INTERNATIONAL STANDARD

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Earth-moving machinery — Electromagnetic compatibility

Engins de terrassement — Compatibilité électromagnétique

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13766 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.

This second edition cancels and replaces the first edition (ISO 13766:1999), which has been technically revised.

Introduction

With the increasing use of electronic devices in areas where earth-moving machinery operates, there is a need to ensure that earth-moving machines are provided with adequate immunity to external electromagnetic fields. As more machines are fitted with electrical and electronic devices, it is necessary to ensure that the emissions of electromagnetic fields from the machines meets acceptable limits.

Electrical and high frequency interference emerge during the normal operation of many parts of an earth-moving machine's devices and systems. They are generated within a large frequency range, with different electrical characteristics and, by conduction and/or radiation, can be imparted to other of the machine's electrical/electronic devices and systems. Narrowband signals, generated by sources of interference inside or outside the machine, can also be coupled in electrical/electronic systems whereby they can influence the normal function of electrical/electronic devices.

Electrostatic discharges are relevant to earth-moving machinery because control elements can be positioned outside the operator's station and potential differences can emerge at contact points. Conducted transients in power supply wiring have to be taken into account because earth-moving machinery often represents open systems and several devices and/or components are combined with one another.

While there are many existing standards for a variety of products and systems, the test method presented in this International Standard provides for the specific test conditions of earth-moving machinery and the "electrical/electronic systems or electronic subassemblies" of earth-moving machines. The test method recognizes that because of the size and usage of earth-moving machinery, the arrangement of the machines in the test facility needs to be responsive to the operating characteristics of these types of machines. This International Standard provides test methods and criteria which are acceptable for earth-moving machinery, considering its unique characteristics and operating parameters.

Because earth-moving machines possess a number of systems that consist of components that can be used on a number of different types of machines, the approach of defining "electrical/electronic systems or electronic subassemblies" for these components is applied for the immunity and emissions test methods. This allows these components to be evaluated by the test method in existing laboratory facilities consisting of specially equipped shielded rooms. When electrical/electronic systems or electronic subassembly tests are conducted, it is necessary to consider the effects of the wiring systems used to connect the subassemblies into the earth-moving machinery. The tests may also be conducted on the machines.

This International Standard is intended to provide the necessary technical specifications for evaluating the electromagnetic performance of earth-moving machinery with respect to government electromagnetic performance laws, directives, rules and/or regulations. Such an example is the European Directive 2004/108/EC.

Earth-moving machinery — Electromagnetic compatibility

1 Scope

This International Standard provides test methods and acceptance criteria for the evaluation of the electromagnetic compatibility of earth-moving machinery as defined in ISO 6165. The following electromagnetic phenomena are evaluated:

— broadband and narrowband electromagnetic interference;

— electromagnetic field immunity test;

— broadband and narrowband interference of electrical/electronic subassemblies;

— electromagnetic field immunity test of electrical/electronic subassemblies;

— electrostatic discharge;

— conducted transients.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5353:1995, *Earth-moving machinery, and tractors and machinery for agriculture and forestry — Seat index point*

ISO 6165:2006, *Earth-moving machinery — Basic types — Vocabulary*

ISO 7637-1:2002, *Road vehicles — Electrical disturbance from conduction and coupling — Part 1: Definitions and general considerations*

ISO 7637-2:2004, *Road vehicles — Electrical disturbances from conduction and coupling — Part 2: Electrical transient conduction along supply lines only*

ISO 10605:2001, *Road vehicles — Test methods for electrical disturbances from electrostatic discharge*

ISO 11451-1:2005, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology*

ISO 11451-2:2005, *Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Off-vehicle radiation sources*

ISO 11452-1:2005, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology*

ISO 11452-2:2004, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy —Part 2: Absorber-lined shielded enclosure*

ISO 11452-3:2001, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 3: Transverse electromagnetic (TEM) cell*

ISO 11452-4:2005, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Bulk current injection (BCI)*

ISO 11452-5:2002, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 5: Stripline*

IEC 60050-161:1998, *International Electrotechnical Vocabulary — Chapter 161: Electromagnetic compatibility*

CISPR 12:2004, *Vehicles, boats and internal combustion engine driven devices — Radio disturbance characteristics — Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices*

CISPR 16-1-1:2006, *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-1: Radio disturbance and immunity measuring apparatus — Measuring apparatus*

CISPR 16-1-4:2004, *Specification for radio disturbance and immunity measuring apparatus and methods — Part 1-4: Radio disturbance and immunity measuring apparatus — Ancillary equipment — Radiated disturbances*

CISPR 25:2002, *Radio disturbance characteristics for the protection of receivers used on board vehicles, boats, and on devices — Limits and methods of measurement*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply

3.1
electromagnetic compatibility
EMC
ability of earth-moving machinery, component, electrical/electronic system or electronic subassembly to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

NOTE Adapted from IEC 60050:1998, 161-01-07.

3.2
electromagnetic disturbance
any electromagnetic phenomenon which may degrade the performance of earth-moving machinery, components, electrical/electronic systems or electronic subassemblies

EXAMPLE An electromagnetic disturbance may be electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

NOTE Adapted from IEC 60050:1998, 161-01-05.

3.3
electromagnetic immunity
ability of earth-moving machinery, components, electrical/electronic systems or electronic subassemblies to perform without degradation in the presence of specific electromagnetic disturbances

NOTE Adapted from IEC 60050:1998, 161-01-20.

3.4
electromagnetic environment
totality of electromagnetic phenomena existing at a given location

[IEC 60050:1998, 161-01-01]

3.5
reference limit
limit value with which the production is required to conform

3.6
reference antenna
designated measurement antenna having preferred measurement data that take precedence in the case of a discrepancy, such as between signal strength levels measured with the reference antenna and those measured with any other antenna

3.7
broadband emission
emission which has a bandwidth greater than that of a particular measuring apparatus or receiver

3.8
narrowband emission
emission which has a bandwidth less than that of a particular measuring apparatus or receiver

3.9
electrical/electronic system
electrical and/or electronic components or set of components intended to be part of an earth-moving machine, together with any electrical connections

3.10
electrical/electronic subassembly
ESA
electrical and/or electronic components or set of components intended to be part of an earth-moving machine, together with any associated electrical connections and wiring, which performs one or more specialized functions

3.11
machine type
earth-moving machinery which does not differ in such essential respects as

— structural shape,

— general arrangement of the electrical and/or electronic components and the general wiring arrangement, and

— the primary material of which its design consists (e.g. steel, aluminium or fibreglass covering parts)

3.12
ESA type
electrical/electronic subassemblies which do not differ in such essential respects as

— function performed,

— arrangement of the electrical and/or electronic components, if applicable, and

— the primary material of the casing

3.13
electrostatic discharge
ESD
transfer of electrostatic charge between bodies of different electrostatic potential in proximity or through direct contact

[IEC 60050:1998, 161-01-22]

3.14
conducted transients
transient voltage or current distributed in the power supply wiring of a machine via a conductor between the source of the transient and the receiver

4 Fulfilment of requirements

The requirements of this International Standard are to be met by earth-moving machinery and its electric/electronic subassemblies when the machinery operates in conformity with its final purpose. The user of this International Standard may chose either of the following alternatives to give evidence of conformity with this International Standard.

a) The performance requirements of this International Standard are met if the electrical/electronic systems or electronic subassemblies are in accordance with the applicable criteria of this International Standard and have been installed in accordance with the requirements given for the electronic subassembly.

b) The performance requirements of this International Standard are met for a complete machine when the criteria, as applicable to this International Standard, are fulfilled. In the case of a complete machine meeting the performance requirements of this International Standard, no measurement of the electrical/electronic systems or electronic subassemblies is required.

5 Requirements — General tests

5.1 Test specimen

The test specimen may be a machine type and/or an ESA type.

Because the test of a single test specimen is to be used to judge the performance of a population of like earth-moving machinery, the reference limits for emissions and immunity shall be made more restrictive by means of a 20 % linear reduction for emissions limits and a 25 % linear increase for immunity limits, so as to account for variability of emissions and immunity due to manufacturing variations in earth-moving machinery or ESA types and in testing factors.

For a subsequent test on a like test specimen, conformity with the reference limits shall be accepted as fulfilment of the requirements of this International Standard.

For electrostatic discharge and conducted transients, the reference limits are valid for all testing of the test specimen.

5.2 Additional requirements for immunity tests

When a test specimen is subjected to the immunity levels specified in 5.5.2 and 5.8.2, no disturbance shall occur during testing which may affect the operator's control of the machine. The operator's control is exercised by means of, for example, steering, braking, or propulsion control. This also concerns movements of parts of the machine and modifications of the state of function, which may generate uncommanded, random or unresponsive machine operation (i.e. hazardous machine behaviour).

Use Annex F or similar evaluation methods to determine whether a potential for any significant changes made to the machine control system or the ESA exists that could require re-testing. This may include any revisions or modifications to the electrical/electronic system that would impact immunity or emission compliance with this International Standard.

ESA that are ancillary to machine operation and which do not alter machine control, such as monitors, alarms, gauges, lights, and wipers, may be tested according to the lesser immunity requirements of 5.5.3 and 5.8.3 or the higher levels of 5.5.2 and 5.8.2.

Traditional (without active semiconductor) control systems such as solenoids and relays need only comply with the reduced immunity requirements according to 5.5.3 and 5.8.3.

5.3 Broadband electromagnetic emission radiated from earth-moving machinery

5.3.1 Method of measurement

Measure the electromagnetic radiation in accordance with Annex B at either of the defined antenna distances. The choice shall be made by the user of this International Standard.

5.3.2 Broadband reference limits

When measurements are made using the method given in Annex B with an earth-moving machine-to-antenna spacing of 10 m ± 0,2 m, the emission reference limits shall be 34 dB(μV/m) (50 μV/m) in the 30 MHz to 75 MHz frequency band, and 34 dB(μV/m) to 45 dB(μV/m) (50 μV/m to 180 μV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in Figure A.1. In the 400 MHz to 1 000 MHz frequency band, the limit remains constant at 45 dB(μV/m) (180 μV/m).

When measurements are made using the method given in Annex B with an earth-moving machinery-to-antenna spacing of 3 m ± 0,05 m, the emission reference limits shall be 44 dB(μV/m) (160 μV/m) in the 30 MHz to 75 MHz frequency band, and 44 dB(μV/m) to 55 dB(μV/m) (160 μV/m to 562 μV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in Figure A.2. In the 400 MHz to 1 000 MHz frequency band, the limit remains constant at 55 dB(μV/m) (562 μV/m).

On the test specimen, the measured values, expressed in dB(μV/m) (μV/m), shall be at least 2 dB below the reference limits.

5.4 Narrowband electromagnetic emission radiated from earth-moving machinery

5.4.1 Method of measurement

Measure the electromagnetic emission in accordance with Annex C at either of the defined antenna distances. The choice shall be made by the user of this International Standard.

5.4.2 Narrowband reference limits

When measurements are made using the method given in Annex C with an earth-moving machinery-to-antenna spacing of 10 m ± 0,2 m, the emission reference limits shall be 24 dB(μV/m) (16 μV/m) in the 30 MHz to 75 MHz frequency band, and 24 dB(μV/m) to 35 dB(μV/m) (16 μV/m to 56 μV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in Figure A.3. In the 400 MHz to 1 000 MHz frequency band, the limit remains constant at 35 dB(μV/m) (56 μV/m).

When measurements are made using the method given in Annex C with an earth-moving machinery-to-antenna spacing of 3 m ± 0,05 m, the emission reference limits shall be 34 dB(μV/m) (50 μV/m) in the 30 MHz to 75 MHz frequency and 34 dB(μV/m) to 45 dB(μV/m) (50 μV/m to 180 μV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in Figure A.4. In the 400 MHz to 1 000 MHz frequency band, the limit remains constant at 45 dB(μV/m) (180 μV/m).

On the test specimen, the measured values, expressed in dB(μV/m) (μV/m), shall be at least 2 dB below the reference limits.

5.5 Immunity of earth-moving machinery to electromagnetic radiation

5.5.1 Test method

The immunity to electromagnetic radiation of the earth-moving machinery shall be tested in accordance with ISO 11451-1 and ISO 11451-2 with horizontal and vertical polarization. Immunity testing should be conducted according to ISO 11451-1, except that forward power may be used as the control regardless of the standing wave ratio of the system.

The testing may be conducted inside an absorber lined chamber or by another comparable method.

The determination of the reference point and relevant operating mode shall be machine-specific, as specified in this International Standard. The substitution method and the 80 % amplitude modulation (AM) with sinusoidal wave of 1 kHz (see ISO 11451-1) are determined as a test method. The testing shall be done in the frequency band of 20 MHz to 1 000 MHz using Table 1 criteria.

A minimum of two antenna locations shall be used. The locations shall be at approximately right angles to each other, with the antenna pointed at the locations of the machine where there are the greatest concentrations of electronic control components. At each location, the antenna shall be first polarized either horizontally or vertically, then rotated 90° to the other polarization and retested.

Table 1 — Maximum frequency step sizes

Frequency band MHz	Linear steps MHz	Logarithmic steps %
> 20 ⩽ 200	5	5
> 200 ⩽ 400	10	5
> 400 ⩽ 1 000	20	2

5.5.2 Earth-moving machinery immunity reference limits for movement control

Reference limit 80 V/m (root mean square value of the unmodulated signal) applies. The maximum value of the test signal with modulation shall comply with the maximum value of an unmodulated test signal. The immunity requirements are fulfilled by a field strength of 100 V/m (25 % above the reference limit). The general requirements for immunity testing given in 5.2 shall be fulfilled. Lower field strengths between 20 MHz and 60 MHz may be used, if appropriate antennas and testing equipment are not readily available. If the reduced field strength falls below 24 V/m (30 V/m for a single sample), other methods of ESA testing shall be used for those frequencies.

5.5.3 Earth-moving machinery immunity reference limits for functions other than movement control (and without active semiconductor-based controls)

Reference limit 24 V/m (root mean square value of the unmodulated signal) applies. The maximum value of the test signal with modulation shall comply with the maximum value of an unmodulated test signal. The immunity requirements are fulfilled by a minimum field strength of 30 V/m (25 % above the reference limit). The general requirements for immunity testing given in 5.2 shall be fulfilled.

Testing at 24 V/m or 30 V/m is only required for frequencies where failures were first detected at 80 V/m or 100 V/m.

5.6 Broadband electromagnetic emissions radiated from ESA

5.6.1 Method of measurement

Measure the electromagnetic interference in accordance with Annex D.

5.6.2 ESA broadband reference limits

When measurements are made using the method given in Annex D, the emission reference limits shall be 64 dB(µV/m) to 54 dB(µV/m) (1 600 µV/m to 500 µV/m) in the 30 MHz to 75 MHz frequency band, this limit decreasing logarithmically (linearly) with frequencies above 30 MHz, and 54 dB(µV/m) to 65 dB(µV/m) (500 µV/m to 1 800 µV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in Figure A.5. In the 400 MHz to 1 000 MHz frequency band, the limits remains constant at 65 dB(µV/m) (1 800 µV/m).

On the test specimen, the measured values, expressed in dB(µV/m) (µV/m), shall be at least 2 dB below the reference limits.

5.7 Narrowband electromagnetic emissions radiated from ESA

5.7.1 Method of measurement

Measure the electromagnetic interference in accordance with Annex E.

5.7.2 ESA narrow band reference limit

When measurements are made using the method given in Annex E, the emission reference limits shall be 54 dB(µV/m) to 44 dB(µV/m) (500 µV/m to 160 µV/m) in the 30 MHz to 75 MHz frequency band, this limit decreasing logarithmically (linearly) with frequencies above 30 MHz, and 44 dB(µV/m) to 55 dB(µV/m) (160 µV/m to 562 µV/m) in the 75 MHz to 400 MHz frequency band, this limit increasing logarithmically (linearly) with frequencies above 75 MHz as shown in Annex A (Figure A.6). In the 400 MHz to 1 000 MHz frequency band the limit remains constant at 55 dB(µV/m) (562 µV/m).

On the test specimen, the measured values, expressed in dB(µV/m) (µV/m) shall be at least 2 dB below the reference limits.

5.8 Immunity of ESA to electromagnetic radiation

5.8.1 Test method

For the testing of the immunity of ESA to electromagnetic fields, apply the test methods specified in ISO 11452-2, ISO 11452-3, ISO 11452-4 or ISO 11452-5. Immunity testing should be conducted in accordance with ISO 11452-1, except that forward power may be used as the control regardless of the standing wave ratio of the system. The chosen combination shall cover the 20 MHz to 1000 MHz band. The substitution method, with 80 % amplitude modulation (AM) with sinusoidal wave of 1 kHz (see ISO 11452-1), has been determined as a test methodology.