International Standard 5010

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

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

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 5010 was developed by Technical Committee ISO/TC 127, *Earth-moving machinery*, and was circulated to the member bodies in June 1983.

It has been approved by the member bodies of the following countries :

Australia	Czechoslovakia	Romania
Austria	Germany, F. R.	Sweden
Belgium	Italy	Thailand
Brazil	Japan	United Kingdom
Canada	Poland	USA

The member bodies of the following countries expressed disapproval of the document on technical grounds :

France
USSR

Printed in Switzerland

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

1 Scope

This International Standard specifies steering system test and performance criteria which allow uniform evaluation of the steering capability of earth-moving machines operating on work sites or that will travel on public roads.

2 Field of application

This International Standard applies to self-propelled, rubber-tyred earth-moving machines having speed capability exceeding 20 km/h.

2.1 Earth-moving machines are considered to be of the following basic types, as defined in ISO 6165 :

- tractor;
- loader;
- dumper;
- tractor-scraper;
- excavator;
- grader.

2.2 Applicable steering systems include the following means of providing power for steering :

- manual steering;
- power-assisted steering;
- full-power steering.

3 References

ISO 3450, *Earth-moving machinery — Wheeled machines — Braking system — Performance requirements and test procedures.*[1)]

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

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

4 Terms and definitions

4.1 steering system : A system including all machine elements between the operator and the ground contacting wheels participating in steering the machine.

4.2 Ackermann steering system : A system using the typical automotive vehicle steering geometry in which a pair of wheels at one axle location is mounted on the machine through substantially vertical steering axes at, or adjacent to, each of those wheels; the angular relationships of the wheels about those vertical axes being coordinated such that in any turn, the horizontal wheel axes, when extended, tend to meet at a common point.

4.3 articulated steering system : A system incorporating a substantially vertical steering axis to connect two portions of the machine; for example, the front and rear chassis sections or frames. Steering is accomplished by articulation between the two machine portions about the steering axis.

4.4 wagon steering system : A form of articulated steering system in which the vertical steering axis is located at a wheel axle position.

4.5 skid steering system : A system using variation of speed and/or direction of rotation between wheels on opposite sides of the machine as the means of changing or controlling the course of the machine.

4.6 manual steering system : A system depending exclusively on the muscular power of the operator to effect normal steering of the machine.

4.7 power-assisted steering system : A 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 7.2.1.)

1) At present at the stage of draft. (Revision of ISO 3450-1975.)

4.8 full-power steering system : A 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 7.2.1.)

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

4.10 steering power source :

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

4.10.2 emergency steering power source : The means for providing power to the emergency steering system; for example, hydraulic pump, air compressor, accumulator, battery.

4.11 failures of the normal steering power source : The 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.

4.12 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.

4.13 steering effort : The necessary force exerted by the operator on the steering control element in order to steer the machine.

4.14 steering angle : The 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.

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

4.14.2 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, location of steering angle measurement shall also be specified.

4.14.3 A steering angle accomplished by a combination of geometries incorporating Ackermann steering is included in 4.14 and requires specifying location of measurement in accordance with 4.14.2.

4.15 tyre circle : The outer type clearance diameter determined in accordance with 10.1.

5 General requirements

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

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

5.2 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 11.1.1.)

5.3 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 11.2.

5.3.1 Machines with rear axle steering shall also meet the steering stability requirements of 11.2.2.

5.3.2 Machines that have maximum rated speeds in excess of 20,0 km/h in reverse shall have similar steering system force, rate, and duration capability in both forward and reverse. This shall be verified by system schematics or calculations. A test in reverse is not required.

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

5.4.1 Pressure control devices as required to avoid excessive pressures in the hydraulic circuit.

5.4.2 Hydraulic hoses, fittings, and tubings with test bursting pressures at least four times the highest pressure limits established by the power source pressure control device(s) for the normal and emergency steering systems.

5.4.3 Plumbing arrangements which avoid excessively tight hose bends, torsion in the installed hoses, or scrubbing and chafing of hoses.

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

5.6 Steering system disturbances shall meet the following conditions.

5.6.1 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.

5.6.2 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.

5.7 Power-assisted and full-power steering systems shall meet the following conditions.

5.7.1 These systems should preferably be separate from other power systems and circuits. Where this is not the case, the power-assisted and full-power 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.

5.7.2 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.

5.7.3 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 11.3, 11.4 or 11.5 are met.

5.8 An emergency steering system shall be provided on full-power steering machines.

This 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.

5.9 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 testing procedure for verifying that the emergency steering system is functional.

6 Ergonomic requirements

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

6.1 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 tend to turn the machine to the right; counterclockwise rotation will tend to turn the machine to the left.

6.2 Steering effort as defined in 4.13 shall be as low as practical and shall not exceed the following values :

6.2.1 Steering effort for normal steering systems shall not exceed 115 N when specified for the steering tests described in clause 11.

6.2.2 Steering effort for emergency steering systems shall not exceed 350 N when specified for the steering tests described in clause 11.

6.3 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.

6.4 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.

7 Performance requirements

7.1 Normal steering

Steering effort (see 4.13) for normally operating systems, whether manual, power-assisted, or full-power, shall not exceed 115 N when negotiating the test courses outlined in 11.2.3 and 11.4.3.

7.2 Emergency steering; power-assisted systems

7.2.1 Steering effort (see 4.13) shall not exceed 350 N during the emergency steering tests outlined in 11.3.5, 11.3.6 and 11.4.4. If this requirement is not met, the steering system shall be classified and tested as a full-power steering system.

7.2.2 A warning device indicating a normal steering power source failure is required. This warning device shall be auditive 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 7.2.1, 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.

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

7.3 Emergency steering; full-power systems

7.3.1 Full-power steering systems shall be provided with an emergency steering power source as defined in 4.10.2.

7.3.2 Steering effort shall not exceed 350 N when tested in accordance with 11.3.5, 11.3.6 and 11.4.4.

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

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

7.4 All steering systems

All steering systems (normal and emergency) shall not be functionally damaged when tested in accordance with 11.1.1.

8 Steering test course

8.1 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 10.1, 11.2.1, 11.3.3, 11.4.1 and figures 1, 2, 3 and 4.)

8.2 Figure 1 test course dimensions shall be determined according to tyre circle wheelbase, and width over tyres. (See figure 1 for information.)

8.3 Figure 4 test course dimensions shall be determined according to tyre circle wheelbase, width over tyres, and machine type. (See figure 4 for information.)

8.4 The stated minimum values in figures 1 and 4 are set forth to maintain a reasonable course for the smallest machines.

8.5 Wheelbase for a multiple axle machine for establishing figure 1 or figure 4 test course dimensions is the distance between the most forward axle and the most rearward axle.

8.6 Figure 1 and 4 test courses of the opposite hand (mirror image) may be used.

8.7 Figure 4 test course, whether as shown or of the opposite hand (mirror image), may have the position of corridor 4 reversed, so that the turn from corridor 3 to 4 may be in either direction. This option assists in fitting the test course into the space available at the test site.

8.8 Except for the alternative test course for figure 3, machines with optional tyre sizes shall be tested with tyres approved by the manufacturer that have the narrowest tyre tread width.

9 Machine specifications for test

9.1 Tractor-scrapers and dumpers that will not travel on public roads 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.

9.2 Tractor-scrapers and dumpers that will travel on public roads shall be at rated maximum gross mass and axle distribution as noted in 9.1 unless this exceeds the legal limit for the public road, in which case the tests shall be conducted at the maximum allowable mass and axle loadings for the public road.

9.3 Wheel loaders, wheel tractors, excavators and graders that will or will not travel on public roads 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.

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

10 Tyre circle test procedure

10.1 The tyre circle used in calculating the test course dimensions for figures 1, 2 and 4) is the outer tyre clearance diameter as determined in ISO 7457 and the following.

10.1.1 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).

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

10.1.3 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.

11 Steering tests

11.1 Tests with all steering systems

11.1.1 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 5.2.)

11.1.2 Machine tyres shall remain within the boundaries of test courses as shown in figures 1, 2 and 4, except machines that will not travel on public roads 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) are exempted.

11.2 Tests with normal steering system

11.2.1 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 shall be permissible.

11.2.2 Machines with rear axle steering shall be driven at 8 ± 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. (See 5.3.1.)

11.2.3 The steering system shall provide sufficient capability to maintain the machine tyres (see 11.1.2) within the figure 1 test course for machines that will travel on public roads or the figure 4 test course for machines that will not travel on public roads, constructed in accordance with clause 8, in forward travel at a sustained speed of 16 ± 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. (See 11.4 for an alternative steering test for machines that will travel on public roads.)

11.3 Tests with emergency steering system for machines that will travel on public roads

11.3.1 Check the emergency steering warning device system for proper functioning as described in 7.2.2 and 7.3.3.

11.3.2 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 11.3.3, 11.3.5, 11.3.6 and 11.3.8.

11.3.3 The emergency steering system performance shall be sufficient to maintain the machine tyres (see 11.1.2) within a straight course 100 m long with a width of 1.25 times the maximum width over tyres while travelling at 16 ± 2 km/h. Normal operator steering corrections shall be permissible.

11.3.4 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.

11.3.5 Emergency steering shall provide adequate steering force and steering duration to maintain the machine tyres (see 11.1.2) within the test course (as determined from figure 1) at 8 ± 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.

11.3.6 Emergency steering shall provide adequate steering force and steering rate to maintain the machine tyres (see 11.1.2) within the test course (as determined from figure 1) at 16 ± 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.

11.3.7 During the tests according to 11.3.5 and 11.3.6, 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.

11.3.8 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 ± 2 km/h. This test shall be conducted to the opposite hand (mirror image) of figure 2 if the figure 1 or 4 test courses were conducted to the opposite hand (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.

11.4 Alternative steering tests for machines that will travel on public roads

For rubber-tyred earth-moving machines that will travel on public roads, the steering tests in this clause may be used as an alternative to those tests in clauses 10, 11.2.3, and 11.3.5 to 11.3.8 of this International Standard which require the use of test courses as shown in figures 1 and 2.

11.4.1 Test course

The alternative test course for machines that will travel on public roads is a circular test course having a machine clearance diameter of 24 m on a surface as specified in 8.1. (See figure 3.)

11.4.2 Test steering angle

The steering angle for subsequent use in this alternative test shall be determined as follows :

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

11.4.2.2 The machine shall be steered into the test course and driven in a continuous circular path at 3 ± 1 km/h. To determine the steering angle corresponding to the test course according to 11.4.1, the outermost part of the machine and its equipment shall follow the test course. (See figure 3.)

11.4.3 Tests with normal steering systems

The steering system shall provide sufficient capability to steer the machine from straight-ahead position to the steering angle as determined from 11.4.2 within a time of 4 s. The forward travel speed shall be 10 ± 2 km/h and the steering effort shall not exceed 115 N. Tests shall be made turning to both the left-hand and right-hand side.

11.4.4 Tests with emergency steering system

11.4.4.1 Emergency steering shall provide adequate steering force and steering duration to steer the machine continuously from straight-ahead once to the left and once to the right to the steering angle determined from 11.4.2 and finish in the straight-ahead position. The forward travel speed shall be 10 ± 2 km/h and the steering effort shall not exceed 350 N.

11.4.4.2 Emergency steering shall provide adequate steering force and steering rate to steer the machine from straight-ahead position to the steering angle determined from 11.4.2 within a time of 6 s. The forward travel speed shall be 10 ± 2 km/h and the steering effort shall not exceed 350 N. Tests shall be made turning to both the left-hand and right-hand side.

11.4.4.3 An emergency steering response test shall be conducted by driving the machine from straight-ahead position to the steering angle as determined from 11.4.2. At the start of steering control actuation, a failure of the normal steering power source(s) shall be simulated. The time from the start of steering control actuation to the steering angle specified in 11.4.2 shall not exceed 6 s. The forward travel speed shall be 10 ± 2 km/h and the steering effort shall not exceed 350 N. The test shall be made turning to the side of greatest time as determined in 11.4.4.2.

11.5 Tests with emergency steering system for machines that will not travel on public roads

11.5.1 Any machine that meets the emergency steering system test requirements of 11.3 or 11.4.4 at the machine mass stated in 9.1 or 9.3 need not be retested to 11.5.2. (See 11.5.2.)

11.5.2 The emergency steering system for machines that will not travel on public roads shall be tested as outlined in 11.3 except that the figure 4 test course shall be used instead of the figure 1 course. Machines with a tyre circle of less than 12 m, all wheel tractors, and all graders shall start the figure 4 test course at "Start 1" and shall terminate the test at "Finish 1". All other machines shall start the figure 4 test course at "Start 2" and terminate the test at "Finish 2".

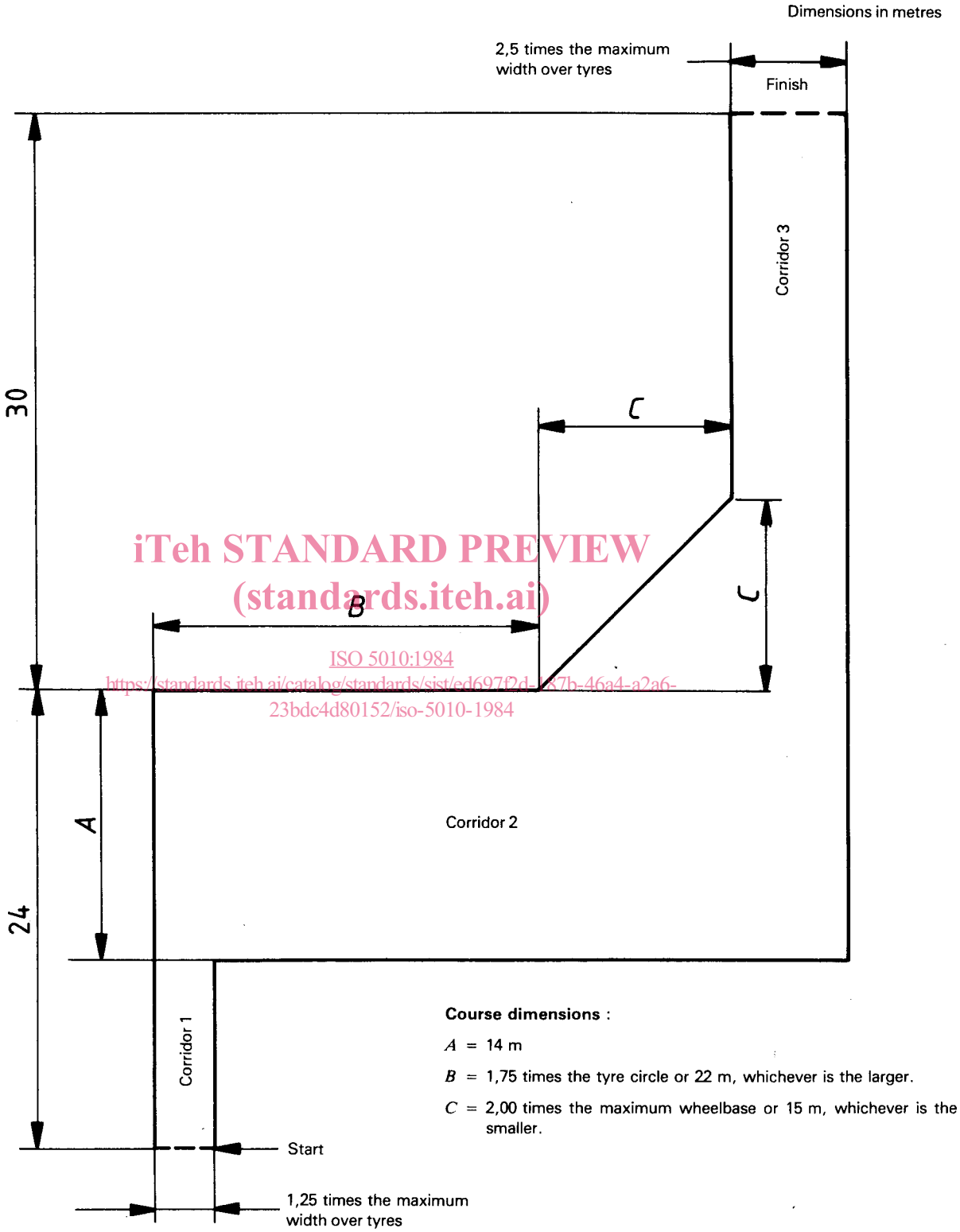

Figure 1 — Steering test course for machines that will travel on public roads