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Earth-moving machinery — Safety requirements for remote operator control systems

Engins de terrassement — Exigences de sécurité relatives aux systèmes de commande à distance utilisés par l'opérateur

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 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 15817 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements*.

This second edition cancels and replaces the first edition (ISO 15817:2005), which has been technically revised.

Earth-moving machinery — Safety requirements for remote operator control systems

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This International Standard specifies the essential safety requirements for remote operator control systems used on earth-moving machinery as defined in ISO 6165. It is not applicable to autonomous control systems that enable a machine to work without the assistance of an operator, nor does it apply to the remote control of attachments on non-remote controlled machines.

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 6165, *Earth-moving machinery — Basic types – Identification and terms and definitions*

ISO 6405-1, *Earth-moving machinery — Symbols for operator controls and other displays — Part 1: Common symbols*

ISO 6405-2, *Earth-moving machinery — Symbols for operator controls and other displays — Part 2: Specific symbols for machines, equipment and accessories*

ISO 9244, *Earth-moving machinery — Machine safety labels — General principles*

ISO 13766, *Earth-moving machinery — Electromagnetic compatibility*

ISO 13850, *Safety of machinery — Emergency stop — Principles for design*

ISO 15998, *Earth-moving machinery — Machine-control systems (MCS) using electronic components — Performance criteria and tests for functional safety*

IEC 60068-2-31, *Environmental testing — Part 2-31: Tests — Test Ec: Rough handling shocks, primarily for equipment-type specimens*

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

3 Terms and definitions

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

3.1
control cable
electric wire for transmitting signals between the remote control box and the receiving unit for a wired remote control system

3.2
direct control
control of the machine by an operator in physical contact with the machine

3.3
emergency stop device
manually actuated device, located on the machine, used to initiate an emergency stop function

3.4
emergency stop function
function that is intended to

— avoid impending, or reduce existing, hazards to persons, damage to machinery or to work in progress, and

— be initiated by a single human action

NOTE 1 Hazards, for the purposes of this International Standard, are those which can arise from

— functional irregularities (e.g. machinery malfunction, unacceptable properties of the material processed, human error),

— normal operation.

NOTE 2 Adapted from ISO 13850:2006, definition 3.1.

3.5
hazard zone
area defined by the intended use of the machine where potential for injury might exist due to movement of the machine and its application

3.6
receiving unit
device located on the machine to receive signals emitted from the remote control box and to process these signals into machine operating orders

NOTE It consists of the following elements:

— receiving element that receives signals from the remote control box;

— monitoring element for confirming signals;

— output intersection element that drives the control devices of the machine.

The receiving unit may also include means of return signal transmission for confirmation.

3.7
remote control
remote operator control
operator control of a machine by wireless or wired transmission of signals from a remote control box not located on the machine to a receiving unit located on the machine

3.8
remote control box
device, not on the machine, that transmits signals to actuate all needed operating functions for control of the machine

NOTE The signals are transmitted from the remote control box to the receiving unit.

3.9
remote control system
system consisting of a remote control box and receiving unit that transmits operational control information to and from a remote controlled machine

3.10
remote controlled operation
operation of a machine by an operator distant from the machine

3.11
remote stop
device on the remote control unit and/or “portable” (e.g. hand-held) device that causes all controlled machine hazardous movement to stop

4 Requirements for remote operator control

4.1 General requirements

4.1.1 Design

The principles of ISO 15998 should be followed in the design of remote control, safety-related, machine control systems using electronic components.

Remote control systems shall be designed so that all powered movement is prevented for any of the following conditions:

a) the operator controls are not activated;

b) loss of the power supply of the remote control system;

c) loss of the signal between the remote control box and the receiving unit;

d) loss of the machine power supply that interrupts any part of the remote control system;

e) any remote control operation interlock not in place and/or functional.

Re-establishing the power supply or the signal between the remote control box and the receiving unit shall not create unintended hazardous machine motion. Resuming remote controlled operation shall only be possible after an intentional reset of machine operation by the operator.

When hazardous zones of the machine are not visible to the remote control operator, there shall be means for the operator to provide a warning before the engine or machinery is started. Exposed personnel shall be given time to leave the hazardous zone or have the means to prevent the engine or machinery from starting.

4.1.2 Wireless control

Remote control systems shall have a means (indicator light, beacon, audible alarm, etc.) of identifying the corresponding controlled machine prior to the start of the remote operation. The warning device specifed in 4.10 may be used.

4.1.3 Wired control

The control cable shall be of sufficient length and flexibility to allow the operator to maintain an operating position outside the hazard zone. Excessive tension on the control cable shall not cause actuation of the controls. Any failure of the control cable or connection shall cause powered machine movement to stop.

4.2 Signal integrity

The signal transmission system shall have an error detection and/or correction system to prevent the machine controls from being actuated by false signals resulting from burst levels of electromagnetic radiation, temporary signal loss, etc. The data communication protocol shall continually verify the integrity of the communication link and of the data being transmitted. If signal integrity cannot be verified, remote controlled powered movement shall stop until signal integrity has been re-established and the operator has performed an intentional reset.

4.3 Operating range (wireless)

The operating range of the remote control shall be sufficient to allow the operator to be outside the hazard zone; this range shall be clearly stated in the operator's manual.

4.4 Remote control box

4.4.1 Design

Machine movement, other than machine stop, shall only be able to be controlled from one remote control box at a time.

By design and the application of ergonomic principles, the remote control box should minimize restriction of the machine operator's freedom of movement.

The presence of electrical power at the remote control box shall be indicated by an optical device, e.g. LED or panel light.

4.4.2 Operator controls

4.4.2.1 General

Continuously running work function controls (e.g. attachment controls) and float controls may be held in a detent position. Other machine operational controls on the remote control box shall return to their neutral position when the operator releases the control or shall require an alternative sustained operator input control (e.g. hold-to-run).

When the controls are in their neutral or detent position, the resulting machine action shall be the same as when the corresponding controls on the machine, if present, are in their neutral or detent position. Instructions shall be provided in the operator's manual for the approved use of continuously running work function controls and float controls.

4.4.2.2 Marking

The controls on the remote control box shall be clearly marked with the directional orientation and direction of movement for the machine and its equipment/attachment, in accordance with ISO 6405-1 and ISO 6405-2. The markings shall be consistent with the control markings on the machine, if the machine is so equipped.

4.4.2.3 Protection against unintended actuation

The controls on the remote control box shall be so arranged, deactivated or guarded as to protect against unintended actuation. A means shall be provided to guard against actuation where the remote control box might fall from the operator's hands or the operator fall while operating the remote control box.

4.4.2.4 Protection against unauthorized actuation

A means to protect against unauthorized actuation shall be provided on the remote control box.

EXAMPLE Key switch or access code.

Operation of the remote control shall not be possible unless this means is enabled.

4.4.2.5 Machine holding function

A means to keep the machine stationary shall be provided on the remote control box.

EXAMPLE Activation of a parking brake or other method as specified in the operator’s manual.

4.4.2.6 Fire suppression system

For remote controlled machines equipped with a fire suppression system, activation shall be automatic or a means to activate remotely shall be provided.

4.5 Machine stop

4.5.1 General

A machine stop control shall be present on the remote control box and on the machine. It shall not be possible to restore the operation of a machine until all stop devices previously operated or activated have been reset. Stop controls shall apply fail-safe design.

4.5.2 Remote stop

A remote stop device shall be present on the remote control box. Control shall generally be obtained by a push-button device or an alternative device which is easily activated. Either the device or its marking shall be red in colour.

Additional remote stop devices, e.g. “portable” hand-held units, that can only control the stop function may also be used, provided they meet the same requirements defined above for a remote stop device on the remote control box.

4.5.3 Emergency stop

Where risk assessment gives clear evidence that the operation of an emergency stop device, located on the machine, is possible without additional risk, at least one emergency stop device conforming with the principles of ISO 13850 shall be present on the machine operable by a person standing at ground level.

4.6 Control selection

4.6.1 Direct control

If the machine can also be direct controlled, a control selecting switch meeting the requirements of 4.6.2 to 4.6.6 shall be provided.

4.6.2 Uncommanded machine motion

Operation of the control selecting switch shall not cause any uncommanded motion of the machine.

4.6.3 On machine override

A means shall be provided for the operator on the machine to deactivate remote control operation while present at the controls. If the override has been activated, the remote control function shall have to be re-enabled to permit remote control operation.

4.6.4 Control selecting switch

The control selecting switch should be located on the machine in the direct line of sight of the operator, as viewed from the operator control area of the direct controlled machine. If the selecting switch is not in direct line of sight, an indication that remote control operation is active shall be provided to the operator when in the operator control area of the direct controlled machine.

4.6.5 Switch interlock

The control selecting switch shall be interlocked, or other means taken (e.g. guarding), to prevent the machine from being inadvertently switched to remote control operation while an operator is operating the machine with direct control.

4.6.6 Unauthorized actuation

The control selection shall be provided with means to prevent unauthorized actuation. This may be in the form of a key switch, lockable switch, access code, a switch in a lockable cab or compartment, or other comparable means.

4.6.7 Remote actuation

When the control selection switch is switched to remote control operation, all machine motion under the control of the remote control system shall be initiated only from the remote control box.

4.7 Electromagnetic compatibility

The remote control system shall be in accordance with ISO 13766.

4.8 Impacts, shocks and vibrations

By design, the remote control box and the receiving unit shall withstand reasonably foreseeable operational impacts and vibrations without these causing inadvertent machine movement.

a) **The remote control box** shall withstand the following tests:

- free fall test according to IEC 60068-2-31;
- shock test according to ISO 15998.

b) **The receiving unit** shall withstand the following tests:

- vibration test according to ISO 15998;
- shock test according to ISO 15998.

4.9 Environmental protection

4.9.1 Remote control box

The degree of environmental protection of the remote control box shall be, at minimum, IP 65, in accordance with IEC 60529.

4.9.2 Receiving unit

The degree of environmental protection is based on the location for the installation of the receiving unit: It shall be IP 54, in accordance with IEC 60529, if the receiving unit is located inside an enclosed cab or a similarly protected location; in all other cases, it shall be at least IP 65.

4.10 Warning devices

4.10.1 Visual devices

A beacon or strobe lamp, coloured to uniquely indicate remote control operation, shall be illuminated whenever the remote control system is active. The beacon shall be located on the machine in a position that can be readily seen by personnel approaching the machine from any direction.

The machine may be equipped with a combination of different coloured beacons or strobes to indicate various states, conditions or operating modes.

EXAMPLE Green for system power on, yellow/amber for operational machine, red for a fault condition.

If more than one beacon or strobe lamp is used, a description of their functions shall be included in the operator's manual.

4.10.2 Audible devices

It shall be possible to operate an audible warning device on the machine (e.g. horn) from the remote control box when the machine is being remotely operated.

4.11 Travelling

4.11.1 Wireless control

If the operator is required to travel with the machine, the maximum travelling speed shall not exceed 10 km/h.

Where the operator is not required to travel with the machine, faster travelling speeds are allowed, where these are determined according to site use conditions and other personnel and the operator are prohibited from being within the hazard zone.

4.11.2 Wired control

When an operator is required to travel with the machine, the maximum travelling speed shall not exceed 6 km/h.

4.12 System information

The following data shall be permanently affixed to the remote control system:

a) manufacturer;

b) system identification;

c) year of manufacture;

d) serial number.

The system identification information shall clearly relate the remote control box to the receiving unit located on the machine. This identification shall be shown on both the remote control box and an easily readable surface on the receiving unit or machine.

4.13 Machine safety label

A machine safety label, in accordance with ISO 9244, shall be displayed on the machine indicating that the machine can be operated by remote control. The machine safety label shall clearly indicate the need to stay clear of the machine. See Annex A for an example.

5 Forward-direction marking

For 360° rotating machines, e.g. excavators, the forward travelling direction shall be marked on both sides of the undercarriage of the machine so as to inform the remote operator of the travelling direction, unless there are other distinguishing features of the machine (e.g. push blade) to indicate forward direction.

For machines where the forward direction is not obvious (e.g. symmetrically designed machines), the forward direction shall be marked on both sides of the machine and on the front and back of the machine.

Wherever possible, markings should be installed such that they are not readily obstructed by dirt, mud, etc. during normal operation of the machine.

For machines with automatic forward direction selection, labelling on the remote control shall be used to indicate the presence of this feature on the machine.

6 Instructions

The operator's manual for wireless remote controlled machines shall provide information about the maximum distance from which the operator can control the machine. For machines that present a hazard to the remote operator when direct vision is used, a suitable warning to maintain a safe distance from the machine during remote operation shall be provided in the operator's manual. Other information specific to remote operation, such as maintaining line of sight, working on slopes, carrying loads, use in extreme conditions/environments, start-up and shut-down procedures and safe practice for maintaining the control box, shall be included.

The operator's manual shall instruct the operator to routinely test the functionality of the warning devices.

Annex A
(informative)

Example machine safety label for remote control

Figure A.1 shows an example of a machine safety label that might be used to indicate that the machine can be operated by remote control.

NOTE In Figure A.1, the warning sign shown in the top panel of the machine safety label has been submitted for ISO 7010 registration according to ISO procedures and is shown here only as an informative example.

Figure A.1 — Example of machine safety label

Bibliography

[1] ISO 13849-1, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

[2] ISO 7010, *Graphical symbols — Safety colours and safety signs — Registered safety signs*

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