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Earth-moving machinery — Object detection systems and visibility aids — Performance requirements and tests

Engins de terrassement — Dispositifs de détection d'objets et d'aide visuelle — Exigences de performances et essais

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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Foreword

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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).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 1, *Test methods relating to safety and machine performance*.

This second edition cancels and replaces the first edition (ISO 16001:2008), which has been technically revised.

The main change compared to the previous edition is as follows:

— Annex G, Annex H and Annex I have been added to include state-of-the-art technologies.

Introduction

This document outlines test procedures and sets criteria for the development of object detection systems (ODSs) and visibility aids (VAs) which indicate to the operator the presence of objects which are within the detection zone of these systems.

Proper job-site organization, operator training and the application of relevant vision standards (ISO 5006 and ISO 14401) address the safety of people on job sites. In some cases, vision of the working area cannot be achieved either by the operator's direct view or indirect view using mirrors. In such cases, operator awareness can be improved by the use of ODSs and VAs.

ODSs and VAs provide information to the operator as to whether a person or object is in the path of the machine, primarily during rearward movement.

It is essential to note that ODSs and VAs have both advantages and disadvantages. There is no device that works perfectly in all situations. It is especially important that the shortcomings of ODSs and VAs be recognized and known to system users. The advantages and disadvantages of selected devices are summarized in Annex A.

The use of a haptic signal (signal that stimulates the operator’s sense of touch, vibration, force and motion) as an alternative to the use of visual and audible signals in ODS warning devices was discussed during the revision of this document, as haptic warnings are now being used in the automotive industry. While this document does not currently allow warning devices that only use haptic signals, they can be incorporated into the warning device to supplement the visual and audible signal. More study is needed to determine the effectiveness of a haptic signal in various earth-moving machinery applications.

Earth-moving machinery — Object detection systems and visibility aids — Performance requirements and tests

1 Scope

This document specifies general requirements and describes methods for evaluating and testing the performance of object detection systems (ODSs) and visibility aids (VAs) used on earth-moving machines. It covers the following aspects:

— detection or visibility or both of objects including people in the detection zone;

— visual, audible, or both warnings to the operator and if appropriate to the persons in the detection zone;

— operational reliability of the system;

— compatibility and environmental specifications of the system.

It is applicable to machines as defined in ISO 6165. An ODS, VA or both can be used to augment the operator's direct vision (see ISO 5006) or indirect vision using mirrors (see ISO 14401). In addition, an ODS, VA or both can be used to provide additional means of object detection or view, for example, where ergonomic considerations limit the effectiveness of direct vision and to avoid repeated turning of the head and upper body.

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 3411, *Earth-moving machinery — Physical dimensions of operators and minimum operator space envelope*

ISO 6394, *Earth-moving machinery — Determination of emission sound pressure level at operator's position — Stationary test conditions*

ISO 9533, *Earth-moving machinery — Machine-mounted audible travel alarms and forward horns — Test methods and performance criteria*

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

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

EN 50132-7:1996, *Alarm systems — CCTV surveillance systems for use in security applications — Application guidelines*

3 Terms and definitions

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

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

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

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

3.1
object detection system
ODS
system that detects objects, including people, that are in the *detection zone* (3.3) and warns the operator

Note 1 to entry: The system generally includes a *sensing device* (3.1.1), *warning device* (3.1.2) and *evaluation device* (3.1.3).

Note 2 to entry: An ODS which operates by detection of a visual image is a *visual* object detection system.

Note 3 to entry: The system can also warn the person on the ground.

3.1.1
sensing device
ODS (3.1) component that detects a *test body* (3.4) in the *detection zone* (3.3)

3.1.2
warning device
ODS (3.1) component that transmits information to the operator or to persons in the *detection zone* (3.3) by visual or audible or both signals

3.1.3
evaluation device
ODS (3.1) component or components that analyse the signals and information transmitted from the sensing device and transform the corresponding signal to the *warning device* (3.1.2)

3.2
visibility aid
VA
system that provides indirect visibility without a *warning device* (3.1.2)

Note 1 to entry: The system generally includes one or more *monitors* (3.2.1) and *cameras* (3.2.2).

3.2.1
monitor
VA (3.2) component that provides a visual image of the *detection zone* (3.3) on a screen

3.2.2
camera
VA (3.2) component that transmits to the monitor an image of the *detection zone* (3.3)

3.3
detection zone
zone within which a *test body* (3.4) is detected by an *ODS* (3.1) or is shown by a *VA* (3.2)

3.4
test body
person or a standard measuring unit representative of a person, used to test the geometry and size of the *detection zone* (3.3)

Note 1 to entry: Depending on the system used, test bodies can be varied (see Annexes B to I).

3.5
self-checking
capability of the system to self-check continuously and immediately to inform the operator, audibly, visually, or both, of a failure

3.6
detection time
time required for an object detection system to detect the *test body* (3.4) in the *detection zone* (3.3) and activate the signal output

3.7
stand-by
operation mode whereby the object detection and visibility aid systems are active, but no information is transmitted by the *warning device* (3.1.2) or *monitor* (3.2.1)

3.8
job-site organization
rules and procedures for managing the working together of machines and people at a job site

EXAMPLE Safety instructions, traffic patterns, restricted areas, operator training, machine and vehicle markings, communications systems.

3.9
warning range
range within the *detection zone* (3.3) in which a distinctive warning is provided to indicate the range between the machine and the object being detected

4 Performance requirements and tests

4.1 General requirements

4.1.1 Test to determine the detection zone boundary

The test shall be performed on a system that is either fitted to the machine or to a representative configuration in accordance with the appropriate annex (see Annexes B to Annex I).

4.1.2 Test body requirements

The test body requirements are specified in Annex B to Annex I.

4.1.3 Evaluation of test results

4.1.3.1 Detection

Detection shall take place unambiguously with an uninterrupted sequence of the signal or information appropriate to the detection zone. For further details, see Annex B to Annex I.

It is possible to combine ODSs and VAs to cover the necessary detection zone in the case where a single system cannot cover the zone.

EXAMPLE A surround view system can be combined with another object detection system, whose detection zone covers the area where the image size achieved by the surround view system is less than required.

4.1.3.2 Evaluation of false signals

False signals, such as the following, should be minimized:

— from objects outside the detection zone;

— from weather conditions of fog, snow, rain, wind, dust, etc.

4.2 Location and fixing of ODS and VA components

Components shall be located and arranged on the machine in accordance with the specification of the component manufacturer so that

— the component does not restrict any function or operation of the machine,

— the component is protected against external damage,

— the component is affixed to the machine so as to deter unauthorized disablement or removal,

— the component is mounted so as to limit exposure to, or amplification of, dynamic loads, temperature, shock or vibration that could prematurely damage the device,

— the attachment and fixings of ODSs and VAs component do not affect the integrity of the protective structures, e.g. rollover protective structures (ROPS).

4.3 Operator station components

4.3.1 Location and images of monitor

The monitor shall be located such that it is in the 180° arc centred in front of the operator.

The image on the monitor should be displayed in the most intuitively logical way for the application, as in the following examples.

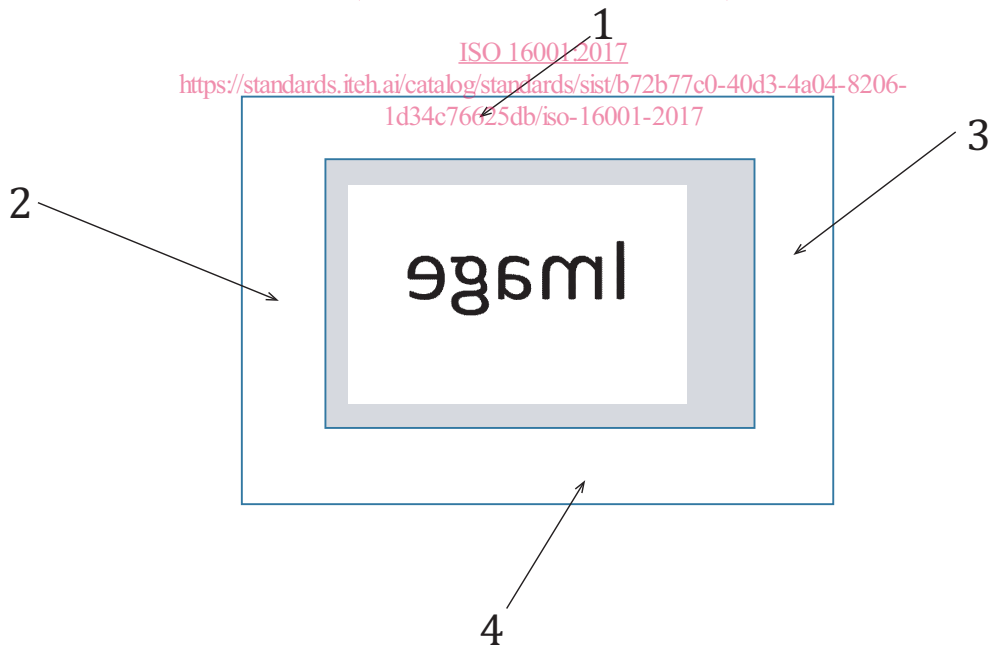
— The image of a rear view camera is commonly displayed as a mirror image (see Figure 1).

— The image of a front view camera is commonly displayed as a “normal” image.

— The image from a side-mounted camera looking downwards is commonly displayed as “normal” image.

— The image from a side-mounted camera looking rearwards could be displayed either as a “normal” or “mirror” image.

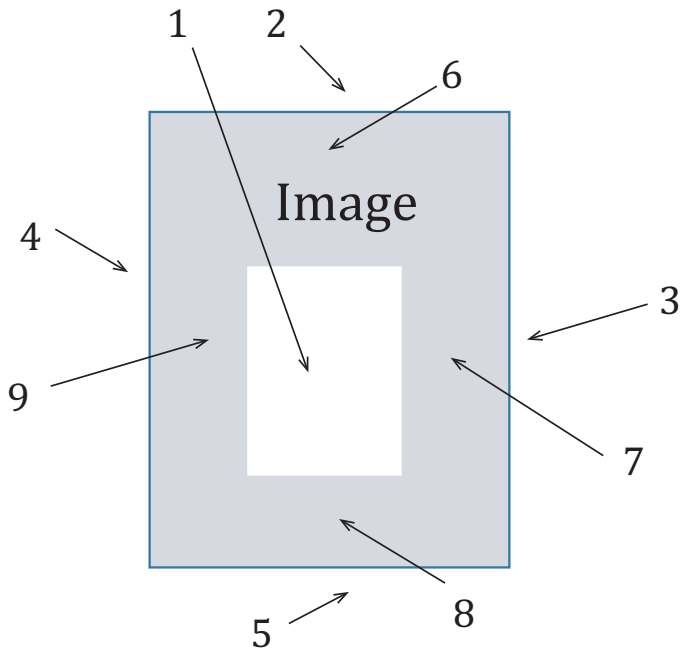
— A 360° “surround view” image is commonly displayed as a “normal” image (see Figure 2).



Key

1	top of monitor	3	right side of monitor
2	left side of monitor	4	bottom of monitor

Figure 1 — Example of a mirror image on the monitor covering the area behind the machine



Key

1	mock surround view of machine	6	ground in front of machine
2	top of monitor	7	ground to right
3	right side of monitor	8	ground in rear of machine
4	left side of monitor	9	ground to left
5	bottom of monitor		

Figure 2 — Example of a normal image on the monitor showing the surround view around the machine

The monitor should be within 1,2 m of the operator's eye point. If the monitor location is more than 1,2 m of operator's eye point, the displayed images shall be proportionally enlarged according to the monitor. The test requirements shall be according to B.8.2, G.4 and G.5. The monitor shall be positioned so as to minimize the glare caused by direct sunlight.

NOTE Factors that influence an operator's ability to detect a person on the monitor are the position of the monitor within the cab, the distance of the operator from the monitor, the size and resolution of monitor, the ambient lighting, the lens on the camera and the distance of the object from the lens.

4.3.2 Warning devices for ODS

Both audible and visual warning devices are required for an ODS. These devices shall provide indications to the operator and may provide indications to workers and other persons present at the work site.

4.3.2.1 Audible devices

Operator station warning devices shall be set at, or shall automatically adjust to, a level at least 3 dB higher than the ambient noise level as measured at maximum governed speed under no load.

All in-cab warnings should be selected so that they are clearly audible at the operator station. The warning signal should be in the frequency range 500 Hz to 3 400 Hz.

In-cab alarms shall be distinguishable from other sounds (for example, warnings or machinery noise) in the operator's station.

NOTE Distinctiveness of the alarm can be achieved by varying the spectral characteristics and the temporal distribution of the signals (see ISO 9533).

4.3.2.2 Visual devices

A green system-status light shall inform the operator that the system is powered and functional. The status light may be continuous or may turn off after the function check is completed.

The warning signals in the cab shall be located such that it is in the 120° arc centred in front of the operator and shall be bright enough to be viewed under sunlight operating conditions. Appropriate shielding may be used to reduce the effect of direct sunlight onto the visual display unit.

The warning signals shall be distinguishable from other instrument panel warnings; the most severe warning shall be a flashing red light.

4.3.2.3 External machine-mounted warning devices

If an external machine-mounted audible warning device is fitted as part of the ODS to alert workers and other persons at the worksite, then the external alarms shall comply with ISO 9533.

External machine-mounted visual warning devices, when fitted, shall be visible to people in the detection zone.

4.4 System activation and initial check

4.4.1 System activation on engine start

The system shall activate automatically on engine start or power-on, shall perform an initial system check, and shall give a proper function indication.

NOTE For a visibility aid, displaying the image from a camera on the monitor fulfils this requirement.

In the case of an ODS malfunction, a warning shall be given to the operator.

4.4.2 System activation from stand-by mode

The system may remain in stand-by mode unless the relevant machine movement mode is selected.

If stand-by mode is provided, the system shall wake up and provide information from the camera or sensor about the direction of the machine motion when the machine moves.

If multiple cameras or sensors are fitted, the system shall provide the camera view or sensor signal appropriate to the direction of travel or other machine movement, for example:

— by using multiple monitors or multiple indicators, each of which provides information about its corresponding camera or sensor;

— by using a single monitor or indicator which sequentially provides information about multiple cameras or sensors;

— by using a single monitor or indicator which simultaneously provides information about multiple cameras or sensors.

4.5 ODS detection time

After the introduction of an object to be detected, the ODS detection time shall not exceed 300 ms.

4.6 Continuous self-checking

The availability of an image of the detection zone on the monitor is sufficient as a monitoring function for a VA.

An ODS shall have a permanent monitoring function including at least the following:

a) an operating indication light (green);

b) if stand-by mode is provided, a stand-by indication light (flashing amber or flashing green) (see 4.3.2.2);

c) a visual or audible or both failure signal if the operation of the system is impaired, including monitoring of each link on the ODS, which includes the monitoring of all machine signals used for system operation, for example:

   — wire break,

   — short-circuit,

   — time management (if applicable),

   — signal output and signal input, and

   — checking of the system.

4.7 Warning device disablement for ODS

The ODS warning device shall not have a means to allow it to be deactivated by a single action. It may be deactivated by two or more separate and distinct actions by the operator.

The activation of the warning device shall be so designed and installed that its operation cannot easily be altered by the operator.

Any exceptions shall be specified in accordance with Annex B to Annex I.

4.8 Electromagnetic compatibility and physical environment operating conditions

The electromagnetic compatibility (EMC) of ODSs and VAs shall comply with ISO 13766.

The physical environmental conditions in which the ODSs and VAs are used shall be according to ISO 15998.

NOTE ISO 19014-3 can be used as an alternative to ISO 15998.

5 Marking and identification

Each major component (e.g. camera, sensor, monitor and controller) shall bear legibly and indelibly the following information:

— manufacturer;

— type and model;

— product serial number;

— regulatory markings, as required.

6 Operator's manual

6.1 Operator's manual

An operator's manual complying with ISO 6750 shall be provided. The manual may be integrated into the appropriate manual for the base machine and shall contain the following, if applicable:

— description of systems function;

— detection area shape and size, and variances according to operational and external factors (e.g. interference, weather, presence of other systems);

— information for job-site organization as it related to the use of ODSs and VAs, as required;

— weather limitations;

— topography limitations, as required;

— instructions for routine maintenance, including necessary countermeasures against environmental conditions that could impair the system's sensitivity or its ability to discriminate objects;

— instructions for activation;

— description of controls;

— instructions concerning safe operation;

— instructions on action in the event of malfunction;

— regulatory certifications (such as RF conformity test certifications required by the regional regulatory body), if required;

— countries for which type approval has been achieved, if required;

— recommended routine for regular performance checks of the ODSs and VAs by the user, as required;

6.2 Other information documents

For ODSs and VAs systems if separately placed on the market shall have additional instructions covering the following:

— detailed description of performance and operating limits, in particular, the effect of different mounting heights and angles;

— instructions for installation and assembly, including mounting location, if required;

— instructions for performance verification;

— information for connection with other components, if required;

— regulatory certifications (such as RF conformity test certifications required by the regional regulatory body);

— electrical supply requirements, as required.

Annex A
(informative)

Selection of ODSs and VAs

A.1 Overview

ODSs and VAs can be used to supplement the direct and indirect vision of the operator. In selecting an ODS or VA, consideration should be given to the operator's information needs and to the operator's ability to respond to the information provided. The operator experiences many demands for attention. When selecting, careful consideration should also be given to the form of information, visual or audible, that is of most use to the operator when an object entering occurs.

It is essential to take into account that ODSs and VAs have both advantages and disadvantages. There is no device that works perfectly to cover the desired detection zone in all situations. There is always a risk that visual information passes unnoticed. Audible information can catch the operator's attention, but can be ignored if too many unwanted warnings are provided. It is especially important that the shortcomings of ODSs and VAs be recognized and known to system users. Some of these shortcomings can be offset by combining two or more technologies. The advantages and disadvantages of some techniques are summarized in Table A.1.

NOTE The basic technologies are being continuously improved. Therefore, some of the shortcomings could be addressed by future developments.

A.2 Consideration of the functional aspects of ODSs and VAs

A.2.1 General

The following machine functions, and operational and environmental aspects, of the ODSs and VAs should be considered.

A.2.2 Operator needs and ability to interface and use the system

These needs are, for example:

— tolerance of false alarm signals;

— signal-to-noise ratio;

— time and frequency of observation for visual systems;

— potential for information overload where multiple ODSs and VAs are used;

— human factors, (e.g. reaction time);

— training and instruction;

— type of warning required by the operator or person in detection zone.

A.2.3 Operating environment

The operating environment can be influenced by, for example:

— open, congested or restricted site;