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Earth-moving machinery — Functional safety —

Part 3: Environmental performance and test requirements of electronic and electrical components used in safety-related parts of the control system

Engins de terrassement — Sécurité fonctionnelle —

Partie 3: Exigences pour la performance environnementale et l'essai des composants électroniques et électriques utilisés dans les parties relatives à la sécurité du système de commande

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements*.

This first edition of ISO 19014-3, together with ISO 19014-1, ISO 19014-2, ISO 19014-4 and ISO/TS 19014-5, cancels and replaces ISO 15998, which has been technically revised.

The main changes compared to the previous document are as follows:

— details added to existing test requirements;

— additional electrical and environmental tests.

A list of all parts in the ISO 19014-series can be found on the ISO website. At the time of publication of this document, Part 2, *Design and evaluation of safety-related machine control systems*, Part 4, *Design and evaluation of software and transmission for safety related parts of the control system*, and Part 5, *Tables of performance levels*, are under development.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document addresses electronic and electrical systems used for functional safety in earth-moving machinery.

The structure of safety standards in the field of machinery is as follows.

Type-A standards (basis standards) give basic concepts, principles for design and general aspects that can be applied to machinery.

Type-B standards (generic safety standards) deal with one or more safety aspects, or one or more types of safeguards that can be used across a wide range of machinery:

— type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise);

— type-B2 standards on safeguards (e.g. two-hands controls, interlocking devices, pressure sensitive devices, guards).

Type-C standards (machinery safety standards) deal with detailed safety requirements for a particular machine or group of machines.

This document, when taken together with the other parts of ISO 19014, is a type-C standard as stated in ISO 12100.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organizations, market surveillance etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e. g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

Earth-moving machinery — Functional safety —

Part 3: Environmental performance and test requirements of electronic and electrical components used in safety-related parts of the control system

1 Scope

This document specifies the minimum requirements for environmental testing of electronic and electrical components identified as safety-related parts of the control system (SRP/CS) used on earth-moving machinery (EMM) as defined in ISO 6165 and their attachments.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 6165, *Earth-moving machinery — Basic types — Identification and terms and definitions*

ISO 13766-1, *Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply — Part 1: General EMC requirements under typical electromagnetic environmental conditions*

ISO 13766-2, *Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply — Part 2: Additional EMC requirements for functional safety*

ISO 16750-2:2012, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads*

ISO 16750-5, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 5: Chemical loads*

ISO 19014-1, *Earth-moving machinery — Safety — Part 1: Risk assessment methodology to determine control system performance requirements*

ISO 20653, *Road vehicles — Degrees of protection (IP code) — Protection of electrical equipment against foreign objects, water and access*

IEC 60068-2-11, *Basic environmental testing procedures — Part 2: Tests — Test Ka: Salt mist*

IEC 60068-2-14, *Environmental testing — Part 2: Tests — Test N: Change of temperature*

IEC 60068-2-27, *Environmental testing — Part 2-27: Tests — Test Ea and guidance: Shock*

IEC 60068-2-38, *Environmental testing — Part 2-38: Tests — Test Z/AD: Composite temperature/humidity cyclic test*

IEC 60068-2-52, *Environmental testing — Part 2-52: Tests — Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60068-2-64:2008, *Environmental testing — Part 2-64: Tests — Test Fh: Vibration, broadband random and guidance*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6165, ISO 19014-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
life cycle
time between commissioning and decommissioning of a component

4 Functional status classifications

4.1 Class A

All safety functions of the device under test (DUT) perform as designed during and after the test.

4.2 Class B

All safety functions of the DUT perform as designed during the test. The DUT may perform outside of the designed tolerance during the test; however, all functions shall automatically return within the specified tolerance after the test. Memory functions shall remain class A.

The functions of the DUT that are required to perform as designed during the test, and the functions that may perform beyond the specified tolerance, shall be specified by the machine manufacturer.

4.3 Class C

For DUTs that are powered and monitored, one or more functions of a DUT do not perform as designed during the test, but return automatically to normal operation after the test.

For DUTs that re not powered and monitored, the DUT performs as designed after the test.

4.4 Class D

One or more functions of a DUT do not perform as designed during the test and do not return to normal operation after the test until the DUT is reset.

5 Tests and requirements

5.1 General

The test conditions specified in this document are the minimum requirements. The EMM manufacturer shall ensure electrical and electronic components are suitable for the environment in which they are used.

The EMM manufacturer shall determine the use environment as it applies to the test conditions in this document. The environmental requirements for each application depend on its mounting location (engine compartment, operator station, chassis, etc.), which shall be taken into account when developing the test specification.

Significant variation in environmental conditions due to diurnal and seasonal cycles can be expected and shall be considered when testing according to this document.

The EMM manufacturer shall test any components that are likely to be submerged in, or exposed to, chemical agents (mining liquids, salts, alkaline, fertilizer, etc.) and ensure the components are immune to contamination or degradation.

Components that are immune to contaminants may be exempt from testing if the EMM manufacturer provides documentary evidence to that effect. The EMM manufacturer shall determine suitability for chemical exposure according to ISO 16750-5. Resistance to the specified chemical agents should be considered as early as possible (e.g. during the material selection process.)

See Annex A for an example of a test checklist, which includes a column for the EMM manufacturer to document the rationale for excluding a test.

NOTE If explosion proofing is required, refer to IEC 60079. National or regional requirements can apply.

5.2 Dust

5.2.1 Purpose

Electronic components (controllers, joysticks, displays, switches, solenoids, etc.) adversely affected by dust ingress shall be protected against the ingress of dust present in the operating environment.

This test verifies that the DUT is immune to dust intrusion. Failure mode is electrical or mechanical malfunction caused by dust intrusion into the DUT housing or dust settling on the surface of electrical contacts.

Components that are sealed and meet a minimum IP rating of 6X according to IEC 60529 or IP rating of IP6KX according to ISO 20653 may be exempt from the requirements of this test.

5.2.2 Test method

Dust testing shall be performed in accordance with ISO 20653 or IEC 60529. The DUT shall be mounted according to its normal mounting orientation in the EMM.

The functional status shall be class C (4.3).

5.3 Chemical resistance

5.3.1 Purpose

This test verifies that the DUT is protected against contact with acids, corrosive gases and salts that can be present in the operating environment.

DUT exposed to specified chemical agents shall be resistant to those agents. The DUT shall be tested with all chemicals with which it is likely to come into contact, except DUT materials for which documentary evidence shows immunity to the contaminant and, therefore, need not be tested.

A material is considered to be immune to a contaminant if there is no change in properties sufficient to affect the material performance.

Manufacturer and type of chemical agents shall be agreed upon between the test laboratory and EMM manufacturer.

5.3.2 Test method

If required, chemical resistance testing shall be performed in accordance with ISO 16750-5. The DUT need not be powered and monitored during this test.

The functional status shall be class C (4.3).

5.4 Salt spray

5.4.1 Purpose

This test verifies the resistance of materials and surface coatings of the DUT to corrosion caused by salt mist and salt water in applications where the DUT is exposed to salts (e.g. road salt, sea mist, salt mines, etc.) The failure mode is corrosion.

Visual examination shall allow identification of the DUT upon completion of the test.

The manufacturer shall determine the applicability of this test according to the DUT's normal mounting location.

5.4.2 Test method

Salt testing shall be performed in accordance with IEC 60068-2-11 or IEC 60068-2-52. The DUT need not be powered and monitored during this test.

The functional status shall be class C (4.3).

5.5 Pressure wash

5.5.1 Purpose

This test verifies that electrical and electronic components (controllers, joysticks, displays, switches, solenoids, etc.) adversely affected by pressure wash are protected against the ingress of liquids present in the operating environment.

5.5.2 Test method

Electronic components that are likely to be pressure washed (outside the operator station or in canopy applications) shall meet IPX6 in accordance with IEC 60529 or IPXK6 in accordance with ISO 20653.

The DUT need not be powered and monitored during this test.

The functional status shall be class C (4.3).

5.6 Random vibration

5.6.1 Purpose

This accelerated test verifies that the DUT operates as designed under random vibration in various severities applicable to on-board electrical and electronic equipment. DUT failure modes include cracking or breakage of materials due to vibration fatigue.

5.6.2 Test method

Vibration testing shall be performed in accordance with IEC 60068-2-64:2008, 8.4.

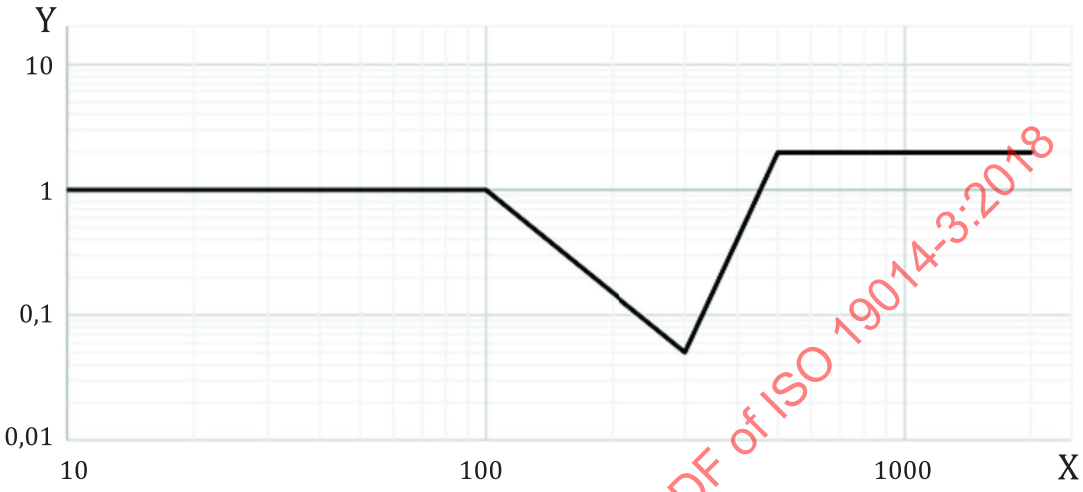
The EMM manufacturer and component supplier should choose the test G level, environmental temperature and accelerated vibration parameters depending on the specific mounting location.

If no vibration data is available for the DUT specific mounting location, or the acceleration spectral density (ASD) measured is lower than shown in Figure 1, the DUT shall be tested according to Figure 1. The tabular data for Figure 1 is listed in Table 1.

The frequency range shall be defined as follows: f_1 = 10 Hz, f_2 = 2 000 Hz. The ASD is linear between the listed frequencies.

The EMM manufacturer shall select the appropriate duration of exposure according to the DUT expected life cycle. The minimum duration shall be 8 h per axis.

The functional status shall be class A (4.1).



Key

Y ASD [(m/s²)²/Hz]

X frequency [Hz]

Figure 1 — Random vibration ASD

Frequency Hz	ASD (m/s²)²/Hz
10	1
100	1
300	0,05
5 00	2
2 000	2

Table 1 — Random vibration ASD

5.7 Operating shock

5.7.1 Purpose

This test verifies that the DUT does not malfunction or break due to mechanical shock from equipment operations, such as bucket or blade impact, bucket rapout, or the use of a hydraulic breaker attachment. Failure modes include mechanical damage (e.g. solder breakage, detached components).

5.7.2 Test method

Shock testing shall be performed in accordance with IEC 60068-2-27.

The test specimen should be fixed to the test equipment with the same mountings as fitted on the machine. It should be tightened as specified by the machine manufacturer.

The minimum shock load shall be an acceleration of 150 m/s^2 (15 *g*) with an 11 ms pulse duration, or preferably 300 m/s^2 (30 *g*) with an 18 ms pulse duration.

The DUT shall be powered and monitored during this test.

The functional status shall be class A (4.1).

5.8 Temperature cycles

5.8.1 Purpose

This test verifies that the DUT operates as designed under varying temperatures with electrical operation of the DUT, e.g. during the use of the system/components at changing ambient temperature.

5.8.2 Test method

Temperature cycling shall be performed in accordance with IEC 60068-2-14, Test Nb, using the temperature limits described below.

The component shall be powered and monitored except during phases of decreasing temperature when heat dissipation of the DUT would inhibit reaching T_{min} inside the DUT.

The lower temperature, T_A, should be chosen from the test temperature of IEC 60068-2-1 and IEC 60068-2-2, but shall not rise above –25 °C.

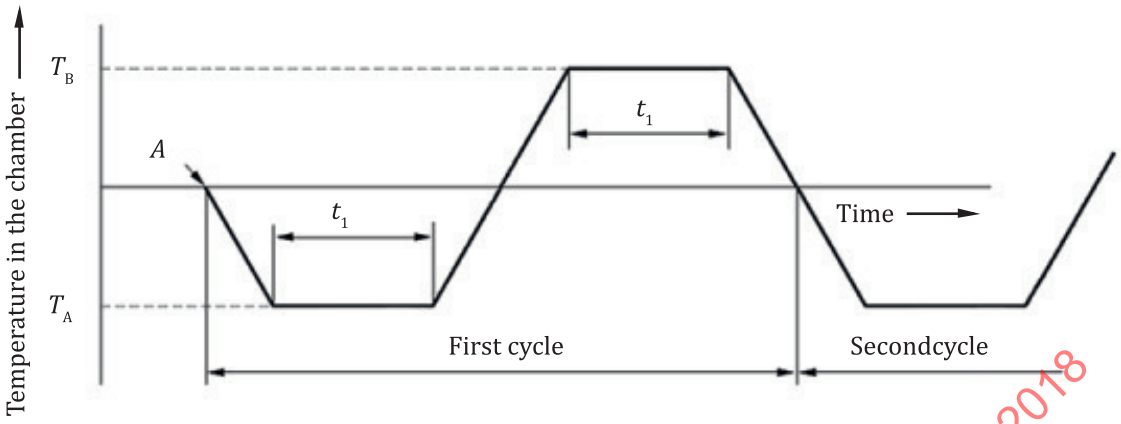
The higher temperature, T_B, should be chosen from the test temperature of IEC 60068-2-1 and IEC 60068-2-2, but shall not fall below +70 °C.

The minimum number of cycles shall be 20 cycles with a minimum dwell time in accordance with IEC 60068-2-14, depending upon the heat capacity of the specimen. The temperature of the chamber should be lowered or raised at a minimum rate of (3 ± 0,6) °C/min.

For the portions of the test that are powered and monitored, the functional status shall be class A (4.1); otherwise, the functional status shall be class C (4.3).

For special operating conditions of the machine and installation conditions of the electronic parts, other environmental conditions may be specified by the manufacturer.

See Figure 2.



Key

A start of the first cycle
T_A lower temperature
T_B higher temperature
t_1 duration of exposure

Figure 2 — Nb test cycle

5.9 Thermal shock

5.9.1 Purpose

This accelerated test verifies that the DUT operates as designed under a high number of temperature cycles in the equipment. The acceleration is possible due to a higher temperature differential in one cycle in comparison with real equipment stress. DUT failure modes include cracking of materials or seal failures caused by ageing and the difference in temperature expansion coefficients.

Because this test creates mechanical defects (cracks), electrical operation is not required.

5.9.2 Test method

Temperature cycling shall be performed in accordance with IEC 60068-2-14, Test Na.

The dwell time can be obtained through a preliminary heat rise test by which the DUT ramp rate is determined. The DUT dwell time at each temperature extreme shall be sufficient for the DUT temperature to stabilize before the next transition.

The severity of the test is defined by the lower and upper temperature limits which may be chosen from the test temperature of IEC 60068-2-1 and IEC 60068-2-2, respectively. Alternatively, the temperature limits may be measured from the known equipment environment if doing so results in significantly different values from those specified in the aforementioned IEC publications.

The functional status shall be class C (4.3).

5.10 Humidity cycles

5.10.1 Purpose

This test verifies that the DUT operates as designed under cyclic high ambient humidity. The failure modes addressed are electrical malfunctions caused by moisture, e.g. leakage current caused by a printed circuit board soaked with moisture. An additional failure mode is a breathing effect which

transports moisture inside the housing when the air inside the DUT cools down and humid ambient air is drawn into the DUT.

5.10.2 Test method

The test shall be performed as specified in IEC 60068-2-38, Test Z/AD. The component should be powered and monitored except during phases of decreasing temperature when heat dissipation of the system/component would inhibit reaching T_{min} inside the system/component.

For the portions of the test that are powered and monitored, the functional status shall be class A (4.1); otherwise, the functional status shall be class C (4.3).

5.11 Overvoltage condition

5.11.1 Purpose

This test verifies that the DUT operates as designed in case of a "jump start" condition or the condition where the alternator's voltage regulator fails and the output voltage of the alternator rises above normal values.

5.11.2 Test method

When the overvoltage conditions stated in 5.11.1 can occur, the test shall be performed in accordance with ISO 16750-2:2012, 4.3.

The functional status shall be class C (4.3).

5.12 Undervoltage condition (reset behaviour at voltage drop)

5.12.1 Purpose

This test verifies that the DUT operates as designed at different voltage drops. This test is applicable to DUT with a reset function, generally a DUT containing microcontrollers or whose processor can freeze in an unintended state during or after a voltage drop.

5.12.2 Test method

Undervoltage testing shall be performed in accordance with ISO 16750-2:2012, 4.6.2.

The functional status shall be class C (4.3).

5.13 Electromagnetic compatibility

5.13.1 Purpose

This test verifies that the DUT is electromagnetically compatible with its environment, i.e. the DUT is immune to electromagnetic interference and does not introduce intolerable electromagnetic disturbances.

5.13.2 Test method

The DUT shall fulfil the requirements of ISO 13766-1 and ISO 13766-2.

The functional status shall be class A (4.1)