INTERNATIONAL STANDARD

ISO 5010

Third edition
2007-06-01

Earth-moving machinery — Rubber-tyred machines — Steering requirements

Engins de terrassement — Engins équipés de pneumatiques — Systèmes de direction

Reference number
ISO 5010:2007(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

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

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

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 5010 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.

This third edition cancels and replaces the second edition (ISO 5010:1992), which has been technically revised.

Earth-moving machinery — Rubber-tyred machines — Steering requirements

1 Scope

This International Standard specifies steering system tests and performance criteria for evaluating the steering capability of rubber-tyred, self-propelled earth-moving machines having a machine speed, determined in accordance with ISO 6014, greater than 20 km/h.

It is applicable to dozers, loaders, back-hoe loaders, excavators, dumpers, scrapers and graders equipped with either manual steering, power-assisted steering or fully powered steering systems as defined in ISO 6165.

It is not applicable to rollers, compactors or pipelayers.

2 Normative references

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

ISO 3450, *Earth-moving machinery — Braking systems of rubber-tyred machines — Systems and performance requirements and test procedures*

ISO 6014, *Earth-moving machinery — Determination of ground speed*

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

ISO 7457, *Earth-moving machinery — Determination of turning dimensions of wheeled machines*

ISO 10968, *Earth-moving machinery — Operator's controls*

ISO 13849 (all parts), *Safety of machinery — Safety-related parts of control systems*

ISO 15998,[1)] *Earth-moving machinery — Machine-control systems (MCS) using electronic components — Performance criteria and tests for functional safety*

IEC 62061, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems*

1) Under preparation.

3 Terms and definitions

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

3.1
steering system
system including all machine elements between the operator and the ground-contacting wheels participating in steering the machine

3.1.1
manual steering system
system depending exclusively on the muscular power of the operator to effect normal steering of the machine

3.1.2
power-assisted steering system
system employing auxiliary power source(s) to supplement the muscular power of the operator to effect steering of the machine

NOTE 1 Without steering auxiliary power source(s), the machine can be steered with muscular power only.

NOTE 2 See 6.2.1.

3.1.3
full power-assisted steering system
fully powered steering system
system in which the steering is performed by one (or several) source(s) of power

NOTE A fully powered steering system can be described as one that would require 115 N or more muscle power to steer without the power assist.

3.1.4
emergency steering system
system used to steer the machine in the event of a failure of the normal steering power source(s) or engine stoppage

3.2 Steering power sources

3.2.1
normal steering power source
means for providing power to effect steering in either power-assisted or fully powered steering systems

EXAMPLE Hydraulic pump, air compressor, electric generator.

3.2.2
emergency steering power source
means for providing power to the emergency steering system

EXAMPLE Hydraulic pump, air compressor, accumulator, battery.

3.2.3
failure of normal steering power source
complete and instantaneous loss of a normal steering power source output

NOTE It is assumed that not more than one failure will occur at the same time.

3.3
steering control element
control element used by the operator to transmit the desired direction of steering of the machine

3.3.1
steering wheel
operating element, circular shaped or shaped as a segment of a circle, used to generate a steering angle to the steered wheels

3.3.2
lever control
operating element consisting of two independent levers that generate control of the relative speed of the left-hand and right-hand sides of the drive system

3.3.3
joystick control
operating element(s), used to apply either a steering angle to the steered wheels, or to generate a relative speed of the drive systems on the left-hand and right-hand side, by actuating the operating element to the left-hand or right-hand side

3.3.4
pushbutton control
operating element consisting of two separate pushbuttons which can generate a steering angle to the steered wheels or generate control of the relative speed of the left-hand and right-hand sides of the drive system

3.3.5
foot pedal control
operating element used to apply either a steering angle to the steered wheels, or to generate a relative speed of the drive systems on the left-hand and right-hand sides, by pressing two separate foot pedals

3.4
steering effort
necessary force exerted by the operator on the steering control element in order to steer the machine

3.5
steering angle
total displacement angle between the front wheels and the rear wheels as they move about one or more vertical steering axes from their normal straight-ahead condition to a turned condition

NOTE 1 The steering angle for multiple-axle machines is determined between the wheels at the farthest forward and farthest rearward axles.

NOTE 2 Ackermann steering inherently has a greater steering angle on the side of the machine toward the inside of the turn as compared to the wheels on the outside of the turn. Therefore, where Ackermann steering is involved, the location of the steering angle measurement also needs to be specified.

A steering angle accomplished by a combination of geometries incorporating Ackermann steering is included, and also requires the location of the steering angle measurement to be specified.

3.6
tyre circle
outer tyre clearance diameter determined in accordance with Clause 9

3.7
working circuit pressure
nominal pressure applied to the specific circuit by the pump(s)

3.8
transfer device
parts of the **steering system** (3.1) being used to transfer forces (actuation forces and steering forces) and/or steering commands between the **steering control element** (3.3), and if applicable, the **steering power source** (3.2)

NOTE The steering forces and/or steering commands can be transferred

— mechanically,

— hydraulically,

— electrically,

— electronically,

or as a combination of these.

3.9
steered wheels
wheels whose direction of movement can be directly or indirectly modified in order to determine the machine′s direction of travel

3.10
safe state
state applied automatically or manually, after a malfunction of the steering-control system whereby the controlled equipment, process or system is stopped or switched to a safe mode in order to prevent unexpected movements or potentially hazardous release of stored energy

NOTE Safe state is a function of many factors, including operating conditions, the technologies involved, fault-detection capabilities and the safety concept. For electro-hydraulic steering control systems, disabling the electronic portions during a fault and relying on the hydraulic steering system is just one of several ways to reach a safe state.

4 General requirements

4.1 All steering systems

The following requirements apply to all steering systems within the scope of this International Standard.

4.1.1 The normal steering control element provided for the operator shall continue in all circumstances to be the steering control means of the operator.

4.1.1.1 When the steering control element is released, the selected turning circle of tyres (see 3.6) shall remain identical or become larger during travel in the forward direction.

4.1.1.2 The steering system shall be designed so that the movement of the steering control element is consistent with its effect. If control operation is not obvious, an operational sign shall be provided (e.g. using symbols).

4.1.1.3 During machine operation, no uncontrolled steering movement shall occur due to the normal operation of the electronic steering control system.

4.1.1.4 The steering control element shall permit the rate of steering to be gradually adjusted. If the steering speed cannot be gradually adjusted, the maximum machine speed shall be limited to 10 km/h.

4.1.2 All steering systems shall be designed and installed on the machine to withstand, without functional damage, anticipated force inputs from the operator under panic conditions. (See 10.1.1.)

4.1.3 The normal steering system sensitivity, modulation and response shall be adequate to allow the skilled operator to maintain the machine consistently within the intended operating path of each operation for which the machine was designed. This shall be verified by meeting the requirements of 10.2. If a steering control does not permit modulated steering speed, the machine speed shall be reduced to $\leqslant$ 10 km/h.

4.1.3.1 Machines with rear axle steering shall also meet the steering stability requirements of 10.2.2.

4.1.3.2 Machines capable of speeds in excess of 20 km/h in reverse shall have similar steering system forces, rates and duration capability in both forward and reverse. This shall be verified by system schematics or calculations. A test in reverse is not required.

4.1.4 Steering hydraulic circuits shall, if used, incorporate the following features:

a) pressure control devices as required to avoid excessive pressures in the hydraulic circuit;

b) hydraulic hoses, fittings and tubing with test burst pressures at least four times the working circuit pressure control device(s) for normal and emergency steering systems;

c) plumbing arrangements which avoid excessively tight hose bends, torsion in the installed hoses, or scrubbing and chafing of hoses.

4.1.5 Steering system reliability shall be enhanced by the selection and design of components arranged so that inspection and maintenance can be readily performed.

4.1.6 Steering system disturbances shall meet the conditions given in 4.1.6.1 and 4.1.6.2.

4.1.6.1 Steering system disturbances due to other machine functions shall be minimized by appropriate arrangement and geometry. Flexure or travel of suspension elements, machine side inclinations or axle oscillations and steering variations due to driving and braking torques at the wheels are among the influences which shall be minimized by suitable system arrangement and geometry.

4.1.6.2 Steering system disturbances due to the influences of external forces on the machine within the applications for which the machine is designed shall not significantly affect steering control.

4.1.7 Power-assisted and fully powered steering systems shall meet the conditions given in 4.1.7.1 and 4.1.7.3.

4.1.7.1 These systems should preferably be separate from other power systems and circuits. Where this is not the case, the power-assisted and fully powered steering systems shall have priority over other systems or circuits except for an emergency steering system and emergency stopping system which shall be maintained at the level of performance specified in ISO 3450.

4.1.7.2 If other systems (consumers) are provided with power from the normal steering power source, any failure in these systems (consumers) shall be considered the same as a failure in the normal steering power source.

4.1.7.3 A change in ratio between the steering control element and steered wheels is permissible after failure of the normal steering power source, provided the requirements of 10.3 are met.

4.1.8 For machines equipped with an emergency steering system, the system should preferably be separate from other power systems and circuits. Where this is not the case, the emergency steering devices and circuits shall have priority over all other systems or circuits except for the emergency stopping system, which shall be maintained at the level of performance specified in ISO 3450.

4.1.9 The operator’s manual for machines equipped with an emergency steering system shall include the following information:

a) an indication that the machine is equipped with an emergency steering system;

b) the emergency steering capability limitations;

c) the field test procedure for verifying that the emergency steering system is functional.

4.1.10 Unintentional operation

All steering control elements, except for the steering wheel, shall be designed, arranged (i.e. operator station layout), taken out of service (i.e. interlocked) or secured such as to reduce the possibility of unintentional activation when a person is entering or leaving the operator area.

4.2 Steering systems with normal and additional steering control elements

If more than one steering control element is to be used, in addition to the requirements of 4.1, the following requirements shall also be fulfilled:

4.2.1 If a conventional steering wheel is one of the steering control elements, it shall always be activated and have a higher priority than any other steering control element and shall be considered as the normal steering control element.

4.2.2 Steering control elements that can be activated/deactivated or which have a restricted speed range shall have visible or audible indication to the operator when activated.

4.2.3 If use of a steering control element is limited to a certain travel speed in accordance with the steering test specified in 10.4, the travel speed of the machine shall be restricted by design to that speed when the steering control element is activated.

4.2.4 The function of the additional steering control element shall be capable of being switched off or disabled, if it is required to be disabled for travel on public roads.

4.3 Steering systems with electrical/electronic transfer device

In addition to the requirements of 4.1, these steering systems shall also meet the requirements of ISO 15998, or ISO 13849 or IEC 62061, as applicable, and the following.

4.3.1 In the case of a single failure of the electrical/electronic steering control system that results in a hazardous condition and where the driving speed of the machine is greater than 10 km/h, the steering system shall pass into the safe state.

4.3.2 For machines having a speed greater than 20 km/h when operated with electrical/electronic steering control system, the following performance criteria shall be met:

a) the steering performance shall be maintained also in case of a single failure[2)];

b) the probability of unintended steering shall be minimized;

c) the operator shall be warned in case of a failure[2)].

4.3.3 In the case of failure in the power source for the additional steering control element and if the normal steering control element is not affected, requirement a) and b) above do not apply.

4.3.4 The requirements specified in 4.3.2 shall be verified by relevant risk analysis methods, such as FMEA, FTA, ETA or similar, as specified by the manufacturer.

2) “Failure” means any failure covered by a diagnostic coverage average of 80 % according to ISO 13849 or similar methods.

5 Ergonomic requirements

The following requirements apply to all steering systems within the scope of this International Standard.

5.1 The machine shall steer in the direction that corresponds to the direction of movement of the steering control element: i.e. steering-wheel rotation shall be such that the clockwise rotation will turn the machine to the right; counterclockwise rotation will turn the machine to the left.

Operation of the steering control element shall be in accordance with ISO 10968 and, as applicable, with the normal functioning of the machine.

5.2 The steering effort, as defined in 3.4, shall be as low as practical and shall not exceed the values given in 5.2.1 and 5.2.2.

5.2.1 The steering effort for normal steering systems using a steering wheel shall not exceed 115 N when specified for the steering tests according to Clause 10.

The steering actuation forces for operating elements — apart from the steering wheel — shall be in accordance with Table 1.

5.2.2 The steering effort for emergency steering systems shall not exceed 350 N for the steering tests according to Clause 10.

5.3 Steering control element movement to produce a given result shall not vary by more than 25 % between right and left turns up to a 30° steering angle. This may be shown by calculations. For Ackermann steering, this angle applies to the wheels toward the inside of the turn.

5.4 When continued moving of the steering control element is required to continue changing the steering angle, it is desirable to make steering control movement for a given steering angle change greater in the vicinity of the straight-ahead position, such as is commonly achieved with variable rate worm steering gears.

Table 1 — Control actuating forces

Control operation	Control-actuating force N		
	Max.	Normal (frequent operation)	Min. [a]
Hand			
lever, forward/backward	230	80	20
lever, sideways	100	60	15
brake lever, upwards	400	60	15
Foot			
pedal	450	120 [b]	30
tread, centre-pivoted	230	50	30
Toe			
pedal	90	50	12
Fingertip			
lever or switch	20	10	2

[a] For information only. Since the actuating force can be variable along the travel of the control lever, the indicated values are intended to be achieved during the movement and, in particular, before any engagement into a detent position.

[b] With back support: 150 N.

6 Performance requirements

6.1 Normal steering

Steering effort (see 3.4) for normally operating systems, whether manual, power-assisted, or fully powered, shall not exceed 115 N when negotiating the test course described in 10.2.3.

6.2 Emergency steering with power-assisted steering

6.2.1 Steering effort (see 3.4) shall not exceed 350 N during the emergency steering tests according to 10.3.5 and 10.3.6. If this requirement is not met, the steering system shall be classified and tested as a fully powered steering system.

6.2.2 A warning device indicating a normal steering power source failure is required. This warning device shall be audible or visual, and shall be activated by failure of the normal steering power source. However, no emergency steering power source or warning device is required, provided that the emergency steering capability remains within the limits specified in 6.2.1, regardless of time or number of steering applications, and that either a significant increase in steering effort or a significant increase in steering wheel movement for a given amount of steering gives a definite indication to the operator of normal steering power source failure.

6.2.3 This emergency steering system shall also function with reverse machine movement if the maximum rated speed in reverse exceeds 20 km/h.

6.3 Emergency steering with fully powered steering

6.3.1 For machines equipped with an emergency steering system, the emergency steering power source shall be as defined in 3.2.2.

6.3.2 Steering effort shall not exceed 350 N when tested in accordance with 10.3.5 and 10.3.6.

6.3.3 A warning device indicating a normal steering power source failure is required. This warning device shall be audible or visual, and shall be activated by failure of the normal steering power source.

6.3.4 This emergency steering system shall also function with reverse machine movement if the maximum rated speed in reverse exceeds 20 km/h.

6.4 All steering systems

All steering systems (normal and emergency) shall remain functionally undamaged after testing in accordance with 10.1.1.

7 Steering test course

7.1 All steering tests shall be performed on courses made on a compacted earth or paved surface which is flat and which has no more than 3 % grade in any direction. (See Clause 9, 10.2.1 and 10.3.3, and Figures 1 and 2.)

7.2 The test course dimensions shown in Figure 1 shall be determined according to tyre circle, wheelbase, width over tyres and machine type.

7.3 The stated minimum values in Figure 1 are set forth to maintain a reasonable course for the smallest machines.

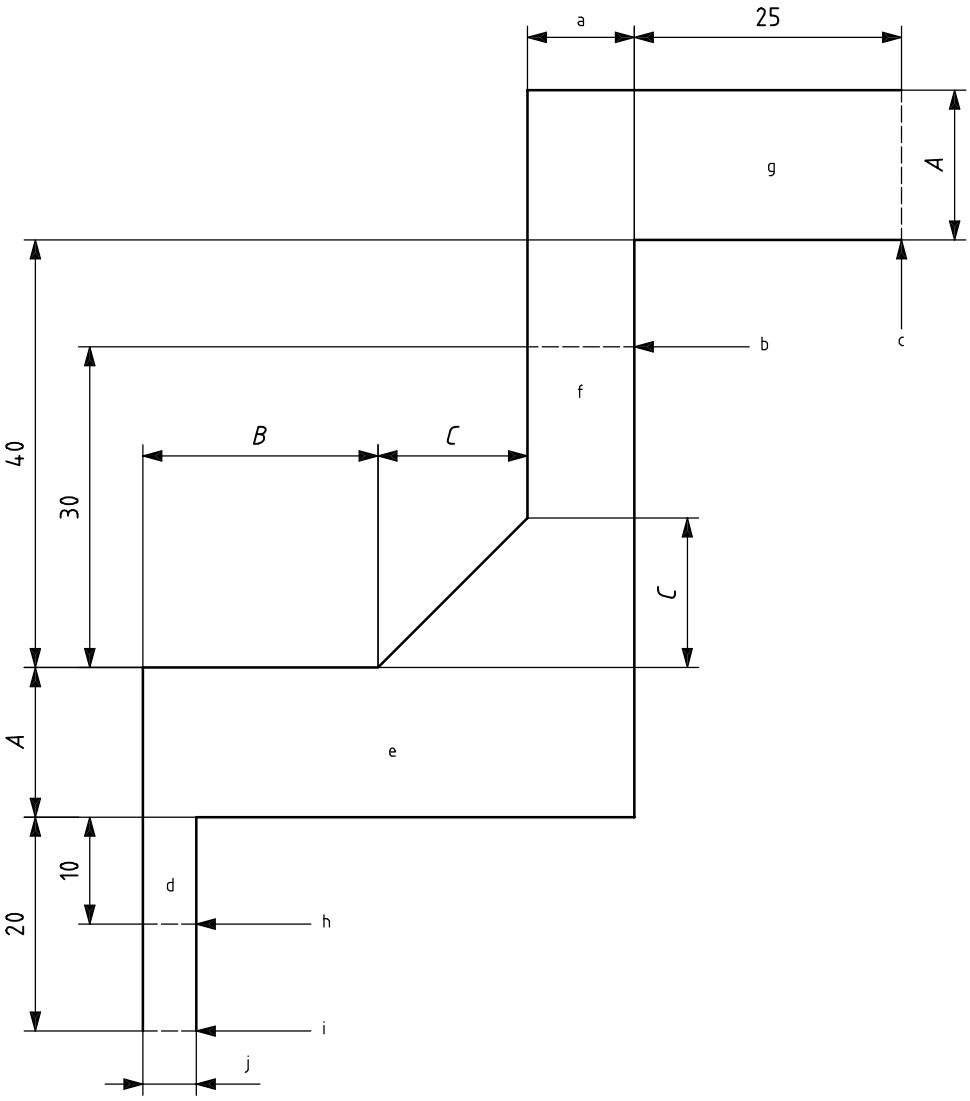
7.4 The wheelbase for a multiple-axle machine for establishing the Figure 1 test course dimensions is the distance between the most forward axle and the most rearward axle.

7.5 The mirror image of the test course shown in Figure 1 may be used.

7.6 Machines with optional tyre sizes shall be tested with tyres approved by the manufacturer having the narrowest tyre tread width.

7.7 Additional steering tests shall be performed according to 10.4, with the additional steering control elements lever control, joystick control and pushbutton control.

Dimensions in metres



Course dimensions

A = 1,1 times the tyre circle or 14 m, whichever is the larger

B = 1,75 times the tyre circle or 22 m, whichever is the larger

C = twice the maximum wheelbase or 15 m, whichever is the smaller

Course length

Machines with a tyre circle of less than 12 m, all wheeled dozers and all graders shall start the test at “Start 1” and terminate the test at “Finish 1”. All other machines shall start the test at “Start 2”and terminate the test at “Finish 2”.

a 2,5 times maximum width over tyres.
b Finish 1.
c Finish 2.
d Corridor 3.
e Corridor 4.
f Corridor 2.
g Corridor 1.
h Start 1.
i Start 2.
j 1,25 times maximum width over tyres.

Figure 1 — Steering test course

8 Machine specifications for test

8.1 Scrapers and dumpers shall be at the manufacturer's rated maximum gross mass and axle distribution, including the mass of the heaviest combination of equipment and attachments approved by the manufacturer, an operator of 75 kg and a full fuel tank.

8.2 Wheeled loaders, wheeled dozers, excavators and graders shall be at the manufacturer's empty machine mass, including the mass of the heaviest combination of equipment and attachments approved by the manufacturer which produce the greatest load on the steered axle(s), an operator of 75 kg and a full fuel tank.

8.3 All component parameters related to steering capability shall be within the manufacturer's specifications, i.e. tyre size and pressure, hydraulic fluid pressure and flow, warning device actuation point, etc.

9 Tyre circle test procedure

The tyre circle (used in calculating the test course dimensions for Figures 1 and 2) is the outer tyre clearance diameter as determined in ISO 7457 and the following.

9.1 Use only the normal steering control element (for example, steering wheel) and the normal steering system. Controls of other functions that can affect the steering path obtained shall not be used (e.g. steering brakes, grader wheel lean, grader rear bogie steer).

9.2 For machines with different right- and left-hand steering circles, use the smaller tyre circle in calculating the test course dimensions.

9.3 Machines with three or more axles which include towed trailing units shall have the tyre circle determined without any semi-trailed or trailing units being towed in order to preclude steering stop interference between the trailing portions and the leading unit.

10 Steering tests

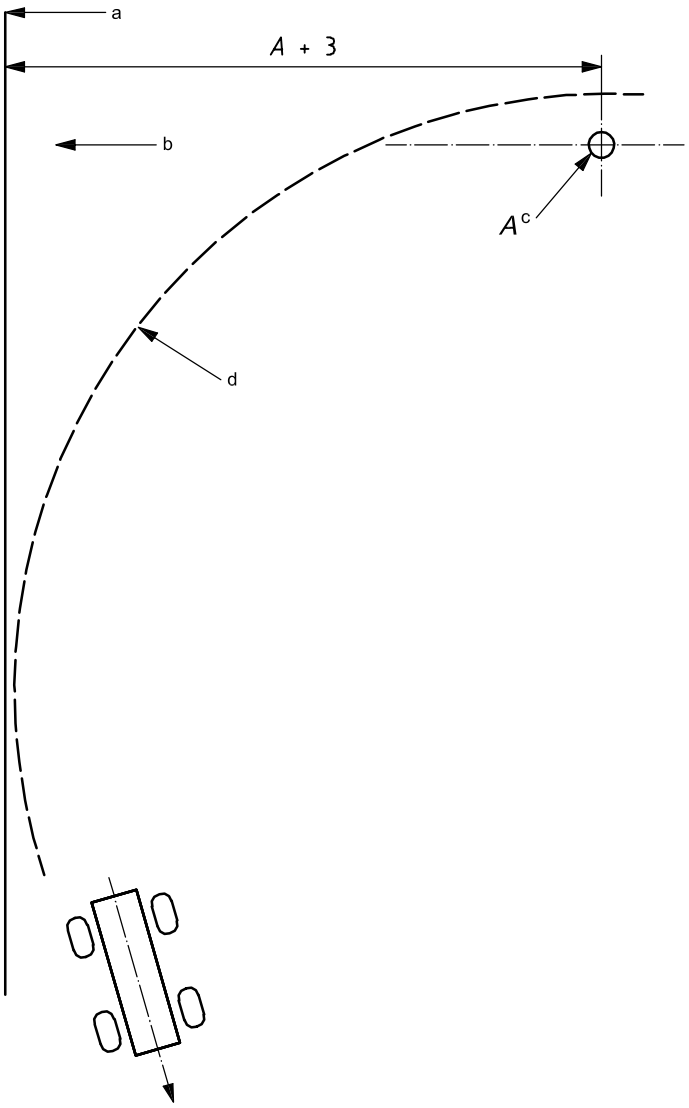
10.1 Tests with all steering systems

10.1.1 Steering systems with a steering wheel as the steering control element shall resist a force of 900 N applied to the steering control element in the direction of the control element movement (see 4.1.2) without any restriction of their function.

Other steering control elements shall resist the double load of the maximum operating force as defined in Table 1.

10.1.2 Machine tyres shall remain within the boundaries of the test courses as shown in Figures 1 and 2, excepting machines with three or more axles which include a towed semi-trailed or trailing section or unit(s), where the tyre path of those semi-trailed or trailing unit(s) is excluded.

Dimensions in metres



Key

A = 1,1 times the tyre circle or 14 m, whichever is the larger

a Perpendicular to original direction of travel.

b Original direction of travel.

c Point A: forward axle location at initiation of steering control movement (see 10.3.8).

d Outside line of tyres.

Figure 2 — Emergency steering response

10.2 Tests with normal steering system

10.2.1 The steering system performance shall be sufficient to maintain the machine tyres within a straight course 100 m long and having a width of 1,25 times the maximum width over tyres while travelling at maximum forward speed. Normal operator steering corrections are permissible.

10.2.2 Machines with rear axle steering shall be driven at 8 km/h ± 2 km/h in a circular path with a diameter corresponding to approximately half of the largest steering angle. When releasing the steering control element, the steering angle shall not increase.

10.2.3 The steering system shall provide sufficient capability to maintain the machine tyres (see 10.1.2) within the test course shown in Figure 1, constructed in accordance with Clause 7, in forward travel at a sustained speed of 16 km/h ± 2 km/h, from the time the axes of the front wheels enter the course until the axes of the front wheels reach the end of the course. The steering effort shall be recorded and shall not exceed 115 N. Several practice runs are permitted to allow the operator to develop an even, modulated application of muscular force on the steering control element.

10.3 Tests with emergency steering system

10.3.1 Check the emergency steering warning device system for proper functioning in accordance with 6.2.2 and 6.3.3.

10.3.2 The power for the normal steering system shall be disconnected if engine-driven because engine power is employed to drive the machine through the test courses specified in 10.3.3, 10.3.5, 10.3.6 and 10.3.8.

10.3.3 The emergency steering system performance shall be sufficient to maintain the machine tyres (see 10.1.2) within a straight course 100 m long and having a width of 1,25 times the maximum width over tyres while travelling at 16 km/h ± 2 km/h. Normal operator steering corrections are permissible.

10.3.4 Emergency steering power available at the beginning of any emergency steering test run shall be no more than is normally available at the instant a normal steering power source failure is indicated.

10.3.5 Emergency steering shall provide an adequate steering force and steering duration to maintain the machine tyres (see 10.1.2) within the test course (as determined from Figure 1) at 8 km/h ± 2 km/h, with the machine moving continuously at that speed from the time the axes of the front wheels enter the course until the axes of the front wheels reach the end of the course.

10.3.6 Emergency steering shall provide an adequate steering force and steering rate to maintain the machine tyres (see 10.1.2) within the test course (as determined from Figure 1) at 16 km/h ± 2 km/h, with the machine moving continuously at that speed from the time the axes of the front wheels enter the course until the axes of the front wheels reach the end of the course.

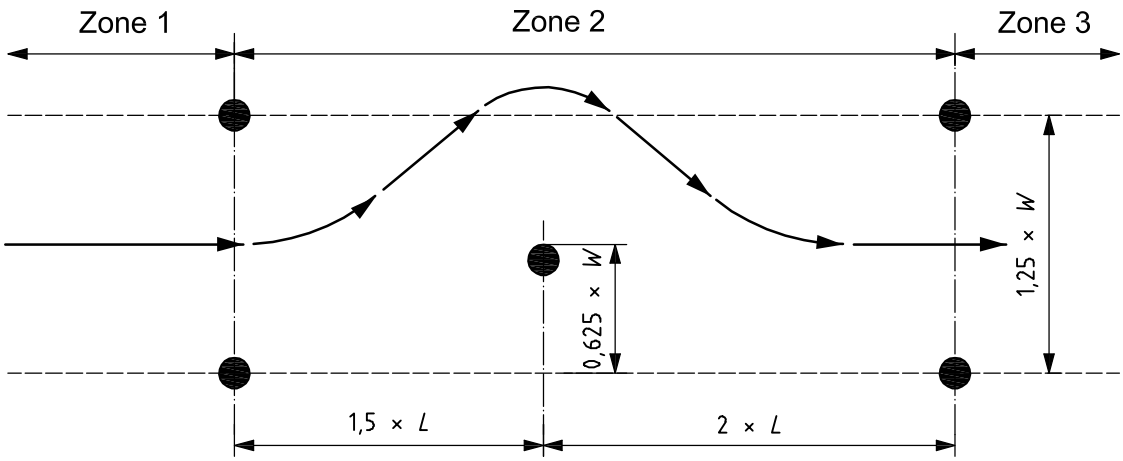
10.3.7 During the tests according to 10.3.5 and 10.3.6, the steering effort shall be recorded and shall not exceed 350 N. Several practice runs are permitted to allow the operator to develop an even, modulated application of the muscular force on the steering control element.

10.3.8 The emergency steering response test specified in this clause shall be conducted by driving the machine through the test course as shown in Figure 2, at 16 km/h ± 2 km/h. This test shall be conducted with the mirror image of the course shown in Figure 2 if the Figure 1 test course was conducted with its own mirror image. Enter the test course with the emergency steering system capability as normally available. Initiate a turn at point A, as shown in Figure 2. The start of steering control actuation should trigger a ground marker located under the front axle, and simultaneously simulate a failure of the normal steering power source(s). The machine shall complete a 90° turn with the tyre track paths remaining within the boundary specified.

10.4 Steering test with additional steering control elements

Additional steering control element(s) shall be tested according to Figure 1. In the case of failure, the highest permitted speed shall be defined according to Figure 3.

Machine tyres shall remain within the boundaries of the test course as shown in Figure 3, excepting machines with three or more axles which include a towed semi-trailed or trailing section or unit(s), where the tyre path of those semi-trailed or trailing unit(s) is excluded (other than avoiding the obstacle).



None of the cones shall be run over.

The machine shall be controllable as a comparable machine with a steering-wheel as operating element and shall provide the same level of safety and efficiency.

Zone 1: The maximum speed should be realized in zone 1. The machine shall enter zone 2 centered between the cones and parallel to the course. Speed may only be reduced after the front edge of the machine has reached the first group of cones.

Zone 2: In this zone, the operator is permitted to do anything that is required for keeping or reducing speed, except for using the brakes. The machine shall swerve around the single cone; additional manoeuvres are not permitted (e.g. a loop turn).

Zone 3: In this zone, the operator may use the brakes after the wheel centre of the front tyre has passed the cones. The machine shall be able to stay within the course until coming to a complete stop.

Key

L total length of machine (e. g. for wheeled loaders, length between counterweight and cutting edge of bucket, with bucket in transport position)

W total width of machine, measured across bucket

Figure 3 — Steering test with additional steering control elements (obstacle avoidance test)

ICS 53.100

Price based on 13 pages