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

Engins de terrassement — Dispositifs de freinage des engins sur roues équipés de pneumatiques — Exigences relatives aux dispositifs et à leurs performances, et méthodes d'essai

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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 3450 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 3450:1985), of which it constitutes a technical revision.

Annex A of this International Standard is for information only.

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

1 Scope

This International Standard specifies minimum performance and test criteria for brake 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 brake systems, and retarders are covered by this International Standard.

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

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

ISO 6016:1982, *Earth-moving machinery — Methods of measuring the masses of whole machines, their equipment and components.*

ISO 6165:—[1], *Earth-moving machinery — Basic types — Vocabulary.*

ISO 7132:1990, *Earth-moving machinery — Dumpers — Terminology and commercial specifications.*

ISO 9248:1992, *Earth-moving machinery — Units for dimensions, performance and capacities, and their measurement accuracies.*

3 Definitions

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

3.1 earth-moving machine: Rubber-tyred machine as defined in ISO 6165 which operates on work sites or travels on public roads.

3.2 brake system: All the components which combine together to stop and/or hold the machine, consisting of a control, means of brake actuation, the brake(s) and, if the machine is so equipped, the retarder.

3.2.1 service brake system: Primary system used for stopping and holding the machine.

3.2.2 secondary brake system: System used for stopping the machine in the event of any single failure in the service brake system.

3.2.3 parking brake system: System used to hold a stopped machine in a stationary position.

3.2.4 Brake system components

3.2.4.1 brake control: Component directly activated by the operator to cause a force to be transmitted to the brake(s).

1) To be published. (Revision of ISO 6165:1987)

3.2.4.2 brake actuation system: All of the components between the control and the brake(s) which connect(s) them functionally.

3.2.4.3 brake(s): Component which directly applies a force to oppose movement of the machine. Brakes may, for example, be of friction, electrical, hydrostatic or other fluid types.

3.2.4.4 retarder: Energy-absorption component normally used to control machine speed.

3.3 common component: Component that performs a function in two or more brake systems.

3.4 machine mass: Operating mass of a machine 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, including operator and full liquid systems according to ISO 6016.

3.5 stopping distance, s: Distance travelled by the machine from the point on the test course at which the machine brake control actuation begins to the point on the test course where the machine is fully stopped.

3.6 mean deceleration, a: Average rate of change of the velocity of the machine from the instant the brake control actuation begins until a full stop is achieved.

NOTE 1 It may be determined from the formula

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

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;

s is the stopping distance, in metres.

3.7 burnish: Procedure to condition the frictional surfaces of the machine brake(s).

3.8 brake system pressure: Fluid pressure available to the brake control.

3.9 brake application pressure: Fluid pressure measured at the brake.

3.10 modulated braking: Capability to continuously and progressively increase and decrease the braking force by operation of the brake control.

3.11 test course: Surface upon which the test is carried out. (See 6.2.)

3.12 cold brakes: Expression designating brakes where

— the brakes have not been actuated in the previous 1 h, except in accordance with 6.9; or

— the brakes have been cooled to 100 °C or less when measured on the brake disc or on the outside of the brake drum; or

— in the case of totally enclosed brakes, including oil-immersed brakes, the temperature measured on the outside of the housing closest to the brake is below 50 °C or within the manufacturer's specifications.

3.13 maximum machine level surface speed: Machine speed determined in accordance with ISO 6014, or equivalent.

4 Instrument accuracy

The instruments used to carry out the required measurements shall conform to conditions of ISO 9248.

5 General requirements

The following requirements for brake systems apply to all machines given in clause 1.

5.1 Required brake systems

The machine shall have the following brake systems:

a) a service brake system;

b) a secondary brake system;

c) a parking brake system.

No brake system shall contain a disconnect such as a clutch or shiftable gear-box which allows the brake(s) to be disabled.

A power source disconnect designed for cold weather starting which also disables a brake system shall require application of the parking brake prior to disconnection.

5.2 Common components

Brake systems may use common components. However, a failure of any single component other than a tyre, or a failure of any single common component, shall not reduce the effectiveness of the machine's stopping capability to less than the secondary performance defined in 5.4, and table 2, 3 or 4, as applicable, with one exception: a common control (lever, pedal, switch, etc.) may be used to actuate combined service and secondary brake systems provided that another dynamic braking capability is provided that will stop the machine within 120 % of the dynamic stopping distance shown for secondary brakes in table 2, 3 or 4, as applicable. This braking capability may be applied automatically and without modulation.

5.3 Service brake system

5.3.1 All machines shall meet the service brake performance requirements of 7.5, 7.6 or 7.7 as applicable.

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

5.3.2 All machines shall have brakes of equal nominal capacity rating applicable to each wheel of 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.

5.3.3 The service brake system shall be modulated as defined in 3.10.

5.4 Secondary brake system

All machines shall meet the secondary brake performance requirements of 7.6 or 7.7, as applicable.

The secondary brake system shall be modulated as defined in 3.10.

5.5 Parking brake system

A parking brake disconnect (release) designed to allow movement of disabled machines shall be located outside the operator's station unless it can be reapplied immediately.

All machines shall meet the parking brake requirements of 7.5.

After being applied, this system shall not depend on an exhaustible energy source. The parking brake system may use common components with other brake systems provided the requirements of 7.5 are met.

5.6 Warning device for stored energy sources

If stored energy is used for the service brake 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 brake performance requirements, whichever level is higher.

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

6 Test conditions

6.1 Manufacturer's precautions shall be observed while carrying out performance tests.

6.2 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 actuated.

6.3 The machine mass and axle load distribution shall be as defined in 6.3.1 or 6.3.2, as applicable.

6.3.1 The test mass of all machines except dumpers and tractor-scrapers shall be as stated in 3.4 without a payload and at the manufacturer's specified axle load distribution.

6.3.2 The test mass of dumpers and tractor-scrapers shall be as stated in 3.4 and include a payload. The machine test mass shall be equal to the manufacturer's specifications for gross mass (the sum of the machine mass and payload) and axle load distribution.

6.4 All parameters relating to braking systems shall be within the machine manufacturer's specifications, i.e. tyre size and pressure, brake adjustment, warning

actuation point, etc. All brake 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.

6.5 When the machine transmission provides a selection of gear ratios, the stopping tests shall be conducted with the transmission in the gear corresponding to the test speed specified. The power train may be disengaged prior to completing the stop.

6.6 Retarders shall not be used during the service brake performance test, but they are allowed to be used during the secondary brake performance test.

6.7 Machines with operator-selectable multiple drive axles shall be brake-performance-tested with the non-braked selectable axle(s) disengaged.

6.8 Equipment (blades, buckets, dozers, etc.) shall be carried in the transport position recommended by the manufacturer.

6.9 Burnishing or 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 verified by consultation with the machine manufacturer.

6.10 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 as specified by the manufacturer.

6.11 Machine test speed shall be that speed measured immediately prior to the brake control being applied.

6.12 Mean deceleration may be calculated as defined in 3.6.

6.13 As a minimum requirement, all data required for completion of the test report in clause 8 shall be recorded.

7 Performance tests

7.1 Brake system controls

7.1.1 The control forces to meet the required brake performance for the systems defined in 3.2 shall not exceed the values in table 1.

Table 1 — Maximum force levels for brake system controls for performance tests

Type of control	Maximum force to be applied N
Finger grasp (flip levers and switches)	20
Hand grasp —	
upwards	400
downwards, sideways, fore-aft	300
Foot pedal (leg control)	700
Foot treadle (ankle control)	350

7.1.2 All brake system controls shall be capable of being applied by a person seated in the driver's seat. The secondary and parking brake system(s) control(s) shall be arranged so that they cannot be released once they have been applied unless they can be immediately reapplied.

7.2 Service brake system recovery capacity (stored energy system)

The engine speed control shall be set to obtain maximum engine rotational speed (r/min) or frequency (min^{-1}). The brake application pressure shall be measured near a brake. The service brake 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):

a) for dumpers, tractor-scrapers and excavators: 12 times at the rate of four applications per minute;

b) for loaders, graders, tractors and backhoe loaders: 20 times at the rate of six applications per minute.

7.3 Secondary brake system capacity (stored energy system)

If the service brake system stored energy reservoir(s) is (are) used to apply the secondary brake system, then, with the energy source disconnected and the machine stationary, the capacity of the service brake system reservoir(s) shall be such that the energy remaining in the reservoir(s) after five full service brake applications shall not be less than that required to meet the secondary brake requirements specified in 7.6.2.4 or 7.7.2.2 as applicable.

7.4 Warning device for stored energy system

The service brake system energy shall be reduced by any suitable means. The warning device (see 5.6) shall activate before system energy drops below the greater of 50 % of the manufacturer's specified maximum operating energy level or the stored energy level required to meet the secondary brake requirements specified in 7.6.2.4 or 7.7.2.2, as applicable. The warning device shall activate prior to an automatic application of a secondary brake system.

7.5 Holding performance

All machines shall be tested in both the forward and reverse directions in accordance with the test conditions specified in clause 6.

7.5.1 With the exception of those machines covered in 7.7, and with the power train disengaged (unless a hydrostatic system is used), the service brake system shall be capable of holding the machine on a 25 % slope.

7.5.2 The parking brake system shall be capable of holding the machine with the power train(s) disengaged as follows:

a) 15 % slope for rigid frame dumpers, articulated dumpers and scrapers with test mass in accordance with 6.3.2;

b) 20 % slope for all other machines with test mass in accordance with 6.3.1.

7.5.3 If the tests given in 7.5.1 and 7.5.2 are impractical, the tests may be carried out either:

a) on a tilt platform with a slip-resistant surface; 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 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 7.5.1 and 7.5.2. The equivalent force, expressed in newtons, is

   2,38 times machine mass in kilograms for a 25 % slope,

   1,92 times machine mass in kilograms for a 20 % slope, and

   1,46 times machine mass in kilograms for a 15 % slope.

7.6 Stopping performance of machines except dumpers defined in 7.7

This clause also includes all dumpers with semi-trailed units as described in figures 3, 8 and 11 in ISO 7132:1990.

7.6.1 Test conditions

7.6.1.1 Brake performance shall be tested from a machine speed which is the greater of 80 % of the maximum level surface machine speed (see 3.13) or 32 km/h. If the maximum level surface speed of the machine is less than 32 km/h, it shall be tested at maximum speed. The test speeds shall be within 3 km/h of the above target speeds.

7.6.1.2 Tests shall be carried out in accordance with the test conditions as specified in clause 6.

7.6.1.3 The test course shall have no more than a 1 % slope in the direction of travel.

7.6.2 Cold test

7.6.2.1 Beginning with cold brakes, the service and secondary brake system stopping distance tests shall be conducted twice while travelling forward, once in each direction of the test course and with at least 10 min between stops.

7.6.2.2 When reporting the test results (see clause 8), the stopping distance and machine speed shall be the average of the two tests (once in each direction of the test course) in 7.6.2.1.

7.6.2.3 The service brake system shall stop the machine within the stopping distance specified in table 2 or 3, as applicable (see 3.4 and 5.3).

7.6.2.4 The secondary brake system shall stop the machine within the distance specified in table 2 or 3, as applicable (see 3.4 and 5.4).

If the machine is equipped with a retarder, it may be used prior to and during this test. If 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 descends specified slopes. An instruction

plate shall be placed in the operator's compartment and be readily visible to the operator.

Table 2 — Stopping distance performance — Machines tested without payload

Service brake stopping distance m	Secondary brake stopping distance m
$\frac{v^2}{150} + 0{,}2(v + 5)$	$\frac{v^2}{75} + 0{,}4(v + 5)$
NOTE — $v > 0$ and measured in km/h (see 7.6.1.1).	

Table 3 — Stopping distance performance — Machines tested with payload except rigid frame or articulated dumpers with a machine mass over 32 000 kg

Service brake stopping distance m	Secondary brake stopping distance m
$\frac{v^2}{44} + 0{,}1(32 - v)$	$\frac{v^2}{30} + 0{,}1(32 - v)$
NOTES 1 $v > 0$ and measured in km/h (see 7.6.1.1). 2 The term $0{,}1(32 - v)$ is deleted from the formula for speeds over 32 km/h.	

7.6.3 Heat fade test

7.6.3.1 Machines shall be tested as stated in 7.6.1.

7.6.3.2 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 sliding the tyres. After each stop, the initial test speed shall be regained as quickly as possible using maximum machine acceleration. A fifth consecutive stop shall be measured and shall not exceed 125 % of the stopping distance reported in 7.6.2.2.

7.7 Stopping performance for rigid frame and articulated steer dumpers over 32 000 kg

This clause applies to those dumpers described in figures 1, 2, 4, 5, 6, 7, 9 and 10 in ISO 7132:1990.

7.7.1 Test conditions

7.7.1.1 Test shall be carried out in accordance with the test conditions specified in clause 6.

7.7.1.2 The test course shall have a downward slope of (9 ± 1) % in the direction of machine travel.

7.7.1.3 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^{-1}) specified by the manufacturer.

7.7.2 Brake tests

7.7.2.1 The service brake system shall be tested by means of five stopping tests at 10 min to 20 min intervals between stops from a machine speed of (50 ± 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.

Table 4 — Stopping distance performance — Rigid frame and articulated steer dumpers with a machine mass over 32 000 kg

Service brake stopping distance m	Secondary brake stopping distance m
$\frac{v^2}{48 - 2{,}6\,\alpha}$	$\frac{v^2}{34 - 2{,}6\,\alpha}$
NOTE — $v > 0$ and measured in km/h (see 7.7.2.1). α is the slope as a percentage.	

7.7.2.2 The secondary brake system shall be tested by means of a single stopping test carried out from a machine speed of (25 ± 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.

7.7.3 Operator instructions and 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 descends specific slopes. An instruction plate shall be placed in the operator's compartment and be readily visible to the operator.

8 Test report

The test report shall contain the following information:

a) a reference to this International Standard;

b) type of machine;

c) make of machine;

d) model and serial number of the machine;

e) condition of the brake system (for example, new, in operation for 1 000 h, etc.);

f) mass and axle distribution of the machines as tested, in kilograms;

g) manufacturer's approved maximum machine mass and maximum axle distribution, in kilograms;

h) tyre size, ply rating, tread pattern and pressure, in megapascals;

i) description of the brakes (for example, disc or drum, hand or foot control);

j) type of brake systems (for example, mechanical or hydraulic);

k) which tests were carried out using a retarder and a description of the retarder (for example, hydraulic or electric);

l) surface of the test course (for example, asphalt, concrete or soil);

m) longitudinal and cross slope of the test course;

n) results of all stopping and holding tests;

o) percentage of the service brake system stored energy after the brake application test calculated from the following formula (see 7.2):

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

where

p is the residual pressure as a percentage,

p_1 is the brake application pressure during the first brake application,

p_2 is the lowest brake application pressure measured during subsequent brake applications;

p) force levels applied to the controls (see 7.1.1);

q) machine maximum level surface speed, in kilometres per hour;

r) secondary brake system capacity for stored energy system (see 7.3).