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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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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.

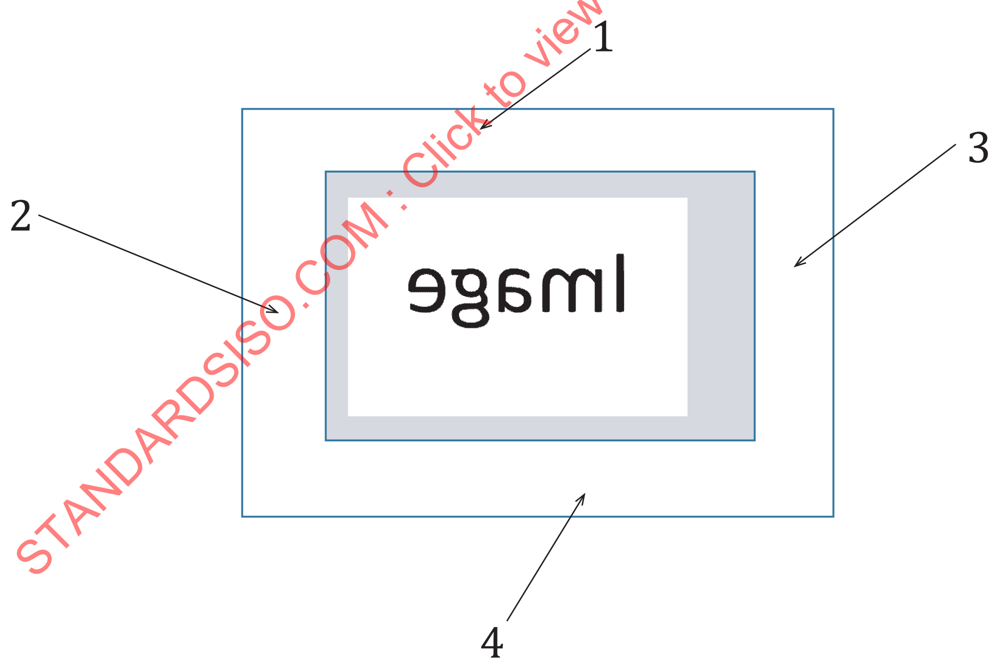
— The image of a rear view camera is commonly displayed as a mirror image (see Figure 1).

— 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

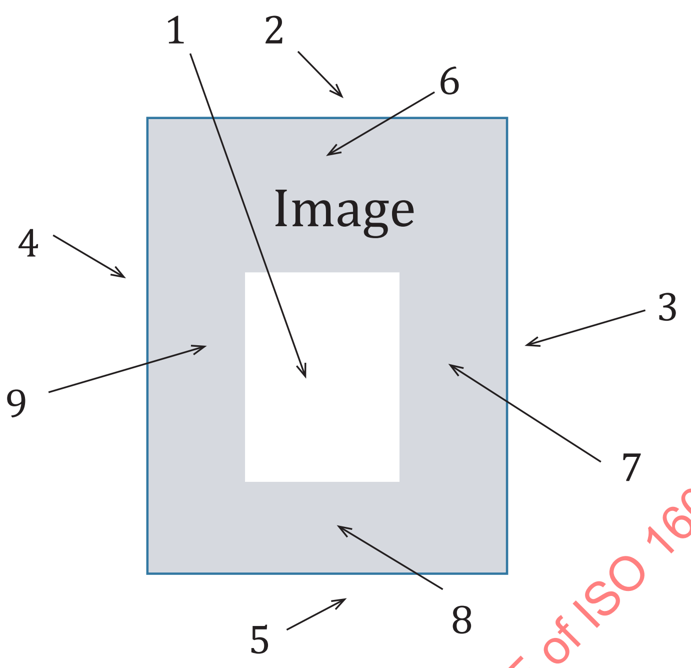
1 top of monitor

2 left side of monitor

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

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;

— topography of the site;

— site conditions (for example, dust, water, light, contrast);

— weather;

— sources of interference (for example, other machines, stronger reflectors or emitters).

A.2.4 Machine functions

These functions can be, for example:

— object entering zones to be covered;

— analysis of machine movement and application at the job site;

— available mounting positions;

— anticipated speed of movement;

— turning circle;

— articulation effects;

— stopping distance.

A.3 Selection of ODSs and VAs

The system should be selected considering the following characteristics:

— visual or sensor detection;

— active or passive response;

NOTE For example, Annex C, Annex D and Annex F type 1 systems are based on active response; on the other hand, Annex B and Annex F type 2 systems are based on passive response. There also exists a combined system such as Annex E, one that is based on passive response triggered by active input.

— visual or audible warning or both;

— response time;

— detection zone;

— operational integrity;

— mounting security;

— overriding, muting and disablement requirements;

— unwanted alarms;

— maintenance, servicing and cleaning requirements;

— performance checking requirements, e.g. periodic detection zone verification;

— ability to distinguish persons (pedestrians) from other obstacles;.

— ability to perform in inclement weather;

— ability to perform in harsh conditions.

Table A.1 — Some advantages and disadvantages of ODSs and VAs

Technology	Description	Advantages	Disadvantages	Range
Fresnel lens	A thin, flat lens using concentric circular grooves in its surface. The grooves act like prisms to bend and focus light.	Allows the driver to see objects below the normal driving position line of sight.	Image can distort near envelope edges. External light can cause lens to be "flooded" with light. External light source needed. Interpretation of image and judging distances can be difficult.	Horizontal: >90°. Vertical: typically 2 m. Depends on mounting position.
Mirror	A reflective surface that provides indirect vision.	Low maintenance and simple to use.	Requires good light conditions. Mounting can affect performance. Can be prone to mechanical damage.	Potentially long, depending upon optical characteristics.
Discriminating external alarm	An alarm system that uses a sensor to trigger an audible warning signal.	Activated when machine movement is selected. Warns only when object is detected.	Relies on pedestrians in the path of the machine to take evasive action. Can be difficult to determine where the direction of sound originates. Potential for confusion if more than one machine is operating in close proximity.	Varies according to decibel output, frequency, mounting position and environmental characteristics.
Ultrasonic	A system that uses reflecting sound waves to detect the presence and measure the distance of an object.	Accurate indication of target distance; both LED and audio signals to operator.	Time delay restricts usage to slow vehicles; limited to operating at reverse speeds of up to 10 km/h. Performance can be affected by adverse weather. Multiple sensors required to cover the entire back area of the machine. Does not discriminate between people and other objects. Limited mounting height above ground.	Horizontal: 6 m max.

Table A.1 *(continued)*

Technology	Description	Advantages	Disadvantages	Range
Fixed-frequency Doppler radar	A system that uses microwave radiation that is emitted and reflected from a moving object; frequency difference indicates motion.	Low cost. Reflects well from most objects. Ignores any dirt on the radar surface and is not affected by snow, wind, rain, etc. Can be designed to detect speed and direction of object.	Difficulty sensing stationary objects; distance can only be inferred from strength of reflected signal. Therefore, at a given sensitivity, the system-responds equally to larger objects farther away from the sensor and to smaller objects closer to the sensor. Not fail safe. Can sense objects outside the vehicle's path. Does not discriminate between people and other objects. Can only detect moving objects.	Range unlimited (but see under "Disadvantages"). Spans up to 160° by design.
Switched-frequency Doppler radar	See description for "Fixed frequency Doppler radar", except that the transmitted frequency is stepped between two or more frequencies.	Can measure range. Reflects well from most objects. Ignores any dirt on the radar surface and is not affected by snow, wind, rain, etc. Can be designed to detect speed and direction of object.	Range measured is the weighted average range of all targets. Therefore, small targets close to the sensor can be masked by larger targets farther away from the sensor. Not fail safe. Does not discriminate between people and other objects. Can sense objects outside the vehicle's path.	Range unlimited, but see under "Disadvantages". Spans up to 160° by design.
Pulse radar	A system that uses reflecting pulses to detect the presence and measure the distance of an object.	Can identify the ranges of multiple targets.	Can sense objects outside the vehicle's path. Does not discriminate between people and other objects.	Range can be limited. Spans up to 160° by design.
Frequency modulated continuous wave (FMCW)	See above, except the transmitted frequency is swept from low to high and back again.	Can identify the ranges of multiple targets. Can be designed to detect speed and direction of object.	Can sense objects outside the vehicle's path. Does not discriminate between people and other objects.	Unlimited. Spans up to 160° by design.

Table A.1 *(continued)*

Technology	Description	Advantages	Disadvantages	Range
Closed circuit television (CCTV)	A device that uses wide-angle lens cameras with a monitor in the cab.	Scratch, dirt and water resistant. Works in low-light conditions.	Distortion makes distances hard to judge. Direct light into the camera causes visibility problems. Direct sun on monitor blocks the image. Objects in shadows are difficult to distinguish. Mud and dust on camera lens can distort the image. Mud and dust can be removed by built-in wash/wipe systems.	Horizontal: up to 127°. Vertical: up to 115°.
Passive infrared (PIR)	A device that senses changes in infrared (IR) emissions from objects.	Ideally detects the difference between a person and the background.	Sensitive to dirt, water and vibration. Cannot measure distance. Cannot distinguish a nearby person from a hot engine afar.	Can be limited in this application; see under “Disadvantages”.
Active infrared (IR)	A device that uses infrared (IR) emissions from objects to detect its presence and measure its distance from the machine.	Unknown.	Unknown.	Unknown.
Contact	Uses brakes that are activated after a switch is triggered by a pivoted bumper.	Simple and relatively inexpensive.	Not suitable for all machines. No advance detection of object or pedestrian. Not considered safe for pedestrian protection. Suitable only for very low-speed applications.	Determined by the dimensions of the device.
Electro-magnetic (radio frequency) signal transponder	System that uses electromagnetic signals or radio waves to communicate between a machine-mounted transceiver and an electronic tag worn by workers or mounted on other obstacles to signal close proximity or collision.	Mutual warnings to both parties. Monitors every direction.	Does not monitor anything without a tag. Radiated power is too weak to pass through the human body and to cover all the detection zone. Directional, like the ultrasonic transponder (see E.4.1). Can detect a person outside the required detection area and requires a judicious choice of the radio frequencies.	Adjustable to 20 m in every direction.

Table A.1 *(continued)*

Technology	Description	Advantages	Disadvantages	Range
Laser	Software-programmable system that uses a pulsed laser and a revolving mirror.	Detection zone can be precisely configured. Different functions can be given to different zones (e.g. apply brakes, sound horn, etc.).	Can suffer from interference from direct sunlight. Heavy steam or plumes of smoke could act as a barrier. Another laser operating on the same wavelength could also signal an alarm. Lens requires frequent cleaning. Diode has limited life (approx. 5 years).	Maximum practical range of 8 m and scan angle of 180°, beam thickness of up to 50 mm.
Ultrasonic transponder	System that uses dual ultrasonic wave to communicate between a “detecting device” installed on the machine and a “responder” worn by the workers to signal close proximity or collision.	Can be adjustable for the detection range required. Sends an alarm directly to both the vehicle operator and the worker. Generates visual and audible warning to the operator and audible warning to the workers.	Does not detect anything without a responder.	Maximum detection range is 12 m, which can be set in 1 m increments. Detection range depends on the choice of a transducer, which is available in 20°, 30°, 40° and 60° directivity.
Colour recognition CCTV	System that analyses CCTV images to detect specific colour tags worn by workers.	Mutual warnings to both parties. Monitors within camera's field of view.	Does not monitor anything without a colour tag.	Detection range is 10 m to 15 m, depending upon camera lens angle.

Table A.1 *(continued)*

Technology	Description	Advantages	Disadvantages	Range
Moving object visual ODS	System that detects objects by analysing visual image of moving objects from the CCTV, then warns the operator (and the person on the ground, if appropriate).	More than one object can be distinguished based on the images provided by the camera. Theoretically, it is possible to add velocity measurement and direction detection to the system's functions.	Difficult to detect stationary objects; can fail to detect object when the machine itself is travelling. Does not discriminate between moving people and other moving objects. Direct light onto the camera causes visibility problems. Objects in shadows are difficult to distinguish. Snow, rain, mist, dust, etc. can cause difficulty in distinguishing objects. Raindrops on the camera can cause distortion on the image and cause it difficult to distinguish the object. If a person does not move (walk), it can be difficult to distinguish the person from static objects such as rocks.	According to manufacturer's specifications
Visual system and morphological recognition	Visual system that uses camera and video analysis algorithms to detect obstacles and their classification according to their appearance.	Obstacle detection with the capability to differentiate pedestrians from hazards and objects to avoid unnecessary triggering of alarms. VA and ODS functionalities are integrated by design; easy installation. Detection zone can be precisely configured.	Cameras shall have direct visibility on the surveillance area. Might not detect a person with "unnatural appearance", i.e. unusual posture or clothing, or incorrect angle from the system's cameras, making identification difficult. Above a certain level, dirt on lenses can lead to degraded detection/ recognition performances.	Maximum range from 6 m up to 15 m

Table A.1 *(continued)*

Technology	Description	Advantages	Disadvantages	Range
Light Detection and Ranging (LIDAR)	An optical remote sensing technology that can measure the distance to, or other properties of a target by illuminating the object with pulsed light. It is a scanning laser rangefinder that generates a 3D point cloud of its environment. Similar to a radar in principle and operation but using laser light instead of radio waves, it is capable of detecting particles and varying physical conditions in the atmosphere.	Can be used close to or at some distance from the machine. No electronic emissions. Good field of detection.	Needs to be evaluated relative to heavy dust and heavy rain conditions.	Detection range is from 1,5 m (min.) to 120 m (max.) Vertical field of detection >20°, with most biased below the horizontal. Horizontal field of detection >250°

Annex B
(normative)

Test procedure for closed-circuit television (CCTV) systems — Additional performance requirements and tests

B.1 Overview and purpose of tests

The tests are designed to measure the performance of CCTV systems intended for use on earth-moving machinery. Aspects of the performance to be determined are

a) overall quality of the image presented in terms of TV lines resolved or equivalent, based on the scale on the test body (see B.2) reading that can be resolved (see B.9.1),

b) limit of operational light levels to maintain minimum proposed resolution (see B.9.2),

c) vertical and horizontal fields of vision for the system (see B.6 and B.7),

d) detection distance (see 4.3.1 and B.8),

e) masking due to direct exposure to high intensity light (see B.9.5), and

f) time taken for the system to respond fully to rapid changes in light levels (see B.9.6).

The tests are not designed to measure aspects of performance due to the camera's height. The performance criteria laid down in these tests assume operating conditions of at least 50 lx average and 20 lx minimum measured illuminance.

B.2 Test body

The Rotakin test body described in EN 50132-7:1996, Annex A shall be used.

B.3 Test areas

For internal tests: 5 m × 5 m level floor area. For external tests: 30 m × 8 m level area.

B.4 Test environment

The test environment shall be evenly lit, free from shaded areas and reflections in field of view.

B.5 Mounting and set-up

B.5.1 Assembly

The CCTV system shall be assembled according to the manufacturer's instructions.

B.5.2 Positioning and alignment

B.5.2.1 Camera

The camera shall be aligned vertically and horizontally to the test body.

B.5.2.2 Test body

The test body shall be vertical and shall face the camera at the centre of the field of view, and at 90° to the optical axis of the lens.

Unless otherwise stated, the image of the test body shall occupy the entire vertical field of view of the monitor.

B.5.2.3 Monitor

The monitor shall be mounted, positioned and aligned so that it is normal to the observer's face, at a comfortable height, and shall be free from glare and reflections.

B.6 Horizontal test

B.6.1 Light levels

Light levels shall be greater than 50 lx and less than 50 000 lx.

B.6.2 Test procedure

Position the test body away from the camera so that the image occupies 25 % of the vertical height at the centre of the monitor screen. Measure and record the distance from the camera to the test body. Move the test body along an arc to the point where the vertical centre line of the image of the test body is at the edge of vision in the monitor screen. Mark the point.

Similarly, establish and mark the point at the opposite side of the monitor screen. Measure and record the distance between the two marks and calculate by trigonometry the horizontal field of view.

B.7 Vertical test

B.7.1 Light levels

Light levels shall be greater than 50 lx and less than 50 000 lx.

B.7.2 Test procedure

Rotate the camera through 90°. Position the test body away from the camera so that the image occupies 25 % of the vertical height at the centre of the monitor screen.

Measure and record the distance from the camera to the test body.

Move the test body along an arc to the point where the vertical centre line of the image of the test body is at the edge of vision in the monitor screen. Mark the point. Similarly establish and mark the point at the opposite side of the monitor screen.

Measure and record the distance between the two marks and calculate by trigonometry the vertical field of view.

B.8 Range

B.8.1 Light levels

Light levels shall be greater than 50 lx and less than 50 000 lx.

B.8.2 Test procedure

Position the test body at a point along the optical axis of the camera so that the screen height of the test body image is 7,0 mm. Measure and record the distance from the test body to the camera.

NOTE The effective operating range of the system is based upon a minimum screen height of 7,0 mm. This is approximately 10 % of the vertical screen height, which is normally considered acceptable for visual detection purposes.

B.9 Additional tests

B.9.1 System resolution

B.9.1.1 Light levels

Light levels shall be greater than 20 lx and less than 200 lx.

B.9.1.2 Test procedure

Position the test body away from the camera so that the image occupies 100 % of the vertical height at the centre of the monitor screen.

Determine and record the CCTV system resolution from the scale on the test body reading from set H to set A.

B.9.1.3 Test criteria

A resolution of better than 200 TV lines or equivalent [see B.1 a)] shall be achieved.

B.9.2 Effect of light on resolution

B.9.2.1 Test procedure

Repeat the procedure according to B.9.1.2 in appropriate steps, from the lowest to the highest light levels stated in the manufacturer's specification. Measure and record the minimum light level at which the minimum resolution specified in B.9.2.2 is observed.

B.9.2.2 Test criteria

A resolution of better than 200 TV lines or equivalent [see B.1 a)] shall be achieved across the specified light level range or the specified light level range reduced to that equivalent to 200 TV lines.

B.9.3 Edge distortion

B.9.3.1 Light levels

Light levels shall be greater than 50 lx and less than 50 000 lx.

B.9.3.2 Test procedure

Position the test body away from the camera so that the image occupies 25 % of the vertical height at the centre of the monitor screen.

Measure and record the distance from the camera to the test body.

Move the test body along an arc to a point indicated by an observer as being at the edge of vision in the monitor screen.

Measure and record the height of the image of the test body.

B.9.3.3 Test criteria

No reduction in the image dimensions shall be observed at the edge for 25 % of the test body height.

B.9.4 Screen edge resolution

B.9.4.1 Light levels

Light levels shall be greater than 50 lx and less than 50 000 lx.

B.9.4.2 Test procedure

Position the test body at 100 % of the vertical height of the monitor screen.

Move the test body to one side of the screen.

Measure and record the resolution.

Rotate the test body through 180° and repeat the procedure for the opposing screen side edge.

B.9.4.3 Test criteria

A minimum resolution of 200 TV lines or equivalent [see B.1 a)] shall be achieved. If this resolution is not achieved across the entire monitor screen, the field of view shall be specified as the angle at which the resolution is achieved.

B.9.5 High intensity light effect

B.9.5.1 Light levels

Test to be carried out outdoors in direct sunlight.

B.9.5.2 Test procedure

Point the camera straight at the sun to produce a masking on the monitor.

Position the test body close to, and in front of, the camera and move the test body directly away from the camera until the image of the test body is wholly obscured by the masking.

Measure and record the width of the masking. This measurement shall be taken at the shoulder point of the test body.

B.9.5.3 Test criteria

Unless otherwise specified, the maximum width of the masking shall be no more than 5 % of the viewable screen width.

B.9.6 Recovery from radical change in light levels

B.9.6.1 Light levels

Place the test body against 10 000 lx for background, in an elevated position so that it is visible with little or no background objects on the monitor.

B.9.6.2 Test procedure

Place a shutter over the camera and hold for 5 s.

Remove the shutter.

Measure and record the time taken for the silhouette of the test body to be clearly discernible.

B.9.6.3 Test criteria

Unless otherwise specified, the recovery time shall be no more than 1,5 s.

B.10 Functional tests

Verify the operation of any additional features of the system, such as mirror versus normal image and day versus night setting for the monitor.

If multiple cameras are installed on the parent machine, each camera shall be tested in accordance with B.6 to B.9, and the results shall be evaluated.

NOTE Some systems can be switched for forward or rearward use. In forward use the image on the monitor is usually set to normal image, while for rearward use the image on the monitor is usually set to mirror image. If a two-camera system, one for forward use and the other for rearward use, is to be connected to a single monitor, then automatic switching between mirror and normal image can be required.

B.11 Recording

B.11.1 Information

The following information about the CCTV system shall be recorded:

— technical specifications for the monitor and camera;

— model number;

— serial number;

— test dates.

B.11.2 Test values

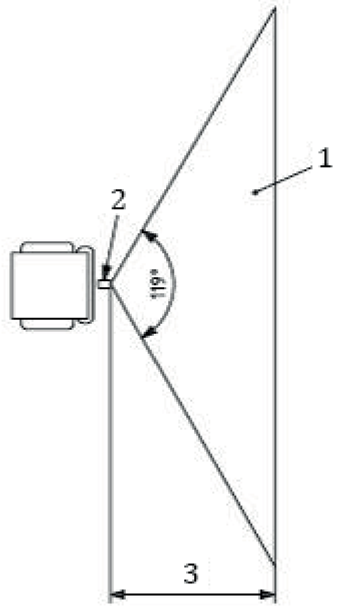
The test values obtained from tests B.6, B.7, and B.8 shall be recorded, as illustrated in Figures B.1 and B.2.

B.11.3 Actual values

The actual values measured for the tests in B.9 shall be recorded with the corresponding test criteria.

B.11.4 Functional performance

Functional performance from test B.10 shall be recorded as either a positive or negative result for each function.



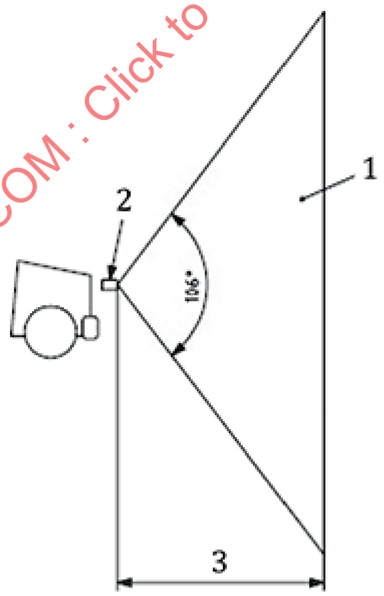
Key

1 recorded angle and range

2 camera

3 range, in m

Figure B.1 — Horizontal field of view — Top view



Key

1 recorded angle and range

2 camera

3 range, in m

Figure B.2 — Vertical field of view — Side view

Annex C
(normative)

Test procedure for radar sensors

C.1 Overview

This annex describes the method for determining the detection zone for radar systems used to detect obstacles near earth-moving machinery. The procedure described in this annex is designed to identify the geometry of the three-dimensional zone within which a person can be reliably detected.

This procedure does not evaluate the position of that zone with respect to the machine on which the radar sensor is to be fitted. Practical considerations regarding the application of this zone to earth-moving machines are given in C.11.

C.2 Test body

The test body shall be that part of a human body which protrudes into the detection zone. In some situations around the edge of the detection zone, the first part of the body to protrude into the zone is the head. This test procedure therefore uses the detection of the head alone as the point of measurement for the edges of the detection zone.

For the tests, a real person with the stature of the medium operator shall be used in accordance with ISO 3411.

NOTE The consistency of results with real people of varying statures has been found to be greater than those with artificial substitute objects.

C.3 Test area

The test area shall be an open space on flat terrain with a dry sand, dry gravel, or combination of dry sand and dry gravel base. No rocks, foliage, or debris larger than 8 cm in diameter shall be in the test area. No large objects such as buildings or heaps shall be within approximately 50 m directly in front of the radar system. No large objects shall be within 25 m of either side of the radar system. All personnel, except those persons conducting the test, shall remain in an area where they are not detected by the radar system.

Mark out a rectangular grid with lines at 1 m intervals over an area equal to the expected detection zone.

C.4 Test environment

The test environment shall be in accordance with 4.8.

C.5 Radar mounting locations

The radar shall be mounted on a static stand in the manner described in the test procedure. No part of the stand shall be within the detection zone of the radar.

The radar mount shall have a facility to tilt the radar in the vertical plane through the angle required by the test procedure and a means of measuring the angle of tilt.

C.6 Test procedure

C.6.1 General

Radar sensors emit and receive within a conical beam that can have a circular or elliptical cross-section. By measuring the horizontal and vertical limits of the detection zone, the full geometry of the zone can be constructed as shown in Figure C.1.

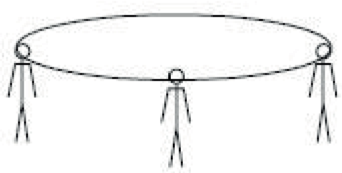


Figure C.1 — Measuring full geometry of detection zone

C.6.2 Measuring horizontal limits

Position the radar as normally oriented on the machine but with the radar beam extending horizontally and the centre of the radar beam at the height of the nose on the head of the test person.

Position the warning device where it can be heard by the test person and the person conducting the test.

Move the test person 0,5 m away from the radar on the centre line of the anticipated detection zone. If the warning device indicates detection, move the test person sideways in each direction until detection does not occur. Record the last position where detection occurs on each side. Record any position between these points where detection does not occur.

Move the test person a further 0,5 m away from the radar and repeat the above procedure.

Repeat the procedure at 1 m intervals away from the radar until detection does not occur.

Record the horizontal limits of the detection zone. Record any areas within this zone where detection did not occur.

C.6.3 Measuring vertical limits

Position the test person 0,5 m away from the radar on the centre line of the horizontal detection zone. If detection occurs, tilt the radar upwards until detection does not occur and record the maximum angle of upward tilt where detection does occur.

Repeat this test at 1 m from the radar and at further intervals of 1 m until the end of the horizontal detection zone.

Invert the radar in the mounting so that the normal top of the detection zone is at the bottom. Check that the centre of the beam is again level with the nose of the test person.

Repeat the above test to record the angle at which detection occurs at each distance from the radar.

C.7 Adaptation of test procedure for different types of radar

Certain types of radar sensor can include relative movement between radar and test object in the detection strategy. If this function is optional, it should be switched off. If the function cannot be switched off, then the test person may mimic the movement required.

Record whichever of the following applies:

a) no movement is required;

b) movement requirement is switched off;

c) movement is always required.

If movement is always required, record the type of movement required and the speed or distance or both.

C.8 Adaptation of test for radar sensors with programmable detection zones

Where a radar sensor can be programmed to create a variety of detection zone shapes and sizes, the tests specified in C.6.2 and C.6.3 shall be used to confirm the maximum dimensions of the detection zone that can be programmed as specified by the manufacturer.

C.9 Recording maximum detection points

The maximum detection points for the horizontal plane shall be shown on a diagram with a 1 m grid as illustrated by the example shown in Figure C.2.

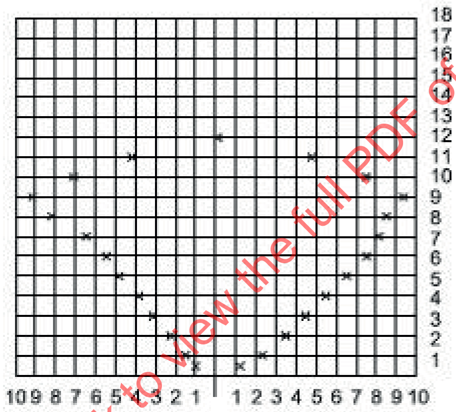


Figure C.2 — Maximum detection points for horizontal plane

The maximum detection points for the vertical plane shall be shown on a diagram with arcs at 1 m spacing, as illustrated in the example shown in Figure C.3.

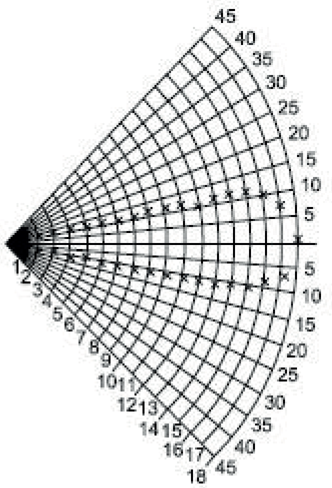


Figure C.3 — Maximum detection points for vertical plane

C.10 Additional testing

C.10.1 Alarms from large objects outside the detection zone

Large structures, such as other machines, can be detected at wider angles and greater distances than a person and can generate unwanted alarms. The test according to C.6.2 shall be repeated using a trihedral metallic reflector as the test object, as shown in Figure C.4. Hold the test object at the height of the horizontal axis of the radar beam with the concave surface pointing toward the radar. Record the detection zone in the same manner as for a person.

NOTE Because it has proven difficult to obtain consistent results with any test object designed to simulate a large structure, this test needs to be regarded as an indication of only the detection zone for large structures.

Dimensions in millimetres

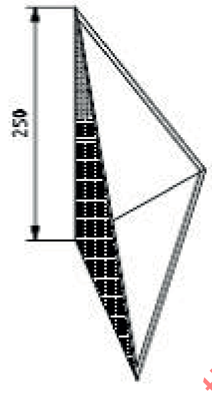


Figure C.4 — Test body simulating large structure

C.10.2 Detection suppressed by large objects in background

Certain methods of radar range measurement can cause large objects in the background to dominate the range measurement and mask the presence of smaller objects closer to the radar. The manufacturer shall state whether such methods are used and explain any additional strategies used to minimize this effect.

A standard test of this effect can give misleading results, because the test might not take into account any additional strategies to minimize this effect. Where such methods are used, the manufacturer shall describe a test using the test object in Figure C.4 to demonstrate the extent to which this effect has been reduced.

C.11 Practical considerations for mounting radars on machines

The manufacturer shall include in the instruction manual practical considerations for mounting radars on machines, with regard to the following.

The tests in C.6 and in C.10 describe the three-dimensional zone within which detection occurs, provided a sufficiently large part of a person penetrates this zone. The tests are conducted with a person, but other objects, including the ground, might also be detected. The detection zone should therefore be positioned to intercept a person but to avoid intercepting the ground, as this can cause unwanted alarms.

Consideration shall be given to the fact that the vertical limits measured apply only on the horizontal centre line. The depth of the conical zone tends to zero at the horizontal limits, as shown in Figure C.2.

Ideally, the radar should be mounted at a height less than 1,5 m. If this mounting height is impractical, then the detection zone close to the radar can be above the height where a man is detected. If the radar beam is tilted down to improve detection close to the radar, unwanted alarms can occur from the ground.

The correct angle of the radar beam should be checked on ground typical of the intended working environment, because the smooth, dry ground of a typical test site causes less reflection back toward the radar sensor than does wet, rutted mud. Some ground, notably sand, might not cause unwanted alarms even when the radar is tilted towards it.

In order to avoid unwanted alarms, the radar should be mounted so that no part of the machine intercepts the detection zone. However, certain radars can include detection strategies that ignore objects which have no movement relative to the radar. The manufacturer should indicate where this detection strategy applies.

Annex D
(normative)

Test procedure for ultrasonic detection systems

D.1 Overview and purpose of tests

The tests described in this annex are designed to measure the performance of ultrasonic detection systems intended for use on earthmoving machinery.

Aspects of the performance to be determined are the following:

— overall performance criteria of the system;

— the performance criteria and limits of detection zone;

— the criteria for location and fixing of the components;

— the operational system's reliability;

— deactivation of the system;

— the detection time;

— physical environment conditions (vibration, shock, temperature, humidity).

The dimensions shown in Figures D.1 to D.3 are for illustrative purposes only and are based upon an example where a 6,0 m range is required. The specific range required depends upon the application of the machine.

This annex describes requirements and tests of ultrasonic detection systems for earth-moving machinery with an operational reverse speed of up to 10 km/h

NOTE 1 An operational speed of up to 10 km/h is typical working mode of wheel loaders, dumpers etc., when reversing.

NOTE 2 Performance requirements and tests of ultrasonic detection systems for slow-moving earth-moving machines (operational reverse speed of up to 3,0 km/h) are determined according to ISO/TR 9953.

D.2 Test body

The geometry of the monitoring area shall be tested with the following test objects.

D.2.1 Test body H for horizontal testing

Test body H for the horizontal test shall consist of a tube 75 mm in diameter and of length 1 700 mm, of grey colour and of hard plastic or metallic construction.

D.2.2 Test body V for vertical testing

Test body V for the vertical test shall consist of a tube 75 mm in diameter and of length 300 mm, of grey colour and of hard plastic or metallic construction.

D.3 Test area

D.3.1 Detection zone shape

The horizontal and vertical detection zone is defined by the dimensions shown in Figure D.1 and Table D.1.

D.3.2 Test surface

The test surface shall be a levelled and firm plane of at least 5,0 m width and 8,0 m length.

D.4 Test environment

The conditions given in 4.8 apply with the following addition:

— wind velocity less than or equal to 5,4 m/s.

D.5 Mounting and set-up

D.5.1 Location and fixing of sensors on machine

The sensors shall be located and arranged on the machine so that the detection zone specified in D.3.1 is covered.

The number of sensors to be used depends on the machine width and on the beam shapes of the sensors.

NOTE Experience has proven that with the current type of ultrasonic sensors with a reach of up to 6,0 m, the following arrangement is appropriate: location of the first sensor, left and right: ≤500 mm from the machine outside boundary. The appropriate number of symmetrically arranged sensors in relation to the machine width is as follows:

Machine width mm	Number of sensors
≤2 500	4
≤3 000	5
≤3 500	6

The device shall be permanently affixed to the machine.

D.5.2 Location and fixing of evaluation device

The evaluation device shall be located inside the operator's station or at an adequate location on the machine so as to prevent environmental and high vibration or shock loads. See 4.8 for physical environment performance criteria required for the device.

D.5.3 Location and fixing of warning (audible and visual) device

The device shall be located at the operator's station and shall meet the requirements of 4.3.2.

D.5.4 Actuation of system

The system shall be provided with a stand-by mode. A separate actuation of the warning device shall be provided that is activated in the reverse operating mode.

The system shall meet the requirements specified in 4.5.

D.5.5 Detection time

The detection time shall be in accordance with 4.5, together with the following: this time shall be calculated as an arithmetic mean of at least 50 measurements in the course of which a test body (as specified in D.2) is moved at a speed of 1 m/s from outside the detection zone to the 3,0 m grid position, i.e. the trigger point for the time measurement.

D.5.6 Operational reliability

D.5.6.1 Systems check

The systems check shall control the function of the whole system and be confirmed by a short audible signal of less than or equal to 10 ms. The systems check shall be automatic after activation of the system. The system shall meet the requirements of 4.5.

D.5.6.2 Malfunction warning

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

D.5.6.3 Operational integrity

The system shall meet the requirements of 4.6.

D.5.7 Tests

D.5.7.1 Adjustment of system

Before starting the test procedure, the system shall be adjusted as follows:

D.5.7.1.1 Adjustment of warning ranges

If the system has two or three warning ranges, these ranges shall be adjusted at the evaluation unit following the system manufacturer's instruction.

EXAMPLE A system with a 6,0 m maximum range is adjusted to the 2,0 m (emergency warning), 4,0 m (pre-warning) and 6,0 m (warning) ranges.

D.5.7.1.2 Sensor adjustment

D.5.7.1.2.1 Height adjustment of the monitoring area

Use the vertical test body, V, and place it at the sensor centre line at maximum reach (as adjusted, see D.5.7.1.1) less 100 mm and move the test body from the ground up to the position where test body V is detected (visual and acoustic signal). Note the height (centre line of test body V) above the ground and adjust the sensor so that this height is 800 mm (–100 mm).

D.5.7.1.2.2 Horizontal adjustment

Use the horizontal test body, H, and place it at half the distance of the maximum reach (as adjusted, see D.5.7.1.1), on both the left and right 100 mm outside of the detection zone as defined in D.3.1.

Adjust the two outer sensors left and right so that test body, H, is detected.

The other sensors shall be adjusted perpendicularly to the machine longitudinal axis.

D.5.7.1.3 Verification of detection warning ranges

If the system has two or three warning ranges, verify the correct adjustment of the range by placing test body H 100 mm before and after the adjusted range (see D.5.7.1.1 and Figure D.2).

For example, for a 2 m warning range:

— at 1,9 m distance from the sensor: emergency warning;

— at 2,1 m distance from the sensor: pre-warning.

D.5.7.2 Static test of detection zone

The test shall be performed on a system that is fitted to the machine.

Alternatively, if the test is performed without a machine, then the sensors shall be arranged 1,2 m above the test surface as specified in D.3.2 and located in accordance with D.5.1.

D.5.7.2.1 Horizontal test

Position test body H statically, with the longitudinal axis in the detection zone, standing perpendicular to the ground, so that its longitudinal axis is in the grid position of each measuring point shown in Figure D.2.

D.5.7.2.2 Vertical test

Position test body V statically, and horizontally in the detection zone, so that its three-dimensional centre is situated in the specific grid position of each measuring point as shown in Figure D.3.

D.5.7.3 Evaluation of the test result

Test bodies H and V shall be detected statically in all grid positions. Detection shall take place unambiguously with an uninterrupted sequence of the signal appropriate to the measuring distance. If the test body is not detected in one position, displace the position to the left and right (test body H) or up and down (test body V) by the width (diameter) of the test body.

The test body shall be detected perfectly in both positions.

D.6 Test report

The test report shall include the following information.

a) System identification

    1) manufacturer;

    2) model;

    3) identification:

        i) evaluation device (part number and serial number);

        ii) warning device (part number and serial number);

        iii) centre (part number and serial number);

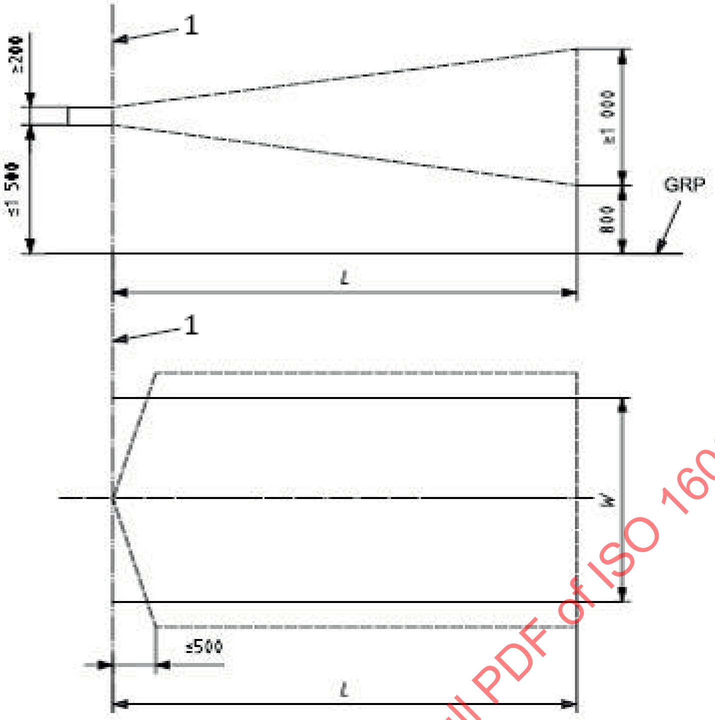
b) Test conditions

    1) test surface;

2) test environment:
   i) wind velocity (m/s);
   ii) temperature (°C);
   iii) relative humidity (%);
3) mounting and set-up
   i) detection zone:
      I) width (mm);
      II) length (mm);
   ii) sensor fixing:
      I) machine;
      II) test bar;
4) sensor arrangement
   i) distance from the outside boundary (mm);
   ii) distance between sensors (mm);
   iii) adjustment of warning ranges;
   iv) emergency warning (mm);
   v) pre-warning (mm);
   vi) warning (mm);
5) system performance:
   i) system activation/check (see D.5.6.1);
   ii) actuation time (see D.5.4);
   iii) detection time (see D.5.5);
   iv) malfunction control (see D.5.6.2);
   v) operational integrity (see D.5.6.3);
   vi) physical environment (see D.4);

c) Test result
   1) horizontal test (see D.5.7.2.1);
   2) vertical test (see D.5.7.2.2);
   3) warning ranges (see D.5.7.1.3).

Dimensions in millimetres



Key

1 reference line (front of the sensor)

L basic length

W basic width, relating to the required detection zone width

GRP ground reference plane

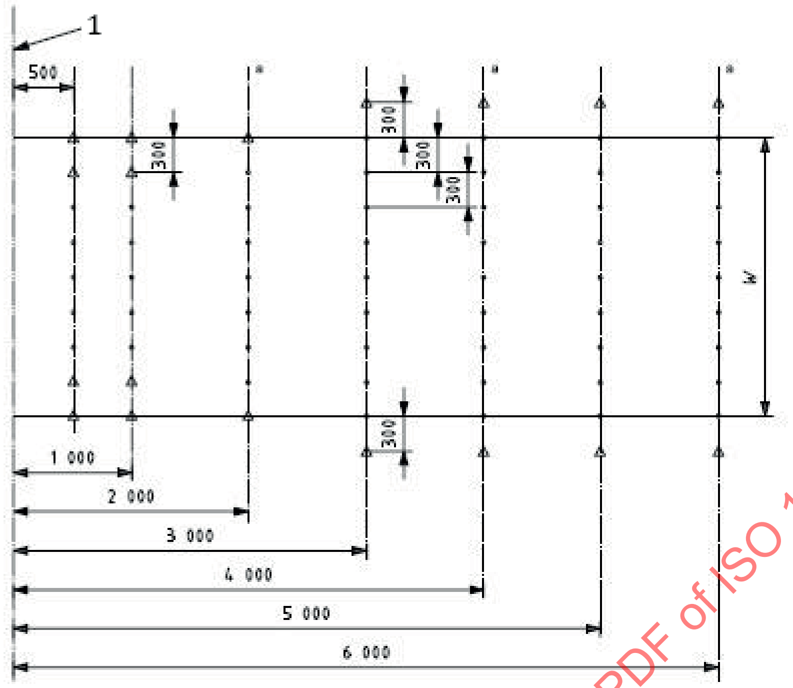
Figure D.1 — Detection zone shape

Table D.1 — Detection zone size

Max. operational reverse speed	*L* m	*W* m
[a]	≥6,0	

[a] Usual rearward operating speed: 0 km/h to 10 km/h in a work cycle.

Dimensions in millimetres



Key

1 reference line (front of the sensor)

● measuring point with test body H

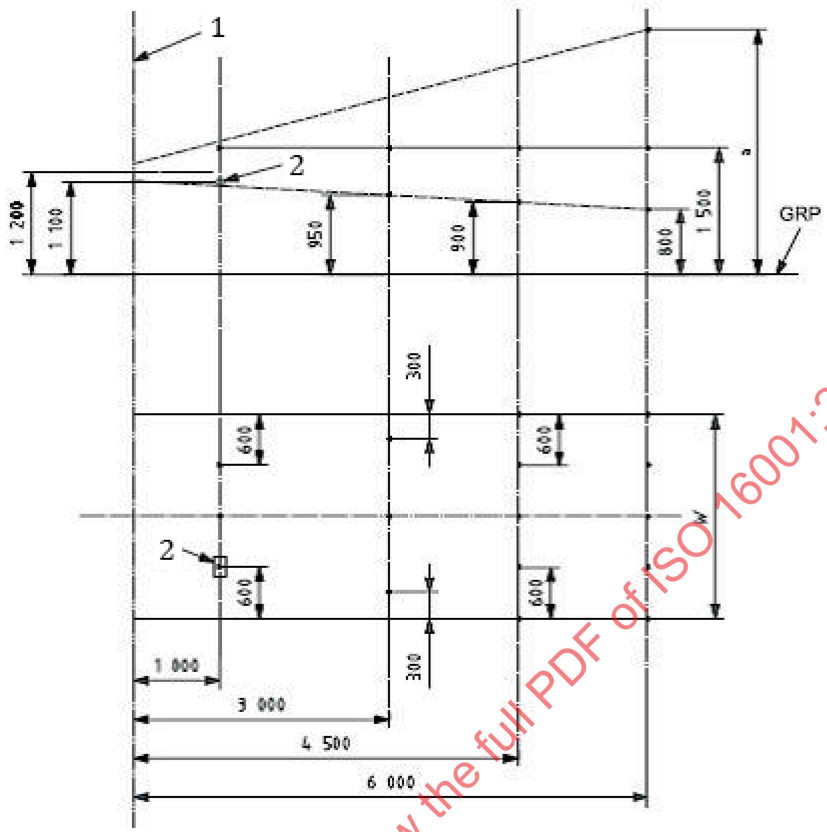
△ optional measuring point

W width

a See D.5.7.1.3.

Figure D.2 — Horizontal detection zone and test grid for static test

Dimensions in millimetres



Key

1 reference line (front of the sensor)

2 test body

● measuring point

GRP ground reference plane

W width

a Maximum.

NOTE If systems are used with warning ranges, make the measurements 100 mm before or behind or both each warning range.

Figure D.3 — Vertical test grid for static test

Annex E
(normative)

Test procedure for ultrasonic transponder systems

E.1 Overview and purpose

This annex provides a test method for verifying the detection zone necessary to prevent accidental contact between the machine and the worker and confirming that the worker who enters the detection zone is detected without fail.

E.2 Test body

The test body shall be a responder worn by a dummy which represents the 50th percentile human body (see Figure E.1). Responders shall be fitted to a helmet, vest, or other outfit that is typically worn by a construction worker.

E.3 Test condition

E.3.1 Test area

The test area shall be a flat surface with a minimum width of 20 m and a minimum length of 20 m.

E.3.2 Test environment

This shall be as follows:

a) temperature in accordance with 4.8;

b) relative humidity in accordance with 4.8;

c) wind velocity of 10 m/s or less.

E.3.3 Mounting of transducer

E.3.3.1 Height and angle

The horizontally set responder position and vertically offset responder position are shown in Figure E.1.

E.3.3.1.1 Horizontally set position

The transducer and responder shall be set at 1,5 m above the ground. The transducer shall be rotated at the position. The detectable rotating angle, clockwise and anticlockwise (counter-clockwise), shall be measured.

E.3.3.1.2 Vertically offset position

The transducer shall be set at 2,5 m above the ground. The responder shall be set at 1,0 m above the ground and at an angle approximately 20° lower in respect to the transducer. The detectable rotating angle, clockwise and anticlockwise (counter-clockwise), shall be measured.

E.3.3.1.3 The distance between the transducer and the responder

The distance, R, between the transducer and the responder shall be set to 0,5 m, 1,0 m, 2,5 m, 5 m, 7,5 m and 10 m.

E.3.3.1.4 Measuring horizontal and vertical patterns

Measurement of the horizontal pattern shall be carried out with the transducer positioned as shown in Figure E.2 a).

Measurement of the vertical pattern shall be carried out with the transducer positioned as shown in Figure E.2 b).

E.3.4 Checking the detection

Whether or not the transducer detects the responder in the measuring range shall be validated by the signals (visual, audible, or both) integrated in this system.

E.3.5 Criteria

The detection range obtained shall be expressed as shown in

— Figure E.3 for (e.g. 60°) oval type transducers, or

— Figure E.4 for (e.g. 30° × 60°) ellipse type transducers.

E.3.5.1 Detection zone distance

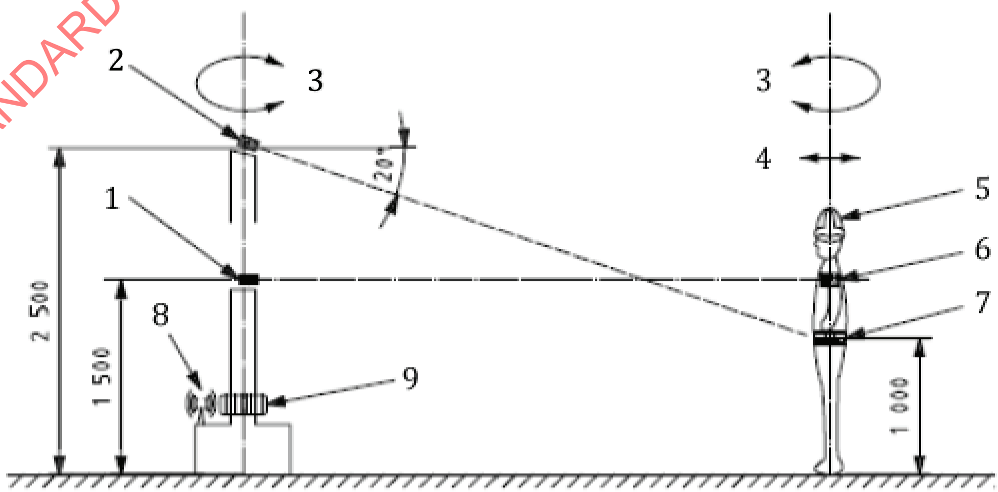
The difference between the maximum distance set at the transducer and the maximum distance at which the responder actually responds shall be ±10 % or less at the horizontally set position.

E.3.5.2 Detection zone width

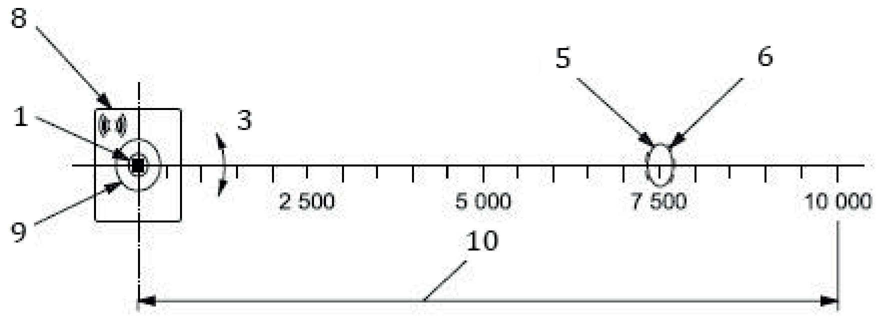
The difference between the nominal width set at the transducer and the width where the responder first responds shall be +20 % or less, and −10 % or more, at the horizontally set position.

The difference between the nominal width set at the transducer and the width where the responder first responds shall be ±20 % or less at the vertically offset position.

Dimensions in millimetres



a) Side view

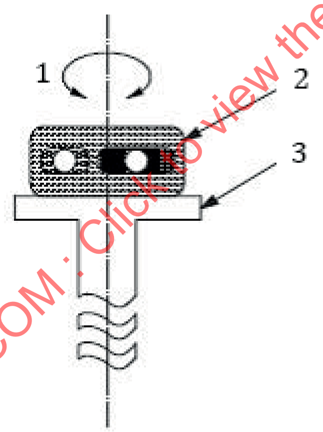


b) Top view

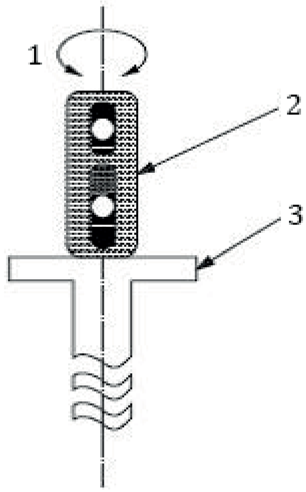
Key

1	first transducer	6	first responder
2	second transducer	7	second responder
3	direction of rotation	8	alarm indication unit
4	direction of movement	9	rotation pedestal
5	dummy	10	detection area

Figure E.1 — Detection area measurement



a) Horizontal pattern



b) Vertical pattern

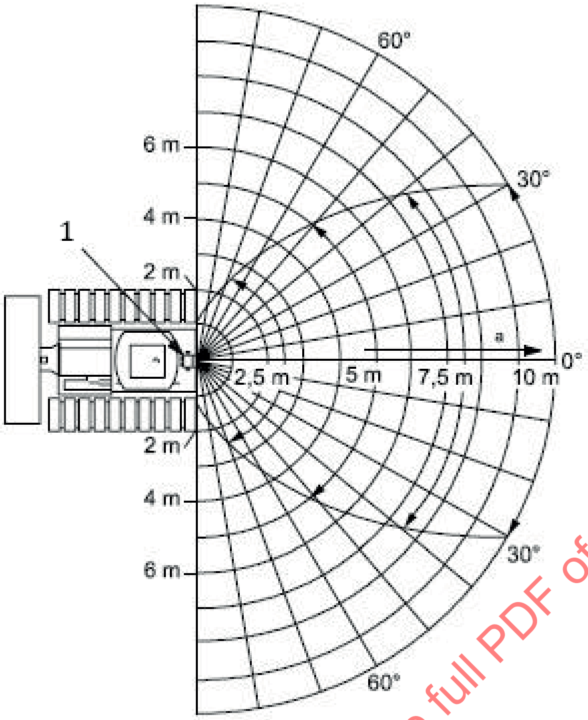
Key

1 direction of rotation

2 transducer

3 rotation pedestal

Figure E.2 — Horizontal and vertical pattern measurement

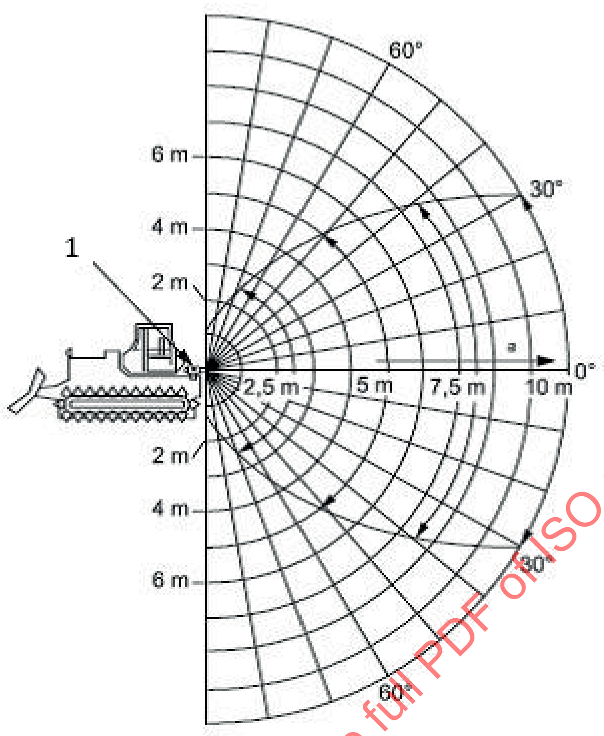


Detection range vs. angle

Range (m)	0,5	1,0	2,5	5,0	7,5	10,0
Angle (degrees)	180	180	130	100	75	60

a) Horizontal pattern

Figure E.3 *(continued)*



Detection range vs. angle

Range (m)	0,5	1,0	2,5	5,0	7,5	10,0
Angle (degrees)	180	180	130	100	75	60

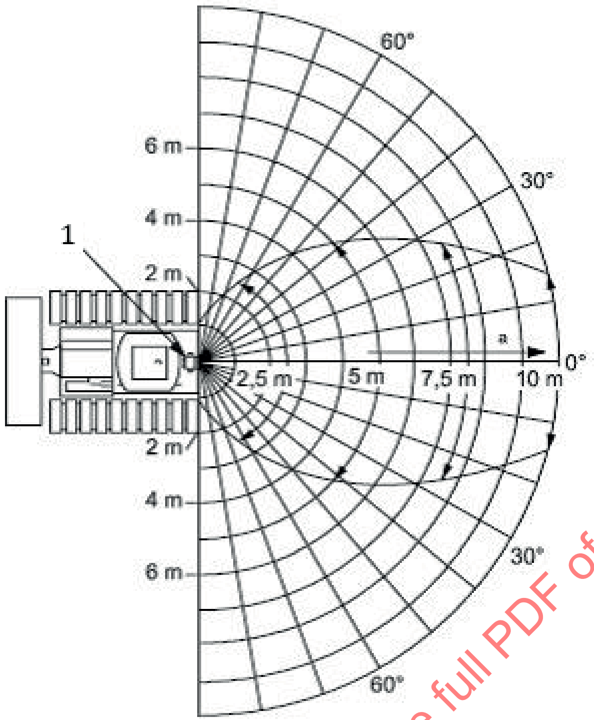
b) Vertical pattern

Key

1 transducer

a Detection range.

Figure E.3 — Detection area (60° oval type transducer)

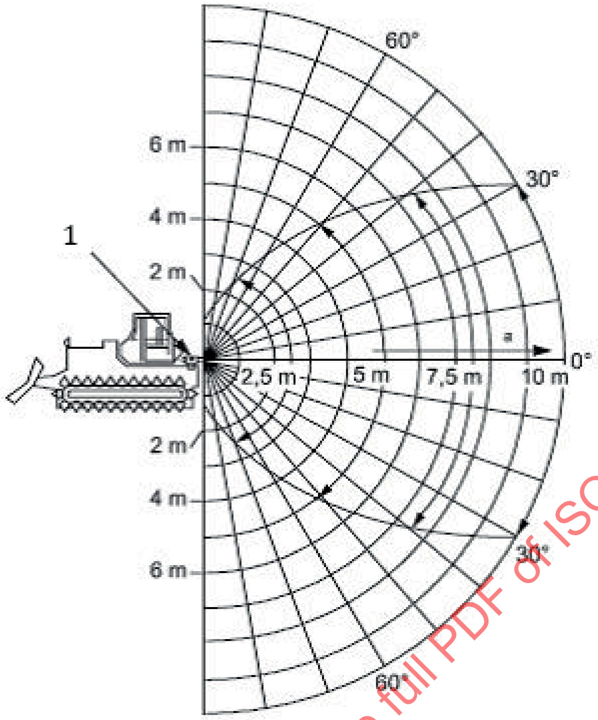


Detection range vs. angle

Range (m)	0,5	1,0	2,5	5,0	7,5	10,0
Angle (degrees)	180	180	120	80	50	30

a) Horizontal pattern

Figure E.4 *(continued)*



Detection range vs. angle

Range (m)	0,5	1,0	2,5	5,0	7,5	10,0
Angle (degrees)	180	180	130	100	75	60

b) Vertical pattern

Key

1 transducer

a Detection range.

Figure E.4 — Detection area (30° × 60° ellipse type transducer)

E.4 Additional test

E.4.1 Directivity of responder

Because installed numbers and positions of the sensors at a helmet or vest are limited, sensing ability differs at the postures of the test body. In order to see the difference, directional sensitivity shall be checked.

E.4.1.1 Test method

With a horizontally set position, the responder shall be set at 5 m from the transducer.

Rotate the responder from 0° to 360° and check whether a non-responding area of angle exists.

E.4.1.2 Criteria

There shall be no non-responding areas of angle.

E.4.2 Audible alarm

To ensure that the alarm is loud enough for the operator and the workers, an alarm volume test shall be conducted.

E.4.2.1 Test method of alarm at operator cab and criteria

The sound pressure level shall be measured at the operator's ear position. The microphone position shall be positioned according to ISO 6394. The sound pressure level of the alarm with low idling engine noise shall be equal to or shall exceed the sound pressure level of the engine at high idling.

E.4.2.2 The alarm at the responder

Effort shall be paid to provide sufficient sound pressure for the workers. For example, the alarm shall be fitted near an ear so that a worker can hear the alarm.

E.4.3 Environmental durability

Environmental durability shall follow the requirements of the main standard unless specified.

E.5 Test report

The test report shall include the following information.

a) Manufacturer/model

b) Test body

c) Test conditions:

  1) test area;

  2) test environment:

    i) temperature;

    ii) relative humidity;

    iii) wind velocity.

E.6 Test results

E.6.1 Detection zone shape

The detection zone shape should be recorded as a diagram or drawing of the measured zone, providing three-dimensional information (see Figures E.3 and E.4).

E.6.2 Additional tests

E.6.2.1 Directivity of responder

Verify and record that there is no position at which the test body does not respond.

E.6.2.2 Audible alarm

Record the sound pressure level at the operator's ear when the alarm sounds with the engine is running at low idling and, for comparison purpose, record the sound pressure level when the engine is running at high idling without the alarm sounds.

E.6.2.3 Environmental durability

With reference to 4.8, record that no malfunction was observed for:

— the temperature test,

— the humidity test, or

— the shock test.

Annex F
(normative)

Test procedure for electromagnetic (EM) signal transceiver systems

F.1 Overview and purpose

This annex provides a test method for determining the detection zone for EM signal transceiver systems used to detect workers and other obstacles that are outfitted with tags near earth-moving machinery. The procedure identifies the geometry of a two-dimensional zone within which a tag is detected. This procedure does not consider the changes that could occur in the detection zone from interference or other effects when the transceiver is mounted on the machinery. See F.10 for aspects that should be considered when installing these systems on actual machinery.

Because there are many variations of this technology, it is helpful to distinguish between the main types.

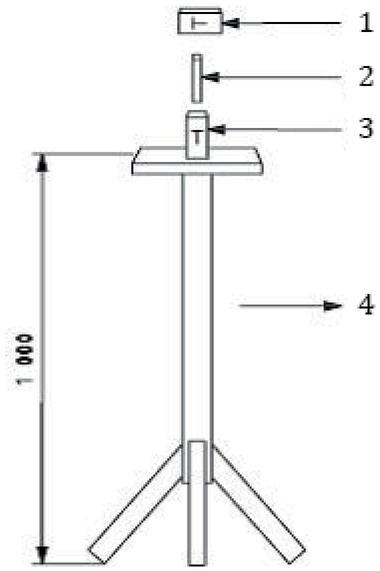
— Type 1: a transmitter and antenna mounted on the machinery radiates an electromagnetic field. The tag detects this field and transmits a signal back to either a separate communications antenna on the machinery or the same antenna used to generate the detection signal. If the tag is within a specified detection range, then an alarm is generated on the machinery to warn the operator. Some systems also generate an alarm at the tag.

— Type 2: the tag radiates an electromagnetic field around the worker or object on which it is mounted. A receiver and antenna mounted on the machinery detects the signal from the tag and generates an alarm for the operator if the tag is within a certain range. An optional and separate signal may be transmitted back to the tag if an alarm is generated at the tag.

F.2 Test body

The test body shall be a stand made from wood (or other material that does not interfere with EM signals) that allows the mounting of the tag in at least three different orientations at a height of 1 m from the ground, with no part of the stand protruding above 1 m. See Figure F.1.

Dimensions in millimetres



Key

1 orientation 3 — lying on side

2 orientation 2 — rotated 90°

3 orientation 1 — normal

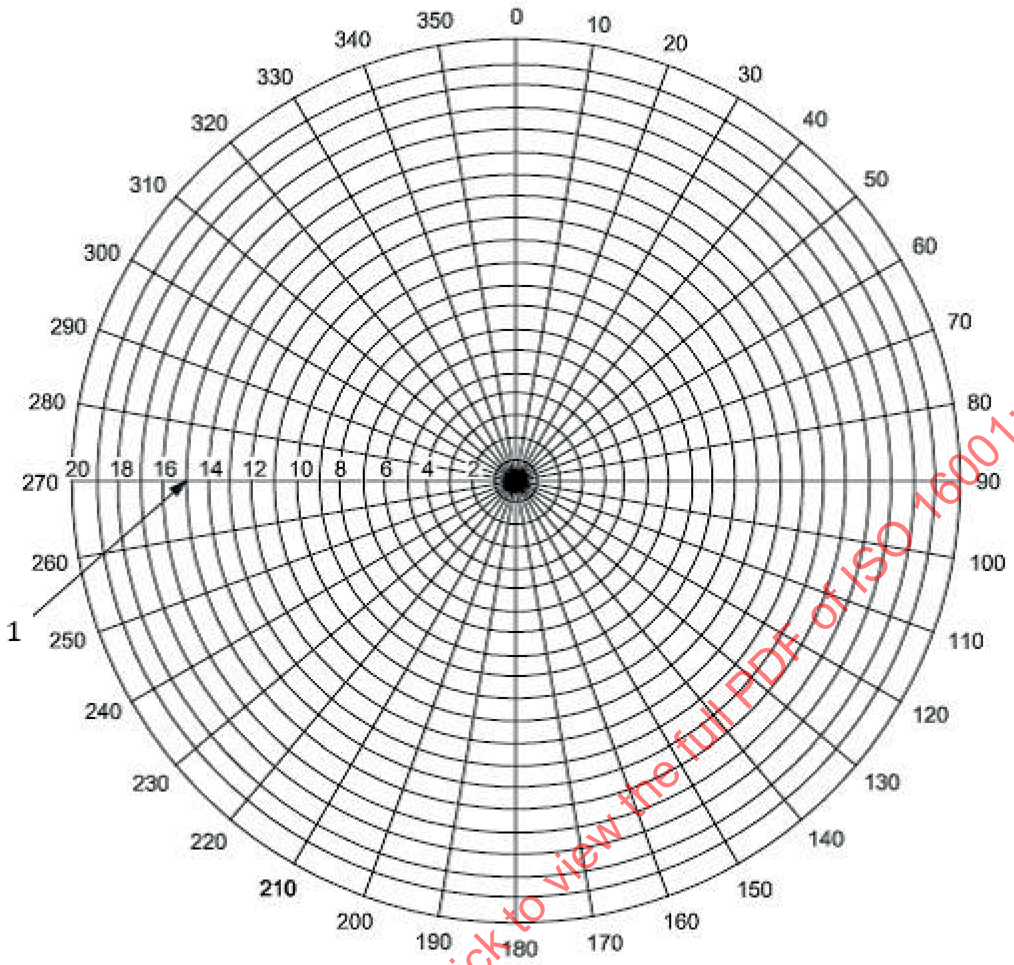
4 direction to machine-mounted antenna

Figure F.1 — Test body showing three tag orientations

F.3 Test area

The test area shall be outdoors in an open area with no obstructions that could cause EM signal interference, buildings, vehicles, or other objects, within a 60 m radius from the centre. Mark out a polar grid with radial lines marked every 10° and concentric circles marked every metre. The total radius of the grid should be as large as the expected detection range of the system. See Figure F.2.

Values in degrees



Key

1 distance from test body, in m

Figure F.2 — Example grid for test area and plotting paper

F.4 Test environment

The test environment shall be in accordance with 4.8.

F.5 Mounting of components meant for machinery

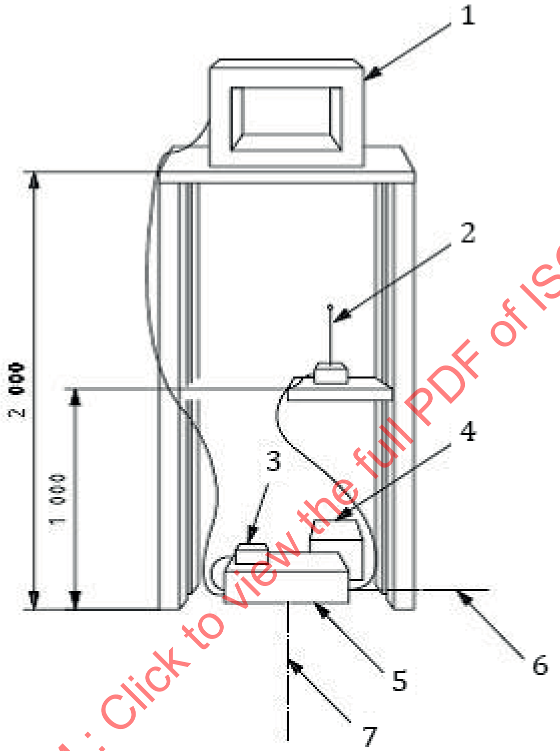
F.5.1 Type 1 system

The components that transmit the detection area signal for the system, i.e. those components normally mounted on the earth-moving machinery, shall be placed in the centre of the test area. The transmitting antenna shall be mounted on a wooden stand (or stand made of another material that does not interfere with EM signals) at a height of 2 m in the same orientation that it would normally be on the machinery; the transmitting antenna shall remain stationary. If a separate antenna is used to communicate with the tags, this antenna shall be mounted at a height of 1 m, directly below the transmitting antenna. The alarm portion of the system shall be situated so that it is easily seen and heard during the tests. See Figure F.3 for an example.

F.5.2 Type 2 system

The components that receive the detection signals from the tags, i.e. those components normally mounted on the earth-moving machinery, shall be placed in the centre of the test area. The receiver antenna shall be mounted on a stand at a height of 2 m in the same orientation that it would normally be on the machinery and it shall remain stationary. If a separate antenna is used to communicate with the tags, it shall be mounted at a height of 1 m directly below the receiving antenna. The alarm portion of the system shall be situated so that it is easily seen and heard during the tests.

Dimensions in millimetres



Key

1 transmitter or receiver normally mounted on machine
2 optional tag communications antenna
3 alarm display
4 power source
5 control electronics
6 270° radial line
7 0° radial line

Figure F.3 — Example of machine component test stand

F.6 Tag mounting

The tag, or component normally worn on the worker or mounted on other obstacles, shall be placed on the test body platform in an orientation expected in working situations. For example, a tag worn on the belt shall be placed on the stand in an upright position similar to the orientation that it would have on the belt of a person facing the components on the machinery. See orientation 1 in Figure F.1. Tags inside a hard hat shall remain in the hard hat and the hat should be placed on the test body platform in an orientation similar to the one it would have on a person standing upright and facing the components on the machinery.

Besides the above tag orientation, two additional orientations shall be tested with the tag in orthogonal positions to simulate, first, a person turned 90° in relation to the first test, and second, a person bent over at the waist or lying down facing the machinery. See Figure F.1.

F.7 Test procedure

F.7.1 System settings

If the range of the system is adjustable, (that is, the range over which a tag is detected can be adjusted according to equipment size or speed, then two sets of tests as described in F.7.2 shall be conducted, one with the range set at minimum and the other with the range set at the manufacturer's recommended maximum.

F.7.2 Measuring detection zone

With the machine components at the centre of the test area according to F.3, place the test body and tag on the 1 m radius circle at the 0° radial line. Record whether detection occurs. Rotate the tag to the second and third positions as described in F.6, recording detection for each case. The person conducting the test should step aside while detection is noted to ensure they are not causing interference.

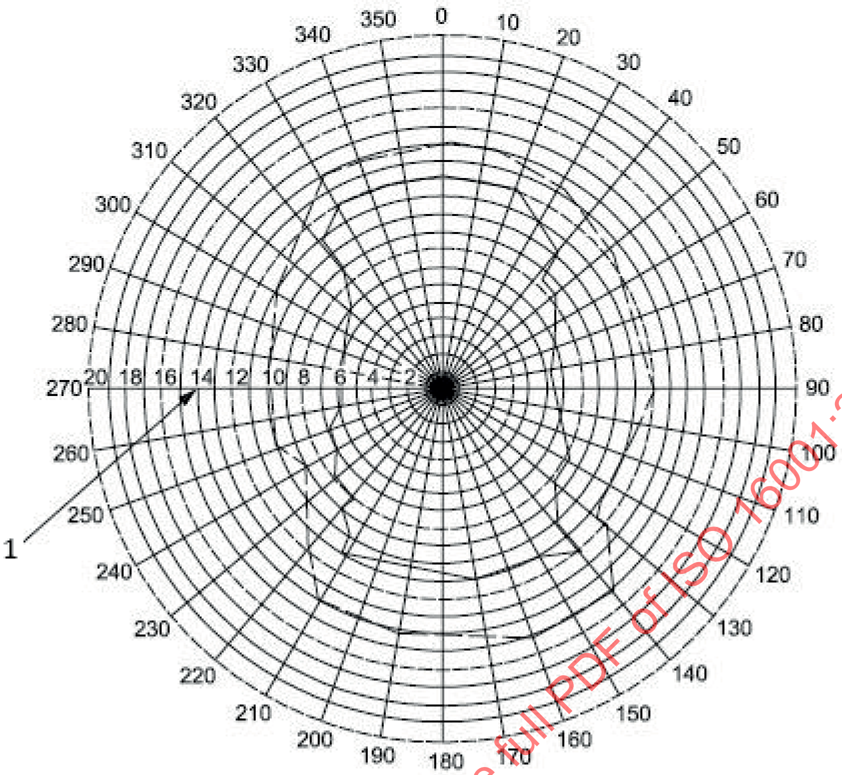
Move the test body away from the centre to the next circle along the 0° radial line and repeat the steps described above. Continue along the radial line until detection does not occur for any tag orientation.

Move to the next radial line and repeat the tests. The test body and tag shall be oriented to face the machine components as described in F.6 (The test body needs to rotate to compensate for movement around the circle). Continue until detection has been recorded for all radial lines and distances from the centre.

F.8 Recording detection zones

Each test point specified in F.7.2 shall be recorded on a polar grid as shown in Figure F.4 in order to indicate the dimensions and shape of the detection zone. Reliable detection should be noted for those points where all three tag orientations were immediately detected by the system. Sporadic detection should be noted for those points where only one or two tag orientations were detected. Furthermore, tag detection shall be considered sporadic if any tag orientation resulted in inconsistent detection at that point. The detection area shall be outlined to indicate the overall shape of the reliable detection zone with sporadic areas identified.

Values in degrees



Key

1	distance from test body, in m
_ _ _ _ _ _ _	sporadic detection area
________	reliable detection area

Figure F.4 — Example plot of reliable and sporadic detection zones

F.9 Verification test for tag on a human

Human shielding of a tag can cause interference and missed detection. An additional test shall be conducted to verify that a tag intended to be worn by a human worker is detected in all orientations. The tag shall be worn on an average-sized person (height between 1,65 m and 1,75 m) in a typical orientation and location as recommended by the manufacturer. The test person shall stand upright facing the machine components mounted on the stand as described in F.5. The person shall stand on the intersection of the 180° radial line and the 8 m circle. Tag detection shall be recorded as "Yes" or "No" for this orientation. The test person shall then rotate his body in place in 45° increments, recording tag detection at each orientation. Results shall be recorded as shown in Table F.1.

Table F.1 — Recording of tag detection for person at range of 8 m

Person's orientation degrees	Tag detection Yes/No
0	
45	
90	
135	
180	
225	
270	
315	

F.10 Practical considerations for mounting EM transceiver systems on machines

The detection zone for these systems, when recorded as described above, could be very different to the detection zone that results after mounting the system on machinery. Interference from the metallic structures on the machine can block portions of the signal, resulting in a detection zone that is truncated in one or more directions. Mounting height and location can also affect the shape of the detection zone. Some manufacturers use this quality of EM signals to limit detection to one area of the machinery. For instance, an antenna mounted on the rear axle of a dump truck might only detect tags at the rear of the truck, and conversely for an antenna mounted on the front bumper. Manufacturers shall make these limitations clear in the installation or operation manual so that it is understood that multiple antennas could be needed for full protection around a piece of machinery. It is recommended that manufacturers include an example plot of the detection area of the system when mounted on a typical piece of machinery.

A computer simulation may also be used as a means of determining system performance. A commissioning test as defined in F.11 shall be performed to confirm the validity of results produced by the computer simulation.

F.11 Commissioning test for machine types

Because of the potential for metallic structures on the machine to block portions of the signal (see F.10), a commissioning test based on the method described in F.7 shall be carried out on each machine type to determine the limitations of detection of the system as installed on the machine. The results shall be recoded in accordance with F.8 and the plot compared with that obtained in the original component test. Where there is significant truncation of the signal, a risk assessment shall be carried out to determine whether multiple antennae are needed to provide additional protection to the areas of truncation.

Annex G
(normative)

Particular performance requirements and tests for CCTV system with surround view

G.1 Overview and purpose of tests

This annex provides particular performance requirements and tests for a surround view on CCTV system, which merges the images from multiple cameras into a single image on a single monitor. This annex modifies Annex B so that the object can be appropriately represented on the monitor and recognized by the operator by a surround views.

The tests in Annex B shall be applied except for modification given in G.4 below.

G.2 Test body

Test body consists of a closed top cylinder 400 mm in diameter and of height 1 600 mm.

Top and bottom should be painted or marked, so that they are discriminated as mock-head and feet.

NOTE Specified dimensions are based on the dimensions of a Rotakin test body as specified in EN 50132–7:1996, Annex A.

G.3 Mounting and set-up

G.3.1 Cameras

The camera shall be set-up on the parent machine as designed.

G.3.2 Test body

The test body shall be vertical and shall be placed in the test evaluation area.

G.4 Test requirement

The purpose of the test is to measure and record the location of the test body at which the size in the monitor of the test body image is 7,0 mm. This test shall be done to each merging overlap image.

NOTE If a single test body is represented as multiple images on the monitor, use images equal to or larger than 7,0 mm height for test recording purposes.

G.5 Test procedure

For merging overlap image from multiple cameras, draw on the ground a mesh covering the detection area with specified size cells as presented on Figure G.1. Cell size shall be specified by manufacture conforming to the risk assessment. The minimum cell size shall be 1 m.

— x-axis (the lateral direction of the base machine) is the line that runs through the rear end of the base machine and perpendicular to y-axis.

— y-axis (the longitudinal direction of the base machine) is the line that runs through the centre point of base machine and parallel to the longitudinal of base machine.

— The centre point of the base machine is based on the parent machine manufacturer's specifications.

Place test body on each point of the mesh. Measure and confirm if the size in the monitor of the test body image is equal to or larger than 7,0 mm.

Repeat the procedure, measure and record the location of the test body, until the test body image size becomes less than 7,0 mm. If some part of the test body is not represented, the head end image and leg end image need to be represented at the same time with the total image height of these ends minimum 7,0 mm for being capable to be appropriately recognized.

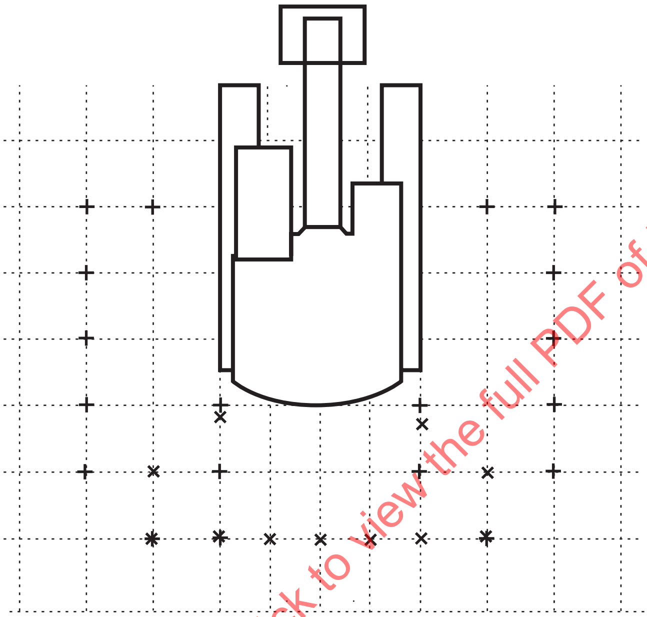


Figure G.1 — Records of merging overlap image

Annex H
(normative)

Particular performance requirements and tests for visual ODS

H.1 Overview and purpose of tests

This annex is applicable to object detection systems that detect based on the camera image of a nearby moving person around the earth-moving machinery. It specifies particular performance requirements and tests (amending those specified in Annex B) for a visual object detection system (ODS) such that the nearby persons around the machines can be appropriately detected avoiding detection loss.

H.2 Test body

See G.2.

H.3 Mounting and set up

H.3.1 Camera

See G.3.1.

H.3.2 Test body

The test body shall be vertical and shall be placed in the test evaluation area.

H.4 Test area

The test area shall be an open flat surface also no visibility obstruction to the visual ODS shall be in the test area. All personnel, except those conducting the test, shall be in an area where they are not detected by the visual ODS. Mark out criss-cross lines at 1 m intervals over the test area from the border of the machine to the distance as specified by the manufacturer.

H.5 Test environment

The test environment shall be in accordance with 4.8 and with the following additions:

— light levels shall be greater than 50 lx and less than 50 000 lx;

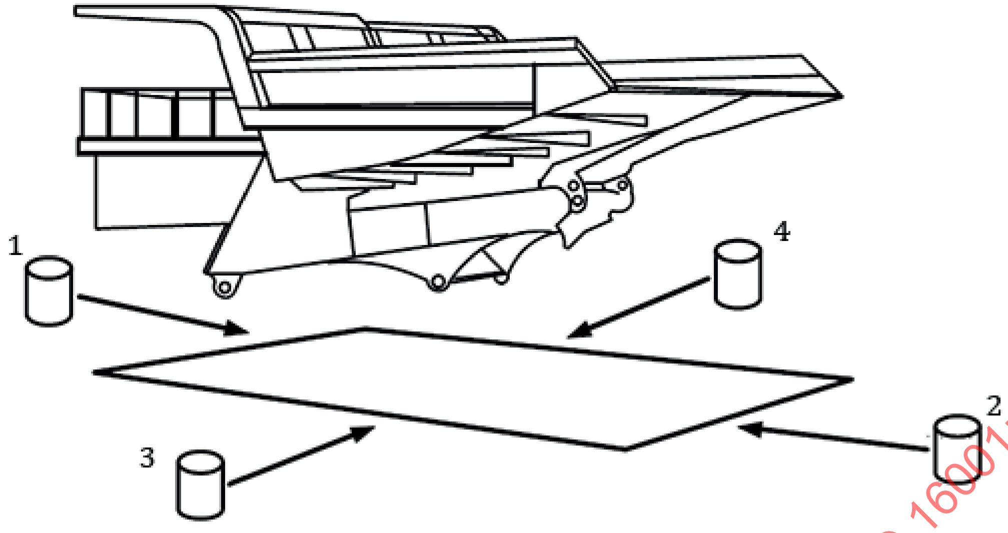
— the camera shall not receive direct sunlight;

— avoid snowfall, rainfall, mist or dust that can otherwise cause the test body difficult to be recognized;

— avoid raindrops, mud or dusts on camera lens that can otherwise cause distortion of the images.

H.6 Test procedure

The test body shall approach each border of the machine (in the following order: from the front, rear, left, and right) at each of the four test conditions.



Key

1 test body approaching from the front side of the machine
2 test body approaching from the rear side of the machine
3 test body approaching from the LH side of the machine
4 test body approaching from the RH side of the machine

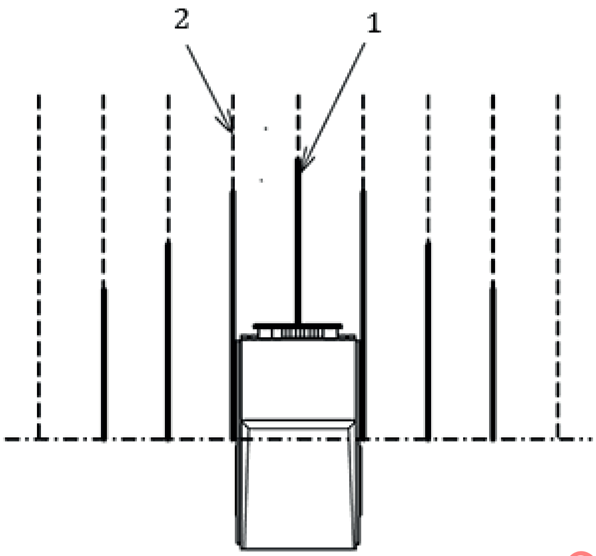
Figure H.1 — Test body approaching the machine border

H.6.1 Test body approaching from the front side of the machine

Test body shall be placed at the distance, where it is not recognized by visual object detection. Let the test body approach, at velocity 4 km/h to the machine front border (0 m). Record the detection range for the test body. If this approaching line is outside the machine LH/RH border, move the test body to the centre of the front and rear end borders of the machine and record the detection range.

Shift sideway by 1 m then repeat the above mentioned movement [approaching velocity 4 km/h to the machine front border (0 m)] and record the detection range.

Then repeat side-shift by 1 m also repeat approaching movement so far as the test evaluation criteria (see H.7) are met.



Key

1 detection range where the test body is appropriately detected (bold line)

2 non-detection range where the test body cannot be detected (broken line)

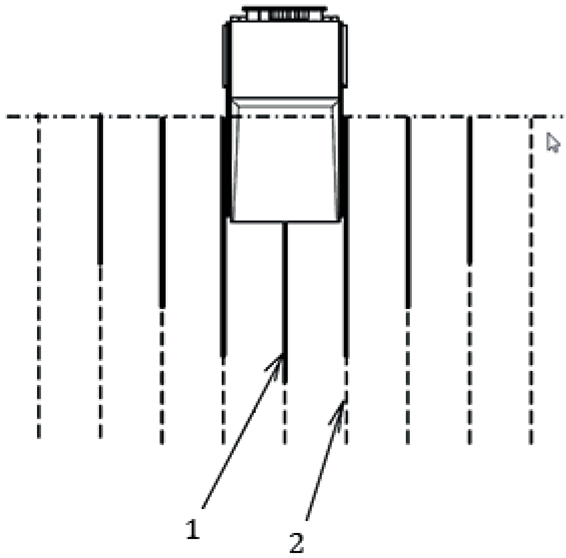
Figure H.2 — Machine front side test area also recording of the detection range

H.6.2 Test body approaching from the rear side of the machine

Test body shall be placed at the distance, where it is not recognized by the visual ODS. Let the test body approach, at velocity 4 km/h to the machine rear border (0 m). Record the detection range for the test body. If this approaching line is outside the machine LH/RH border, move the test body to the centre of the front and rear end borders of the machine and record the detection range.

Shift sideway by 1 m then repeat the above mentioned movement [approaching velocity 4 km/h to the machine rear border (0 m)] and record the detection range.

Then repeat side-shift by 1 m also repeat approaching movement so far as the test evaluation criteria (see H.7) are met.



Key

1 detection range where the test body is appropriately detected (bold line)

2 non-detection range where the test body cannot be detected (broken line)

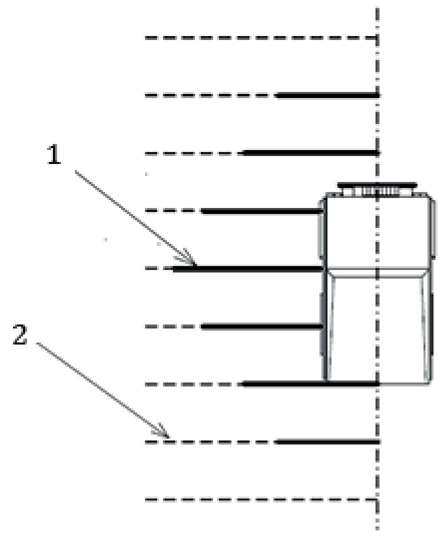
Figure H.3 — Machine rear side test area also recording of the detection range

H.6.3 Test body approaching from the LH side of the machine

Test body shall be placed at the distance, where it is not recognized by the visual ODS. Let the test body approach, at velocity 4 km/h to the machine LH side border (0 m). Record the detection range for the test body. If this approaching line is outside the machine front end/rear end border, move the test body to the centre line of the LH and RH borders of the machine and record the detection range.

Shift fore or aft by 1 m then repeat the above mentioned movement [approaching velocity 4 km/h to the machine LH side border (0 m)] and record the detection range.

Then repeat fore or aft shift by 1 m also repeat approaching movement so far as the test evaluation criteria (see H.7) are met.



Key

1 detection range where the test body is appropriately detected (bold line)

2 non-detection range where the test body cannot be detected (broken line)

Figure H.4 — Machine LH side test area also recording of the detection range

H.6.4 Test body approaching from the RH side of the machine

Test body shall be placed at the distance, where it is not recognized by the visual ODS. Let the test body approach at velocity 4 km/h to the machine RH side border (0 m). Record the detection range for the test body. If this approaching line is outside the machine front end/rear end border, move the test body to the centre line of the LH and RH borders of the machine and record the detection range.

Shift fore or aft by 1 m then repeat the above mentioned movement [approaching velocity 4 km/h to the machine RH side border (0 m)] and record the detection range.

Then repeat fore or aft shift by 1 m also repeat approaching movement so far as the test evaluation criteria (see H.7) are met.