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(R) BRAKE PERFORMANCE—RUBBER-TIRED EARTHMOVING MACHINES—SAE J1473 OCT90

SAE Standard

Report of the Off-Road Technical Committee, approved December 1984. Equivalent to ISO DIS 3450. Completely revised by the SAE Off-Road Machinery Technical Committee October 1990. Rationale statement available.

1. Scope—This SAE Standard applies to self-propelled, rubber-tired loaders, tractors, graders, backhoe loaders, tractor-scrapers, excavators, and dumpers as defined in SAE J1057 SEP88. Service, secondary and parking brake systems, and retarders are included.

1.1 Purpose—This document specifies brake system minimum performance and test criteria to enable uniform evaluation of the brake capability of earthmoving machines as defined in the scope.

2. References

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1057 SEP88—Identification Terminology of Earthmoving Machines

2.1.2 ISO PUBLICATIONS—Available from ANSI (American National Standards Institute) 11 West 42nd Street, New York, NY 10036.

ISO 3450—Earthmoving Machinery—Wheeled Machines—Braking System Performance Requirements and Test Procedures

ISO 6165—Earthmoving Machinery—Basic Types—Vocabulary

ISO 7132—Earthmoving Machinery—Dumpers—Terminology

2.2 Definitions

2.2.1 RUBBER-TIRED EARTHMOVING MACHINE—Wheeled machines as defined in SAE J1057 SEP88.

2.2.2 BRAKE SYSTEMS—All the components which participate in stopping and holding the machine. Such systems consist of a control, means of power transmission, brakes, and if the machine is so equipped, the retarder.

2.2.2.1 *Service Brake System*—The primary system used for stopping and holding the machine.

2.2.2.2 *Secondary Brake System*—The system used for stopping the machine in the event of any single failure in the service brake system.

2.2.2.3 *Parking Brake System*—A system used to hold a stopped machine in a stationary position.

2.2.2.4 *Brake System Components*

2.2.2.4.1 Control—The component directly activated by the operator to cause a force to be transmitted to the brake(s).

2.2.2.4.2 Power Transmission Means—All of the components between the control and the brake(s) which connect(s) them functionally.

2.2.2.4.3 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.

2.2.2.4.4 Retarder—An energy absorption component normally used to control machine speed while descending grades.

2.2.3 COMMON COMPONENT—A component that performs a function in two or more brake systems.

2.2.4 MACHINE MASS—Operating mass of the machine up to that mass which includes the heaviest combination of equipment approved by the manufacturer of the machine; an operator of 75 kg; and with the machine fully fueled and serviced.

2.2.5 STOPPING DISTANCE—The distance traveled by the machine from the point on the test course at which the machine brake control actuation begins to the point where the machine is fully stopped.

2.2.6 MEAN DECELERATION—The average rate of change of the velocity of the machine, from the instant the brake control actuation begins until a full stop is achieved. It may be determined from the formula:

$$a = \left(\frac{V^2}{2L}\right) \qquad \text{(Eq.1)}$$

where:

a = mean deceleration in meters/second squared

V = velocity in meters/second of the machine immediately prior to brake control actuation

L = Stopping distance in meters.

2.2.7 BURNISH—A procedure to condition the frictional surfaces of the machine brake(s).

2.2.8 BRAKE SYSTEM PRESSURE—The gas or hydraulic pressure available at the brake mechanism.

2.2.9 TEST COURSE—The surface upon which the test is conducted.

2.2.10 COLD BRAKES—Brakes shall be considered to be "cold" if any of the following conditions are met:

2.2.10.1 The brakes have not been actuated in the previous 1 h, except in accordance with 5.9.

2.2.10.2 The brakes have been cooled to 100 °C or less when measured on the brake disc or on the outside of the brake drum.

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

3. Instrumentation

3.1 A means to measure and record these parameters within the specified accuracy are listed in Table 1.

TABLE 1—INSTRUMENT ACCURACY

Parameter	Instrument Accuracy Indicated Reading
Brake System Pressure	±3.0%
Machine Speed	±3.0%
Machine Mass	±2.5%
Stopping Distance	±1.0%
Brake Control Actuating Force	±3.0%
Grade	±1.0%

4. General Brake Requirements

4.1 Required Brake Systems—All machines shall be equipped with:

4.1.1 A service brake system

4.1.2 A secondary brake system

4.1.3 A parking brake system

4.2 Common Components—Brake systems may use common components; however, in the event of a failure of any single component other than a tire, the brake systems shall provide machine stopping capability meeting the secondary brake system performance requirements specified.

4.3 Service Brake System—All machines shall meet the service brake performance requirements (see 6.6 and 6.7).

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

4.3.2 All tractor scrapers and dumpers shall have braked wheels on at least one axle of the prime mover and one axle of each trailing unit. All other machines shall have at least two braked wheels (one right hand and one left hand).

4.4 Secondary Brake System—All machines shall meet the secondary brake performance requirements (see 6.6 and 6.7).

4.5 Parking Brake System—After being applied, this system shall not be dependent upon an exhaustible energy source. The parking brake system may use common components with other brake systems provided the requirements of 6.5.2 or 6.5.3 are met.

4.6 Warning Device (stored Energy Sources)—If stored energy is used for the service brake system, that system shall be equipped with a warning device which activates before system energy drops below the greater of 50% of the manufacturer's specified maximum operating energy level or the level required to meet the secondary stopping requirements. The device shall readily attract the operator's attention by providing a continuing visual or audible warning. Gauges indicating pressure or vacuum do not meet this requirement.

5. Test Conditions

5.1 Manufacturer's precautions shall be observed while conducting performance tests.

5.2 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 brake test. The test course shall not have more than 3% grade at right angles to the direction of travel. Grade in the direction of travel shall be as specified for the test being conducted. The approach to the test course shall be of sufficient length, smoothness, and uniformity of grade to ensure reaching the required machine speed before the brakes are actuated.

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5.3 Machine mass shall be as defined in 2.2.4 at the manufacturer's specified axle distribution. Dumpers and tractor-scrapers shall be loaded to the manufacturer's specified gross machine mass.

5.4 All parameters related to brake systems shall be within the machine manufacturer's specifications, i.e., tire size and pressure, brake adjustment, warning device actuation point, etc. All brake system pressures shall be within the machine manufacturer's specifications range. No manual adjustment(s) shall be made to the brake system during any one performance test.

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

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

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

5.8 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 verified by consultation with the machine manufacturer.

5.9 Immediately prior to a test, the machine shall be operated until the engine, transmission, and machine fluids are at normal operating temperature.

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

5.11 As a minimum, all data required by the test report (Section 7) shall be recorded and reported.

6. Performance Tests

6.1.1 Control forces needed to meet the required brake performance for the systems defined in 2.2.2 shall not exceed these values in Table 2:

TABLE 2—MAXIMUM CONTROL FORCES

Control Type	Force
Finger grasp (flip levers and switches)	20N
Hand grasps	
Upwards	400N
Downward	300N
Sideways	300N
Foot pedal (leg control)	700N
Foot treadle (ankle control)	350N

6.1.2 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 from the driver's seat after any application unless immediate reapplication can be made from the driver's seat.

6.2 Service Brake System Recovery Capacity (Stored Energy System)—The engine speed control (throttle) shall be set to obtain maximum engine rotational speed (rpm). The service brake system shall have the capability to deliver at least 70% of the pressure measured during the first brake application after the service brakes have been fully applied as follows (see 5.4).

6.2.1 FOR DUMPERS, TRACTOR-SCRAPERS, AND EXCAVATORS—12 times at the rate of four applications per min.

6.2.2 FOR LOADERS, GRADERS, TRACTORS, AND BACKHOE LOADERS—20 times at the rate of six applications per min.

6.3 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 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 is not less than that required to meet the secondary stopping requirements in 6.6.2.4 or 6.7.3.

6.4 Warning Device (Stored Energy System)—The service brake system energy shall be reduced by any suitable means. The warning device (see 4.6) shall activate before system energy drops below the greater of 50% of the manufacturer's specified maximum stored energy level or the stored energy level required to meet the secondary stopping requirements (see 6.6.2.4 or 6.7.3). The warning device shall activate prior to any automatic application of a secondary brake system.

6.5 Holding Performance—All machines shall be tested in both the forward and reverse directions on a test course as described in 5.2.

6.5.1 With the exception of those machines covered in 6.7, the service brake system shall be capable of holding the machine on a 25% grade.

6.5.2 The parking brake system shall be capable of holding the machine with the power train disengaged as follows:

a. Rigid frame dumpers, articulated dumpers and scrapers loaded to manufacturers gross machine mass; 15% grade.

b. All other machines at the maximum empty mass; 18% grade.

6.5.3 If the tests in 6.5.1 and 6.5.2 are impractical, the tests may be carried out either:

6.5.3.1 On a tilt platform (a skid resistant surface that may be inclined),

6.5.3.2 By applying a pulling force to the stationary machine with the brake set and with the transmission in neutral on a test course as described in 5.2 with no more than 1% grade in the direction of travel. The pulling force shall be applied horizontally near the ground to achieve a minimum force equivalent to the grades specified in 6.5.1 and 6.5.2. The equivalent force in Newton is 2.38 times machine mass in kg for a 25% grade; 1.74 times machine mass in kg for an 18% grade; and 1.46 times machine mass in kg for a 15% grade (see 5.3).

6.6 Stopping Performance—This section applies to all machines except rigid frame and articulated steer dumpers with machine mass of 32 000 kg or more. Included are all dumpers with semitrailed units as described by Figures 4.1.1.4, 4.2.1.1, 4.3.1.2, 4.3.13, and 4.3.1.4 of SAE J1057 SEP88.

6.6.1 TEST CONDITIONS

6.6.1.1 Brake performance shall be tested from a machine speed of 32 km/h ± 3 km/h or the machine's maximum level surface speed if less.

6.6.1.2 Tests shall be performed in accordance with the test conditions specified in Section 5.

6.6.1.3 The test course shall not have more than 1% grade in the direction of travel.

6.6.2 COLD TESTS

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

6.6.2.2 Stopping distance and machine speed used in reporting the test results shall be the average of the two tests (once in each direction of the test course) described in 6.6.2.1.

6.6.2.3 The service brake system (see 4.3) shall stop the machine within the stopping distance specified in Table 3.

6.6.2.4 The secondary brake system (see 4.4) shall stop the machine within the distance specified in Table 3. If the machine is equipped with a retarder, it may be used prior to and during this test.

If a 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 grades. An instruction plate shall be placed in the operator's compartment and be readily visible to the operator.

If the service and secondary brake systems are actuated by only one control (lever, pedal, switch, etc.), another secondary brake system shall be provided that will stop the machine with the distance calculated from:

$$L = \frac{V^2}{34} \qquad \text{(Eq.2)}$$

where:

V = Machine velocity in km/h immediately prior to the brake control being applied

L = Stopping distance in meters

6.6.3 HEAT FADE TEST

6.6.3.1 Machines shall be tested as stated in 6.6.1.

6.6.3.2 The service brakes shall be applied and released to complete four consecutive stops at or as near as possible to the machine's maximum deceleration without sliding tires. 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 specified in Table 3.

6.7 Stopping Performance—This section applies to rigid frame and articulated steer dumpers with a machine mass of 32 000 kg or more as described by Figures 4.1.1.1, 4.1.1.2, 4.1.1.3, 4.1.1.5, 4.1.2.1, 4.1.2.2, 4.1.2.3, 4.1.2.4, 4.3.1.1, and 4.3.2.1 of SAE J1057 SEP88.

6.7.1 TEST CONDITIONS

6.7.1.1 Tests shall be performed in accordance with the Test Conditions in Section 5.

6.7.1.2 The test course shall have a 9% ± 1% downgrade in the direction of machine travel.

6.7.1.3 The transmission shall be engaged in a gear such that the engine does not exceed the machine manufacturer's maximum specified engine speed (rpm).

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TABLE 3—STOPPING PERFORMANCE FOR ALL MACHINES EXCEPT RIGID FRAME OR ARTICULATED DUMPERS OVER 32 000 KG

Machine Type	Machine Mass, kg	Stopping Distance, Meters Service Brake System	Stopping Distance, Meters Secondary Brake System
Machines that will travel on public roads (see 6.6)	any mass permitted		
a. Maximum level speed 32 km/h and greater		$\frac{V^2}{68}$	$\frac{V^2}{39}$
b. Maximum level speed less than 32 km/h		$\left(\frac{V^2}{68}\right) + 0.1(32-V)$	$\left(\frac{V^2}{39}\right) + 0.1(32-V)$
Machines that will not travel on public roads (see 6.6)			
a. Maximum level speed 32 km/h and greater	less than 32 000	$\frac{V^2}{68} + \frac{V^2}{124}\left(\frac{M}{32\,000}\right)$	$\frac{V^2}{39} + \left(\frac{V^2}{130}\right)\frac{M}{32\,000}$
b. Maximum level speed less than 32 km/h	less than 32 000	$\frac{V^2}{68} + \frac{V^2}{124}\left(\frac{M}{32\,000}\right) + 0.1(32-V)$	$\frac{V^2}{39} + \frac{V^2}{130}\left(\frac{M}{32\,000}\right) + 0.1(32-V)$
c. Maximum level speed 32 km/h and greater	32 000 and greater	$\frac{V^2}{44}$	$\frac{V^2}{30}$
d. Maximum level speed less than 32 km/h	32 000 and greater	$\left(\frac{V^2}{44}\right) + 0.1(32-V)$	$\left(\frac{V^2}{30}\right) + 0.1(32-V)$

V is machine speed expressed in km/h (see 6.6.1).
M is machine mass expressed in kg (see 5.3).

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TABLE 4—STOPPING PERFORMANCE FOR RIGID FRAME OR ARTICULATED DUMPERS OVER 32 000 KG

Machine Type	Machine Mass, kg (See 5.3)	Stopping Distance, Meters Service Brake System	Stopping Distance, Meters Secondary Brake System
Rigid frame and articulated steer dumpers that will not travel on public roads (see 6.7)	32 000 and greater	$\frac{v^2}{48-2.6(\%\text{grade})}$	$\frac{v^2}{34-2.6(\%\text{grade})}$

NOTE: v is machine speed expressed in km/h (see 6.7.1 and 6.7.2)

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