC 1000
Surge immunity	pr ENV 50142	1000-4-5
Conducted disturbances induced by RF fields	pr ENV 50141	IEC 801-6
Radiated, radio-frequency electromagnetic fields	pr ENV 50140	1000-4-2

Up to now TC 110 CENELEC Committee has deemed it not necessary to draw up Basic Standards about emission measurements, except for CISPR 16, which contains both test methodology and test instrumentation.

Beside the Basic Standards, TC 110 CENELEC Committee is preparing the Generic Standards, general rules that are applicable to every product that usually operates in a definite environment.

In Generic Standards are provided both a set of specific EMC requirements and a list of tests that must be necessarily performed on the products operating in the same environment.

In particular, different performance criteria (A,B,C) are included in the Generic European Standards relating to immunity: these criteria are quite different from the five IEC criteria reported in 6.2 because Generic Standards are applicable to various and different equipment operating in the same environment.

Criterion A ["The equipment shall continue to operate as intended. No degradation of performance or loss of function is allowed below a specified performance level, when the equipment is used as intended"] is equivalent to the evaluation criteria stated in this Technical Report.

The applicability of the less severe criterion B ["The equipment shall continue to operate as intended after the test. During the test, degradation of performance is however allowed. No change of actual operating state or stored data is allowed"] or C ["Temporary loss of function is allowed, provided the loss of function is self recoverable or can be restored by the operation of the controls"] shall be taken into consideration, in the future, for manipulating industrial robots.

EN 50081-2 and pr EN 50082-2 are reference Generic Standards for the industrial environment.

On the whole, the set of rules applicable to products that are meant for the European Community is similar to the EMC International Standards.

Annex D
(informative)

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1) To be published.

2) To be published. (Revision of IEC 801-3:1984)

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