

# International Standard



# 3450

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## Earth-moving machinery — Wheeled machines — Performance requirements and test procedures for braking systems

*Engins de terrassement — Engins sur roues — Exigences de performance et procédures d'essai des systèmes de freinage*

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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.

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. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 3450 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*.

This second edition cancels and replaces the first edition (ISO 3450-1975), from which the figures have been deleted (now covered by clause 3); presentation has also been revised.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

# Earth-moving machinery — Wheeled machines — Performance requirements and test procedures for braking systems

## 1 Scope

This International Standard specifies minimum performances and test criteria for braking systems to enable uniform assessment of the braking capability of earth-moving machinery which operates on work sites or travels on public roads. Service, secondary and parking braking systems and retarders are covered by this International Standard.

## 2 Field of application

This International Standard applies to self-propelled, rubber-tired loaders, tractors, graders, backhoe loaders, tractor-scrappers, excavators and dumpers as defined in ISO 6165.

## 3 References

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

ISO 7132, *Earth-moving machinery — Dumpers — Terminology and commercial specifications*.

ISO 7133, *Earth-moving machinery — Tractor-scrappers — Terminology and commercial specifications*.

## 4 Definitions

For the purposes of this International Standard, the following definitions apply.

**4.1 earth-moving machine:** Wheeled machine as defined in ISO 6165 which operates on work sites or travels on public roads.

**4.2 braking systems:** All the elements which combine together to brake and hold the machine. Such systems consist of a control, means of power transmission and the brake itself.

**4.2.1 service braking system:** The primary system used for stopping and holding the machine.

**4.2.2 secondary braking system:** The system used for stopping the machine in the event of any single failure in the service braking system.

**4.2.3 parking braking system:** A system used to hold a stopped machine in a stationary position.

### 4.2.4 Braking system elements

**4.2.4.1 control:** The element directly activated by the operator to cause a force to be transmitted to the brake(s).

**4.2.4.2 power transmission means:** All of the elements between the control and the brake(s) which connect them functionally.

**4.2.4.3 brake(s):** The component which directly applies a force to oppose movement of the machine. Brakes may, for example, be of friction, electrical or fluid types.

**4.2.4.4 retarder:** An energy absorption device normally used to control machine speed while descending grades.

**4.3 common component:** A component that performs a function in two or more braking systems.

**4.4 maximum machine mass:** Operating mass of a machine up to that mass which includes the heaviest combination of cab, canopy, ROPS or FOPS with all their components and mountings, and equipment approved by the manufacturer of the machine, an operator of 75 kg and full fuel tank and full lubricating, hydraulic and cooling systems.

**4.5 stopping distance,  $l$ :** The distance travelled by the machine from the point on the test course at which the machine brake control is initially actuated to the point where the machine comes to a complete halt.

**4.6 mean deceleration,  $a$ :** The average rate of change of the velocity of the machine from the instant the brake control is initially actuated until the machine comes to a complete halt.

It may be determined from the equation

$$a = \frac{v^2}{2l}$$

where

- $a$  is the mean deceleration, in metres per second squared;
- $v$  is the velocity of the machine immediately prior to the brake control being activated, in metres per second;
- $l$  is the stopping distance, in metres.

**4.7 burnish:** A procedure to condition the frictional surfaces of the machine brake(s).

**4.8 braking system pressure:** The pressure in the air or hydraulic reservoir(s), if so equipped, to assist the application of force to the brakes.

**4.9 test course:** The surface upon which the test is carried out.

**4.10 cold brakes:** Brakes shall be considered to be "cold" when the machine has not been subjected to braking for at least 1 h, other than in preparing for the tests carried out in accordance with 7.9, or the brakes have been cooled to 100 °C or less when measured on the brake disc or the outside of the brake drum.

## 5 Instrument accuracy

The instruments used to carry out the required measurements shall be accurate to the levels given in table 1.

Table 1 — Instrument accuracy levels

Parameter being measured	Instrument accuracy %
Brake system pressure	± 3,0
Machine speed	± 3,0
Machine mass	± 2,5
Stopping distance	± 1,0
Brake control actuating force	± 3,0
Slope	± 1,0

## 6 General requirements

The following requirements for braking systems apply to all machines listed in clause 2.

### 6.1 Required braking systems

All machines shall be equipped with

- a) a service braking system;
- b) a secondary braking system;
- c) a parking braking system.

### 6.2 Common components

Braking systems may use common components; however, in the event of a failure of any single component other than a tyre, the braking systems shall be capable of bringing the machine to a halt in accordance with performance requirements specified for the secondary braking system. (See also 8.6.2.4.)

### 6.3 Service braking system

All machines shall meet the service braking performance requirements of 8.6 and 8.7.

**6.3.1** If other systems are provided with power from the service braking system, any failure in these systems shall be considered to be the same as a failure in the service braking system.

**6.3.2** All machines shall have brakes applicable to at least one axle. Machines with semi-trailed units shall have brakes applicable to at least one axle of the towing machine and one axle of the semi-trailed units.

### 6.4 Secondary braking system

All machines shall meet the secondary braking performance requirements of 8.6 and 8.7.

### 6.5 Parking braking system

Once applied, this system shall not be dependent upon an exhaustible energy source unless redundant energy sources exist and the machine manufacturer includes any system limitation in the operator's manual for the machine.

The parking braking system may use common components which also form part of other braking systems provided that the requirements given in 8.5.2 or 8.5.3 are met.

### 6.6 Warning device for the stored energy sources

If stored energy is used for the service braking system, that system shall be equipped with a warning device which is activated before the system energy drops below 50 % of the maximum operating energy level specified by the manufacturer or the level required to meet the secondary braking performance requirements, whichever level is higher.

The device shall readily attract the operator's attention by providing a nonstop visible and/or audible warning. Gauges indicating pressure or vacuum do not meet this requirement.

## 7 Test conditions

**7.1** Precautions specified by the manufacturer shall be taken while carrying out performance tests.

**7.2** The test course shall consist of a hard, dry surface with a well-compacted base. Ground moisture may be present to the extent that it does not adversely affect the braking test.

The test course shall not have a slope of more than 3 % at right angles to the direction of travel. Slope in the direction of travel shall be as specified for the test being carried out.

The approach to the test course shall be of sufficient length, smoothness and uniformity of slope to ensure the required machine speed is reached before the brakes are applied.

**7.3** Maximum machine mass shall be as defined in 4.4 and shall not exceed the axle distribution specified by the manufacturer. The rated payload shall be included for dumpers (see ISO 7132) and tractor-scrappers (see ISO 7133) only, up to the maximum machine gross mass and the axle distribution approved by the manufacturer.

**7.4** All parameters relating to braking systems, i.e. tyre size and pressure, brake adjustment, warning device actuation point, etc., shall be within the machine manufacturer's specifications. All braking system pressures shall be within the machine manufacturer's specification range. No manual adjustment(s) shall be made to the braking system during any single performance test.

**7.5** When the machine transmission provides a selection of gear ratios, the stopping tests shall be carried out with the transmission in the gear suitable for the test speed specified. The power train may be disengaged prior to completing the stop.

**7.6** Retarders shall not be used in these tests unless the specific test states otherwise or the retarder is always activated by the brake control that is used to activate the service or secondary braking system being tested.

**7.7** Blades, buckets, dozers and other equipment shall be carried in the transport position recommended by the manufacturer.

**7.8** Burnishing (conditioning) of brakes before testing is permissible. The burnishing procedure shall be indicated in the operator's and/or maintenance manual for the machine and shall be checked by consulting the machine manufacturer.

**7.9** Immediately prior to a test, the machine shall be operated until the machine fluids, i.e. engine and transmission oils, are at normal operating temperature.

**7.10** Machine speed shall be measured immediately prior to the brake control being applied.

**7.11** As a minimum requirement, all data required for completion of the test report (see clause 9) shall be recorded and reported.

## 8 Performance tests

### 8.1 Braking system controls

**8.1.1** The force applied to the control which is necessary to activate the braking system, as defined in 4.2, in order to achieve the required braking performance shall not exceed the levels given in table 2.

Table 2 — Maximum force levels for braking system controls

Type of control	Maximum force to be applied N
Finger grasp	20
Hand grasp upwards	400
fore-aft	300
sideways	300
Foot pedal	700
Foot pedal (centrally pivoted)	350

**8.1.2** All braking system controls shall be capable of being applied by someone sitting in the driver's seat. The secondary and parking braking system(s) control(s) shall be arranged so that they cannot be released from the driver's seat once they have been applied unless they can be immediately reapplied from the driver's seat.

### 8.2 Service braking system recovery capacity (stored energy system)

The engine speed control (throttle) shall be set to obtain maximum engine rotational speed (r/min) or frequency ( $\text{min}^{-1}$ ). The service braking system pressure shall be measured near a brake. The service braking system shall be capable of delivering at least 70 % of the pressure measured during the first brake application after the service brakes have been fully applied in the following way (see 7.4):

- for dumpers, tractor-scrappers and excavators: 12 times at the rate of four applications per minute;
- for loaders, graders, tractor and backhoe loaders: 20 times at the rate of six applications per minute.

### 8.3 Secondary braking system capacity (stored energy system)

If the stored energy reservoir(s) of the service braking system are used to apply the secondary braking system, then, with the energy source disconnected and the machine stationary, the

capacity of the service braking system reservoir(s) shall be such that energy remaining in the reservoir(s) after five full service brake applications shall not be less than that required to meet the secondary stopping requirements specified in 8.6.2.4.

#### 8.4 Warning device for the stored energy system

The service brake system energy shall be reduced by any suitable means. The warning device (see 6.6) shall be activated before the system energy drops below 50 % of the maximum stored energy level specified by the manufacturer or the stored energy level required to meet the secondary stopping requirements specified in 8.6.2.4, whichever level is higher. The warning device shall be activated before a secondary braking system is automatically applied.

#### 8.5 Holding performance

All machines shall be tested in both the forward and reverse directions on a test course as described in 7.2.

**8.5.1** The service braking system shall be capable of holding the machine on a 25 % slope.

**8.5.2** The parking braking system shall be capable of holding the machine on a 15 % slope, if tested with rated payload, or on an 18 % slope, if tested without payload. For dumpers and tractor-scrappers, the rated payload is included (see 7.3). The power train(s) shall be disengaged.

**8.5.3** If the tests outlined in 8.5.1 and 8.5.2 are impractical, the tests may be carried out either

- a) on a tilt platform with a skid-resistant surface that may be inclined; or
- b) by applying a pulling force to the stationary machine with the brake applied and with the transmission in neutral on a test course as described in 7.2 with no more than a 1 % slope in the direction of travel. The pulling force shall be applied horizontally near the ground to achieve a minimum force equivalent to the slopes specified in 8.5.1 and 8.5.2. The equivalent force, expressed in newtons, is 2,38 times machine mass for a 25 % slope, 1,74 times machine mass for a 18 % slope and 1,46 times machine mass for a 15 % slope. For dumpers and tractor-scrappers, the rated payload is included (see 7.3).

#### 8.6 Stopping performance (not including those machines covered by 8.7)

The requirements given in table 3 are applicable for all machines, except rigid frame and articulated steer dumpers with a maximum machine mass of 32 000 kg or more. All dumpers and semi-trailed units as shown in figures 3, 8 and 11 in ISO 7132 are included. For dumpers not included in this clause, see 8.7.

##### 8.6.1 Test conditions

**8.6.1.1** Braking performance shall be tested from a machine speed of  $32 \pm 3$  km/h or the maximum level surface speed of the machine, if less.

**8.6.1.2** Tests shall be carried out in accordance with the test conditions specified in clause 7.

**8.6.1.3** The test course shall not have more than 1 % slope in the direction of travel.

##### 8.6.2 Cold tests

**8.6.2.1** Starting out with cold brakes, stopping distance tests for service braking and secondary braking systems shall both be carried out twice in the forward direction of machine travel, once in each direction of the test course, with at least 10 min between stops.

**8.6.2.2** Stopping distance and machine speed used when reporting the test result (see clause 9) shall be the average of the two tests (once in each direction of the test course) described in 8.6.2.1.

**8.6.2.3** The service braking system shall stop the machine within the stopping distance specified in table 3 (see 6.3).

**8.6.2.4** The secondary braking system shall stop the machine within the distance specified in table 3 (see 6.4).

If the machine is equipped with a retarder, it may be used prior to and during this test. When the retarder is used, the machine manufacturer shall include in the operator's manual the maximum machine speed and/or the transmission gear to be engaged when the machine is travelling down specified slopes. An instruction plate shall be placed in the operator's compartment and be readily visible to the operator.

The secondary braking system may have common components (see 6.2) with the service braking system between the application point of force applied to the operator's control and master valve. These common components shall be highly reliable and another braking system shall exist which can stop the machine within a stopping distance calculated from the following formula:

$$l = \frac{v^2}{34}$$

where

$l$  is the stopping distance, in metres;

$v$  is the velocity of the machine, in kilometres per hour, immediately prior to the brake control being applied.

##### 8.6.3 Procedure for heat fade test

**8.6.3.1** Machines shall be tested as stated in 8.6.1.

**8.6.3.2** The service brakes shall be applied and released to complete four consecutive stops at or as near as possible to the maximum deceleration of the machine without causing the wheels to lock. The machine shall build up again to the initial

**Table 3 — Stopping performances for machines covered by requirements given in 8.6**

Type of machine	Maximum machine mass (see 7.3) <i>m</i> kg	Stopping distance for the service braking system <sup>1) 2)</sup>  m	Stopping distance for the secondary braking system <sup>1) 2)</sup>  m
Machines that will travel on public roads	Any mass permitted	$\frac{v^2}{68}$	$\frac{v^2}{39}$
Machines that will not travel on public roads	$m < 32\ 000$	$\frac{v^2}{68} + \frac{v^2}{124} \left[ \frac{m}{32\ 000} \right]$	$\frac{v^2}{39} + \frac{v^2}{130} \left[ \frac{m}{32\ 000} \right]$
	$m \geq 32\ 000$	$\frac{v^2}{44}$	$\frac{v^2}{30}$

1) *v* is the speed of the machine expressed in kilometres per hour (see 8.6.1).

2) For machines with maximum level surface speed lower than the normal test speed of 32 km/h, the correction formula of  $+ 0,1 (32 - v)$

shall be added to all formulae for stopping distances shown in table 3.

test speed after each stop using maximum machine acceleration capability. A fifth consecutive stop shall be measured and shall not exceed 125 % of the stopping distance specified in table 3.

**8.7 Stopping performance** (for those machines not specified in 8.6)

The requirements given in table 4 are applicable for rigid frame and articulated steer dumpers with a maximum machine mass of 32 000 kg or more as shown in figures 1, 2, 4, 5, 6, 7, 9 and 10 in ISO 7132.

**8.7.1 Test conditions**

**8.7.1.1** Tests shall be carried out in accordance with the test conditions specified in clause 7.

**8.7.1.2** The test course shall have a downward slope of  $9 \pm 1$  % in the direction of machine travel or the test shall be carried out so as to develop an equivalent total energy input to the braking system.

NOTE — Equivalent total energy input test to be developed.

**8.7.1.3** The transmission shall be engaged in such a gear that the engine does not exceed the maximum engine rotational speed (r/min) or frequency (min<sup>-1</sup>) specified by the manufacturer.

**8.7.2 Test procedures**

**8.7.2.1** The service braking system shall be tested by means of five stopping tests at 10 to 20 min intervals between stops from a machine speed of  $50 \pm 3$  km/h or the maximum level surface speed of the machine if less. Each stopping distance shall not exceed that specified in table 4.

**8.7.2.2** The secondary braking system shall be tested by means of a single stopping test carried out from a machine speed of  $25 \pm 2$  km/h. If the machine is equipped with a retarder, it may be used prior to and during this test. The stopping distance shall not exceed that specified in table 4.

**8.7.3 Instruction plate**

The dumper manufacturer shall include in the operator's manual the maximum dumper speed and/or the transmission gear to be engaged when the loaded dumper is travelling down specific slopes. An instruction plate shall be placed in the operator's compartment and be readily visible to the operator.

**9 Test report**

The test report shall contain the following information:

- a) a reference to this International Standard;
- b) the type of machine;
- c) the make of machine;

**Table 4 — Stopping performances for machines covered by requirements given in 8.7**

Type of machine	Maximum machine mass (see 7.3) <i>m</i> kg	Stopping distance for the service braking system <sup>1)</sup>  m	Stopping distance for the secondary braking system <sup>1)</sup>  m
Rigid frame and articulated steer dumpers that will not travel on public roads	$m > 32\ 000$	$\frac{v^2}{48 - 2,6 \text{ (slope, in percent)}}$	$\frac{v^2}{34 - 2,6 \text{ (slope, in percent)}}$

1) *v* is the speed of the machine expressed in kilometres per hour (see 8.7.2).

- d) the model and serial number of the machine;
- e) the condition of the braking system (for example, new, in operation for 10 h, etc.);
- f) the mass and axle distribution of the machine as tested, in kilograms;
- g) the manufacturer's approved maximum machine mass and axle distribution, in kilograms;
- h) the size, ply rating, tread pattern and tyre pressure, in megapascals (MPa);
- j) a description of the brakes (for example, disc or drum, hand or foot control);
- k) the type of braking systems (for example, mechanical or hydraulic);
- m) which tests were carried out using a retarder and a description of the retarder (for example, hydraulic or electric);
- n) the surface of the test course (for example, asphalt, concrete or soil);

- p) the longitudinal and cross slope of the test course;
- q) the results of all stopping and holding tests shall be given in table form as below (see 8.5, 8.6 and 8.7);
- r) percentage of the braking system stored energy after the brake application test calculated from the following formula (see 8.2)

$$p = \frac{p_2}{p_1} \times 100$$

where

- $p$  is the residual pressure as a percentage;
- $p_1$  is the brake pressure during the first brake application;
- $p_2$  is the lowest brake pressure measured during subsequent brake applications.
- s) the force levels applied to the controls (see 8.1.1);
- t) machine maximum level surface speed in km/h;
- u) the secondary braking system capacity (stored energy system) (see 8.3).

iTeh STANDARD PREVIEW

Braking system tested	Load	Direction of travel	Slope %	Machine speed v km/h	Stopping distance / m
Service	Rated Empty	Level	%	km/h	
Secondary		Downhill			
Parking		Uphill			