INTERNATIONAL STANDARD

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

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

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Foreword

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

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.

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

This second edition cancels and replaces the first edition (ISO 5010:1984). The alternative steering test, the less stringent test, has been deleted and the more stringent test retained as any steering system meeting the stringent test method will also meet the other requirements.

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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 applies to tractors, loaders, back-hoe loaders, excavators, dumpers, tractor-scrapers and graders equipped with either manual (unassisted) steering, power-assisted steering or fully powered steering as defined in ISO 6165.

For the present, this International Standard excludes rollers, compactors and piplelayers.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3450:1985, *Earth-moving machinery — Wheeled machines — Performance requirements and test procedures for braking systems.*

ISO 6014:1986, *Earth-moving machinery — Determination of ground speed.*

ISO 6165:1987, *Earth-moving machinery — Basic types — Vocabulary.*

ISO 7457:1983, *Earth-moving machinery — Measurement of turning dimensions of wheeled machines.*

3 Definitions

For the purposes of this International Standard, the following 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. Without steering auxiliary power source(s), the machine can be steered with muscle power only. (See 6.2.1.)

3.1.3 fully powered steering system: System in which steering is provided by steering power source(s). Without the power source(s), the machine cannot reasonably be steered with muscle power only. (See 6.2.1.)

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 source

3.2.1 normal steering power source: Means for providing power to effect steering in either power-assisted or fully powered steering systems, for example, hydraulic pump, air compressor, electric generator.

3.2.2 emergency steering power source: Means for providing power to the emergency steering system, for 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. It is assumed that not more than one failure will occur at the same time.

3.3 steering control element: Manual control means by which the operator provides muscular power inputs to the steering system to effect the desired steering of the machine, including the typical steering-wheel or any equivalent manual control means.

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.

NOTES

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

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 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: That nominal pressure applied to the specific circuit by the pump(s).

4 General requirements

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

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

4.2 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.)

4.3 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.

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

4.3.2 Machines that have 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.

4.4 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.

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

4.6 Steering system disturbances shall meet the conditions in 4.6.1 and 4.6.2.

4.6.1 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.

4.6.2 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.

4.7 Power-assisted and fully powered steering systems shall meet the conditions in 4.7.1 and 4.7.3.

4.7.1 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 an emergency steering system and emergency stopping system which shall be maintained at the level of performance specified in ISO 3450.

4.7.2 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.

4.7.3 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.

4.8 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 the emergency stopping system, which shall be maintained at the level of performance specified in ISO 3450.

4.9 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.

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 clockwise rotation will turn the machine to the right; counterclockwise rotation will turn the machine to the left.

5.2 Steering effort as defined in 3.4 shall be as low as practical and shall not exceed the values in 5.2.1 and 5.2.2.

5.2.1 Steering effort for normal steering systems shall not exceed 115 N when specified for the steering tests described in clause 10.

5.2.2 Steering effort for emergency steering systems shall not exceed 350 N for the steering tests described in clause 10.

5.3 Steering control element movement to produce a given result shall not vary 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.

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: power-assisted steering

6.2.1 Steering effort (see 3.4) shall not exceed 350 N during the emergency steering tests in 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 of 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: 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 not be functionally damaged when tested 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 with 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 Figure 1 test course dimensions 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 Wheelbase for a multiple axle machine for establishing figure 1 test course dimensions is the distance between the most forward axle and the most rearward axle.

7.5 The figure 1 test course in a mirror image may be used.

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

8 Machine specifications for test

8.1 Tractor-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 Wheel loaders, wheel tractors, 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 may affect steering path obtained shall not be used (for example, 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 All steering systems shall withstand, without functional damage, a force of 900 N applied to the steering control element in the direction of the control element movement. (See 4.2.)

10.1.2 Machine tyres shall remain within the boundaries of test courses as shown in figures 1 and 2, except 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.

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 with 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 $\pm$ 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 figure 1 test course, constructed in accordance with clause 7, in forward travel at a sustained speed of 16 km/h $\pm$ 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 as described in 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 with a width of 1,25 times the maximum width over tyres while travelling at 16 km/h $\pm$ 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.

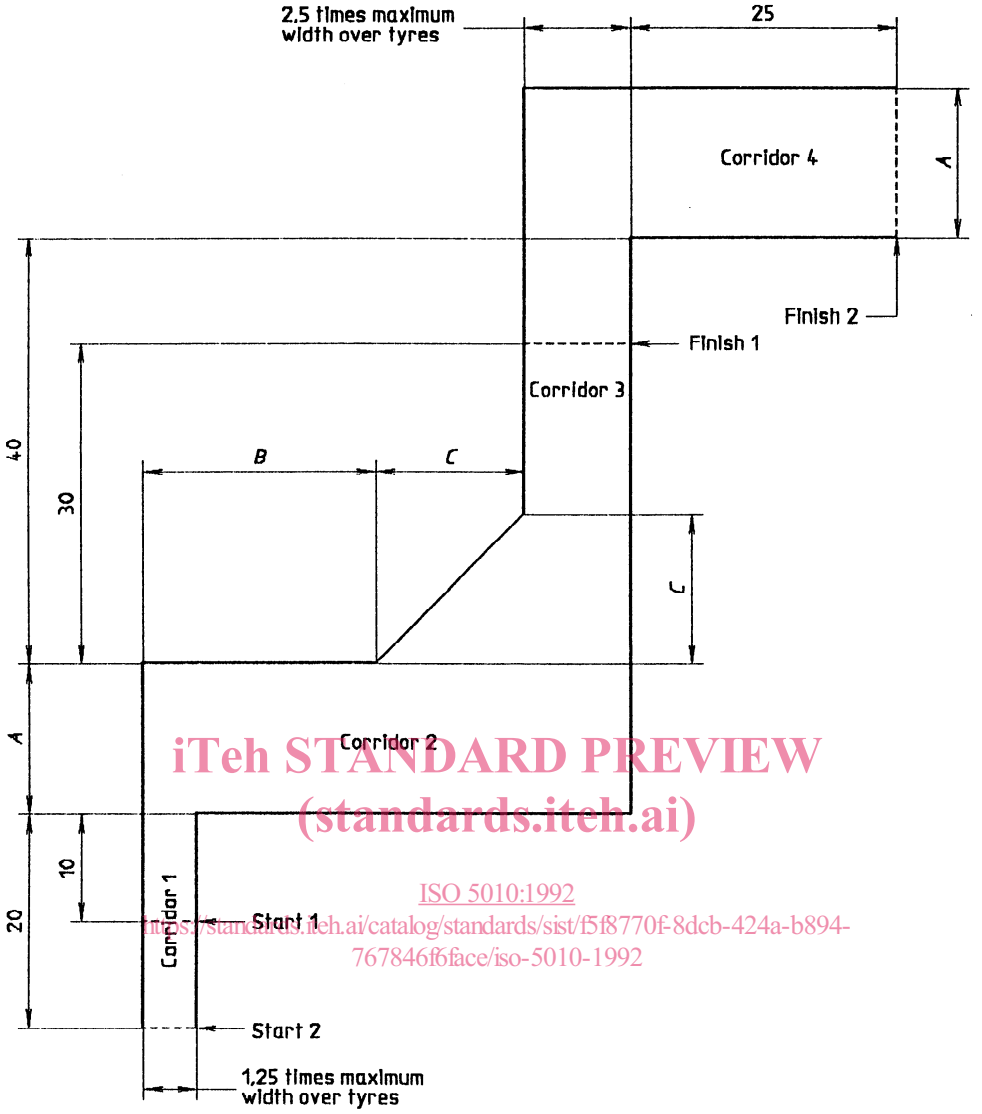
10.3.5 Emergency steering shall provide adequate steering force and steering duration to maintain the machine tyres (see 10.1.2) within the test course (as determined from figure 1) at 8 km/h $\pm$ 2 km/h with the machine moving continuously at that speed from the time the axes of the front wheels enter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

10.3.6 Emergency steering shall provide 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 $\pm$ 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 in 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 $\pm$ 2 km/h. This test shall be conducted to the mirror image of figure 2 if the figure 1 test course was conducted with the mirror image. Enter the test course with emergency steering system capability as normally available. Initiate a turn at point A. 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.

Dimensions in metres



Course dimensions

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

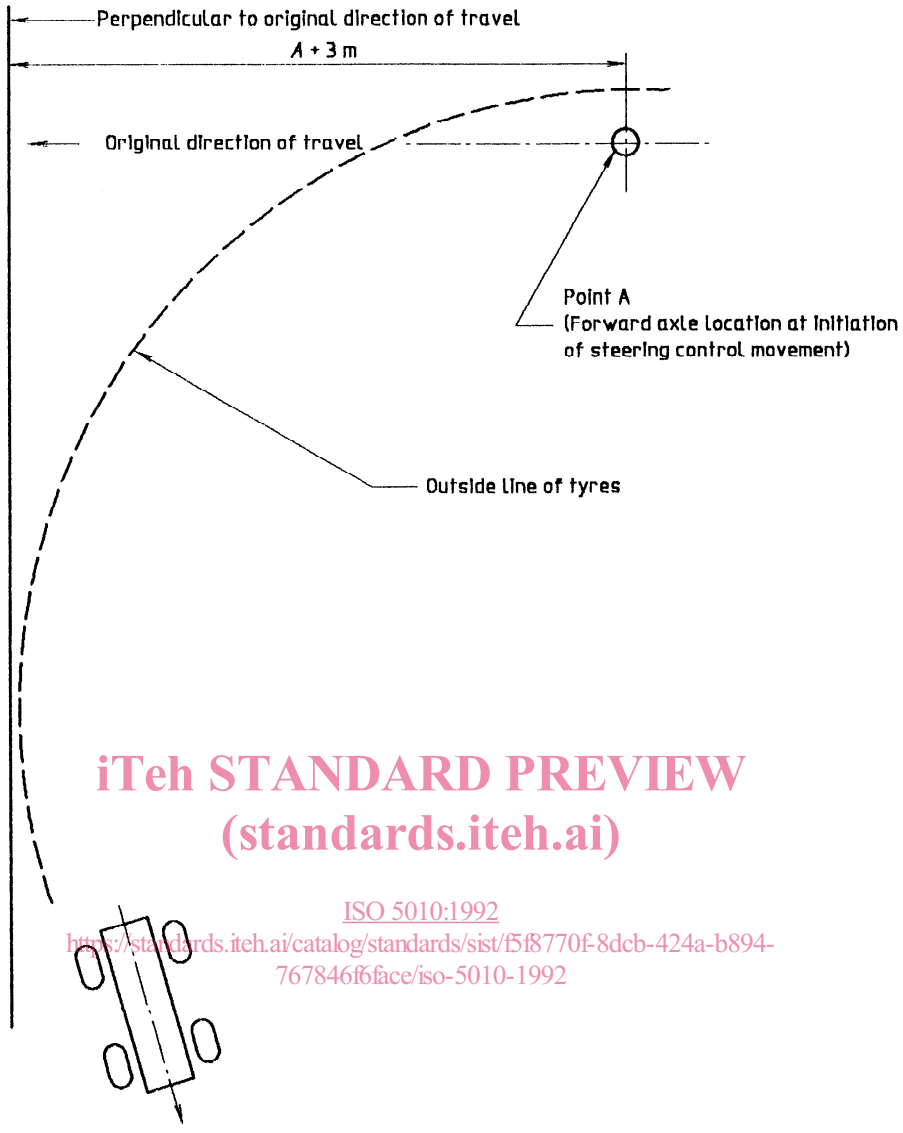
B = 1,75 times the tyre circle or 22 m, whichever is the larger.

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 wheel tractors and all graders shall start the test at "Start 1" and shall terminate the test at "Finish 1". All other machines shall start the test at "Start 2" and shall terminate the test at "Finish 2".

Figure 1 — Steering test course



Course dimensions

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

Figure 2 — Emergency steering response