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drivetrain or as an alternate, the motors and gear final drives may be disengaged from the drive train before stopping distance tests are run.

4.2.1.1 *Alternate Test for Machines Using Hydrostatic Drives*—If it is difficult to remove the hydrostatic motor retarding force, or to disengage the motor and gear final drive from the drive train, the secondary braking system may be tested in the following way:

With the unit stationary, variable motors set to maximum displacement, and any mechanical transmissions set in the lowest speed range, apply the secondary brake and engage the hydrostatic drive system at full rated pressure alternately in forward and reverse. The unit must remain stationary. The brake must be capable of stopping a moving vehicle.

4.2.2 APPLICATION—The secondary system shall be capable of being applied from the operator's position. The system shall be arranged so that it cannot be released by the operator unless immediate reapplication can be made to stop the machine.

4.2.2.1 *Automatic Application, Stored Energy System Excluding Hydrostatic Systems*—The secondary braking system may be applied automatically in addition to the manual control. With automatic application, a continuous audible or visual warning device should activate before the secondary braking system applies.

4.2.2.2 *Automatic Application, Hydrostatic Systems*—The secondary braking system may be applied automatically, without any warning device activation, if the braking system releases hydraulically and is spring applied with loss of hydraulic system charge pressure.

4.3 Parking Brake System—All machines shall be equipped with a parking brake system capable of being applied and released from the operator's position.

4.3.1 PARKING BRAKE SYSTEM PERFORMANCE ON GRADE OR SIMULATED GRADE— The parking brake system shall have the capability of holding the machine stationary on a 15% grade with the machine at maximum gross machine mass including all accessories and capacities per the manufacturer's specifications. The test course shall be as specified in paragraph 5.1.1 except for grade. This criteria applies to both forward and reverse direction.

4.3.1.1 *Alternate Tests*—If the test specified in paragraph 4.3.1 is impractical, either of the following tests may be conducted:

1. Test unit on a tilt platform with a skid resistant surface tilted to a 15% angle.

2. Test unit by applying a pulling force to a stationary machine with the parking brake set and transmission in neutral or if hydrostatic drive, with pump bypassed. The test course will be described in paragraph 5.1.1. This force shall be applied horizontally to achieve a minimum force equivalent to a 15% grade. This force in N is machine mass in Kg times 1.46.

4.3.2 REMAIN APPLIED—The parking brake system when applied shall maintain the parking performance in compliance with paragraph 4.3.1 despite any contraction of the brake parts, exhaustion of energy, or leakage of any kind.

5. Brake Test Criteria

5.1 Facilities and Instrumentation

5.1.1 The test course shall consist of a hard, dry surface (ground moisture may be present to the extent that it does not adversely affect the braking surface) with a well compacted base. The approach will be of sufficient length, smoothness, and uniformity of grade to assure stabilized travel speed of machine. 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.

5.1.2 A means to measure stopping distance with an accuracy of ± 1%.

5.1.3 A means to measure machine test speed with an accuracy of ± 3%.

5.1.4 A means for determining machine mass (weight) with an accuracy of ± 2.5%.

5.1.5 A means for measuring the braking system energy source, when applicable, with an accuracy of ± 3%.

5.1.6 A means for measuring the force required by the operator to actuate the braking system with an accuracy of ± 3%.

5.2 Test Requirements

5.2.1 All parameters related to braking systems shall be within the machine manufacturer's specifications; that is, tire size and pressure, brake adjustment, warning device actuation point, etc. All power-assist pressures shall be within the machine manufacturer's specification range. No manual adjustment(s) shall be made to the brake system during any one performance test.

5.2.2 MACHINE MASS—Machine to be tested with maximum fuel and sprinkler water, and at manufacturer's stated maximum mass.

5.2.3 Stopping distance is to be measured in meters from the point at which the brake control application begins to the point at which the machine is at rest.

5.2.4 Stopping tests are to be conducted from maximum machine speed.

5.2.5 Stopping tests shall be conducted with the transmission in the gear commensurate with the speed required in paragraph 5.2.4 where applicable. The power train may be disengaged prior to completing the stop.

5.2.6 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.

5.2.7 Control force input necessary to apply the braking systems to achieve the required braking performance shall not exceed the following values:

Control Type	Force
Finger Grasp	20 N
Hand Grasp	
Upwards	400N
Fore-Aft	300N
Sideways	300N
Foot Pedal	700N
Foot Treadle	350N

5.2.8 On machines where hydrostatic braking is used as the service brake, the stopping and holding performance of this system shall be conducted with the engine running.

5.2.9 When testing a vibratory machine, all tests shall be conducted without vibration.

TABLE I—BRAKE PERFORMANCE REQUIREMENTS

Machine Operating Mass Kg M	Service Brake System Stopping Distance L for Mass M	Secondary Brake System Stopping Distance L for Mass M
< 5,400	$L = 0.14V + 0.02V^2$	$L = 0.134V + 0.058V^2$
> 5,400 < 13,600	$L = 0.2V + 0.02V^2$	$L = 0.22V + 0.057V^2$
> 13,600	$L = 0.28V + 0.02V^2$	$L = 0.29V + 0.057V^2$

L = stopping distance meters (m)
V = machine speed in kilometers per hour (km/h)
M = machine operating mass in kilogram (kg)

ed. BRAKING PERFORMANCE—RUBBER-TIRED CONSTRUCTION MACHINES—SAE J1152 APR80

SAE Recommended Practice

Report of the Construction Machinery Technical Committee, approved July 1976, editorial change April 1980. This document incorporates material from SAE J166, J236, J237, J319, and J1080, which have been discontinued. Rationale statement available.

1. Scope—Minimum performance criteria for service braking systems, emergency stopping systems, and parking systems for off-highway, rubber-tired, self-propelled loaders, dumpers, tractor scrapers, graders, cranes, excavators, and tractors with dozer are provided in this SAE Recommended *ed.* Practice. Refer to SAE J1057 (July, 1973) and J1116 (July, 1975) (Sections 1.1, 1.2, and 2) for machine identification.

2. Purpose

2.1 To define minimum braking system performance for in-service machines.

NOTE: This is not a design standard.

2.2 To provide test criteria by which machine braking system compliance may be verified.

3. Braking Systems

3.1 **Service Braking System**—The primary system of any type used for stopping and holding the machine.

3.2 **Emergency Stopping System**—The system used for stopping in the event of any single failure in the service braking system.

3.3 **Parking System**—A system to hold stopped machine stationary.

NOTE: Common Components—The above braking systems may use common components. However, a failure of a common component shall not reduce the effectiveness of the machines stopping capability below the emergency stopping performance as defined in paragraph 4.2.1.

4. Braking System Performance

4.1 **Service Braking System**—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).

4.1.1 STOPPING PERFORMANCE—The service braking system, when tested in accordance with Section 5, shall stop the machine within the distance specified in the appropriate table.

4.1.2 HOLDING PERFORMANCE—The service braking system shall have capability equivalent to holding the machine stationary on a dry swept concrete grade under conditions as listed:

Machine	Grade	Condition
Loaders	30%	Loaded to manufacturers gross mass (weight) rating and distribution. Bucket to be in SAE carry position.
Dumpers & Tractor Scrapers	25%	Loaded to manufacturers gross machine mass (weight) rating and distribution.
Graders	30%	Cutting edge to be in the transport position.
Cranes & Excavators	25%	Unloaded, with components in the transport position as recommended by the manufacturer.
Tractors with *ed.* Dozer	30%	Lowest part of cutting edge to be 460 mm (18 in) above test surface.

The criteria shall apply to both forward and reverse directions.

4.1.3 SYSTEM RECOVERY—With the machine stationary, the service braking systems primary power source shall have capability of delivering at least 70% of maximum brake pressure measured at the brakes when the brakes are fully applied twelve (12) times at the rate of four (4) applications per minute with the engine at maximum governed rpm for dumpers, tractor scrapers, cranes

ed. TABLE 1—LOADERS, TRACTORS WITH DOZERS—Brake Performance Requirements (SI Units)

Machine Mass kg	Machine Speed, km/h									
	6	10	14	18	22	26	30	34	38	42
	Service Brake Maximum Stopping Distance—Metres (Emergency Brake Stopping Maximum Stopping Distance—Metres)									
Up to 16 000	0.3 (0.9)	1.5 (4.5)	2.9 (8.7)	5.2 (15.6)	7.1 (21.3)	9.2 (27.6)	11.6 (34.8)	14.4 (43.2)	17.2 (51.6)	20.4 (61.2)
Over 16 000 to 32 000	—	—	—	6.6 (19.8)	9.2 (27.6)	12.2 (36.6)	15.5 (46.5)	19.3 (57.9)	23.5 (70.5)	28.1 (84.3)
Over 32 000 to 64 000	—	—	—	7.9 (23.7)	11.1 (33.3)	14.8 (44.4)	19.0 (57.0)	23.8 (68.4)	29.2 (87.6)	35.0 (105.0)
Over 64 000 to 127 000	—	—	—	9.1 (27.3)	12.9 (38.7)	17.4 (52.2)	22.5 (67.5)	28.3 (84.9)	34.8 (104.4)	41.9 (215.7)
Over 127 000	—	—	—	11.0 (33.0)	15.8 (47.4)	21.3 (63.9)	27.8 (83.4)	35.0 (105.0)	43.2 (129.6)	52.2 (156.6)

Brake Performance Requirements (U.S. Customary Units)

Machine Mass, lb	Machine Speed, mph											
	4	6	8	10	12	14	16	18	20	22	24	26
	Service Brake Maximum Stopping Distance—Feet (Emergency Brake Maximum Stopping Distance—Feet)											
Up to 36 000	2 (6.0)	5 (15.0)	8 (24.0)	15 (45)	20 (60)	25 (75)	31 (93)	38 (114)	45 (135)	53 (159)	61 (183)	70 (212)
Over 36 000 up to 70 000	—	—	—	19 (57)	25 (75)	33 (99)	41 (123)	51 (153)	61 (183)	72 (216)	84 (252)	97 (292)
Over 70 000 up to 140 000	—	—	—	22 (66)	31 (93)	40 (120)	50 (150)	62 (186)	75 (225)	89 (267)	105 (315)	121 (364)
Over 140 000 to 280 000	—	—	—	26 (78)	36 (108)	47 (141)	60 (180)	74 (222)	89 (267)	107 (321)	125 (375)	145 (435)
Over 280 000	—	—	—	31 (93)	43 (129)	57 (171)	73 (219)	91 (273)	111 (333)	132 (396)	156 (468)	181 (543)

and excavators; and twenty (20) times at the rate of six (6) applications per minute with the engine at maximum governed rpm for loaders, graders, and *ed.* tractors with dozer.

4.1.4 WARNING DEVICE—The service braking system using stored energy shall be equipped with a warning device which actuates before system energy drops below 50% of the manufacturers specified maximum operating energy level. The device shall be readily visible and/or audible to the operator, and provide a continuous warning. Gauges indicating pressure or vacuum shall not be acceptable to meet these requirements.

4.2 Emergency Stopping System—All machines shall be equipped with an emergency stopping system.

4.2.1 STOPPING PERFORMANCE—The emergency stopping system, when tested in accordance with Section 5, shall stop the machine within the distances shown in parenthesis in the appropriate table.

4.2.2 EMERGENCY APPLICATION—The emergency system shall be capable of being applied by a person seated in the operator's seat. The system shall be arranged so that it cannot be released from the operator's seat after any application unless immediate reapplication can be made from the operator's seat to stop the machine or combination of machines.

4.2.2.1 In addition to the manual control, the emergency stopping system may also be applied automatically. If an automatic emergency stopping system is used, the automatic application shall occur after the warning device is actuated.

4.3 Parking System—All machines shall be equipped with a parking system capable of being applied by a person seated in the operator's seat.

4.3.1 PARKING SYSTEM PERFORMANCE—The parking system shall have capability equivalent to holding the machine stationary on a 15% dry swept concrete grade under all conditions of loading. This criterion shall apply to both forward and reverse directions.

4.3.2 REMAIN APPLIED—The parking system while applied shall maintain the parking performance in compliance with paragraph 4.3.1 despite any contraction of the brake parts, exhaustion of the source of energy or leakage of any kind.

5. Brake Criteria

5.1 Facilities and Instrumentation

5.1.1 The test course shall consist of a clean swept, level, dry concrete or other specified surface of adequate length to conduct the test. The approach will be of sufficient length, smoothness, and uniformity of grade to assure stabilized travel speed of the machine. The braking surface shall not have over 1% grade in the direction of travel, or more than 3% grade at right angles to the direction of travel.

5.1.2 An instrument to measure the stopping distance with an accuracy of ±1%.

5.1.3 A means to measure the test speed with an accuracy of ±5% of actual speed.

5.1.4 A means for determining the machine mass (weight).

5.1.5 A means for measuring the braking system energy level as required in paragraphs 4.1.3 and 4.1.4.

5.1.6 A means for measuring the force required by the operator to actuate the braking system.

5.2 Test Requirements

5.2.1 All tests to be conducted with the applicable braking system fully charged.

5.2.2 Stopping tests to be conducted under the following conditions:

TABLE 2—DUMPERS—Brake Performance Requirements (SI Units)

Machine Mass, kg	Machine Speed, km/h			
	24	32	40	48
	Service Brake Maximum Stopping Distance—Metres (Emergency Brake Maximum Stopping Distance—Metres)			
Up to 45 000	10.9 (27.1)	17.0 (46.2)	26.5 (70.4)	36.0 (99.5)
Over 45 000 to 90 000	14.2 (31.6)	22.3 (52.1)	32.1 (77.7)	43.5 (108.5)
Over 90 000 to 180 000	19.2 (38.1)	29.0 (60.9)	40.4 (88.7)	53.5 (121.6)
Over 180 000	24.2 (44.9)	35.6 (69.9)	48.8 (99.9)	63.5 (135.0)

Brake Performance Requirements (U.S. Customary Units)

Machine Mass, lb	Machine Speed, mph			
	15	20	25	30
	Service Brake Maximum Stopping Distance—Feet (Emergency Brake Maximum Stopping Distance—Feet)			
Up to 100 000	36 (90)	59 (153)	88 (234)	122 (330)
Over 100 000 to 200 000	47 (105)	74 (173)	106 (258)	144 (360)
Over 200 000 to 400 000	64 (126)	96 (202)	134 (294)	177 (403)
Over 400 000	80 (149)	118 (231)	161 (331)	210 (448)

TABLE 3—COMBINATION DUMPERS AND DUMPER TRAINS—Brake Performance Requirements (SI Units)

Machine Mass, kg	Machine Speed, km/h			
	24	32	40	48
	Service Brake Maximum Stopping Distance—Metres (Emergency Brake Maximum Stopping Distance—Metres)			
Up to 45 000	10.9 (27.1)	17.9 (46.2)	26.5 (70.4)	36.9 (99.5)
Over 45 000 to 90 000	17.6 (36.0)	26.8 (58.1)	37.6 (85.1)	50.2 (117.3)
Over 90 000 to 180 000	25.9 (47.1)	37.9 (72.9)	51.5 (103.7)	65.9 (139.5)
Over 180 000	37.6 (62.7)	53.4 (93.6)	71.0 (129.6)	90.2 (170.6)

Brake Performance Requirements (U.S. Customary Units)

Machine Mass, lb	Machine Speed, mph			
	15	20	25	30
	Service Brake Maximum Stopping—Feet (Emergency Brake Maximum Stopping Distance—Feet)			
Up to 100 000	36 (90)	59 (153)	88 (234)	122 (330)
Over 100 000 to 200 000	58 (119)	89 (192)	125 (282)	166 (389)
Over 200 000 to 400 000	86 (156)	125 (241)	171 (344)	221 (462)
Over 400 000	124 (207)	177 (310)	235 (429)	298 (565)

Machine	Condition
Loaders	Unloaded, with bucket in SAE carry position (Reference SAE J732c (June, 1975)).
Dumpers & Tractor Scrapers	Loaded to manufacturers gross machine mass (weight) rating and distribution.
Graders	Cutting edge to be in the transport position.
Cranes & Excavators	Unloaded, with components in the transport position as recommended by the manufacturer.
Tractors with *ed.* Dozers	Lowest part of cutting edge to be 460 mm (18 in) above test surface.

TABLE 4—TRACTOR SCRAPERS—Brake Performance Requirements (SI Units)

Machine Mass, kg	Machine Speed, km/h			
	24	32	40	48
	Service Brake Maximum Stopping Distance—Metres (Emergency Brake Maximum Stopping Distance—Metres)			
Up to 23 000	10.9 (26.7)	17.6 (45.8)	26.4 (69.4)	36.4 (98.2)
Over 23 000 to 45 000	14.2 (31.2)	22.1 (51.5)	31.8 (77.0)	43.0 (107.3)
Over 45 000 to 68 000	17.6 (35.8)	26.7 (57.6)	37.3 (84.2)	49.7 (116.1)
Over 68 000	20.9 (40.0)	30.9 (63.3)	43.0 (91.8)	56.4 (125.2)

Brake Performance Requirements (U.S. Customary Units)

Machine Mass, lb	Machine Speed, mph			
	15	20	25	30
	Service Brake Maximum Stopping Distance—Feet (Emergency Brake Maximum Stopping Distance—Feet)			
Up to 50 000	36 (88)	58 (151)	87 (229)	120 (324)
Over 50 000 to 100 000	47 (103)	73 (170)	105 (254)	142 (354)
Over 100 000 to 150 000	58 (118)	88 (190)	123 (278)	164 (383)
Over 150 000	69 (132)	102 (209)	142 (303)	186 (413)

5.2.3 Stopping distance to be measured in metres (feet) from the point at which the brake control is applied to the point at which the machine is stopped.

5.2.4 Stopping tests to be conducted from at least one speed for each machine as listed:

Machine	Speeds
Loaders, Tractors *ed.* with Dozers	Not less than 26 km/h (16 mph) or maximum speed if less than 26 km/h (16 mph).
Dumpers, Tractor Scrapers	Not less than 32 km/h (20 mph) or maximum speed if less than 32 km/h (20 mph).
Graders	Not less than 30 km/h (18 mph) or maximum speed if less than 30 km/h (18 mph).
Cranes, Excavators	Not less than 32 km/h (20 mph) no more than 48 km/h (30 mph) or maximum speed if less than 32 km/h (20 mph).

5.2.5 Stopping test shall be conducted with the transmission in gear commensurate with the speed required in paragraph 5.2.4. The power train may be disengaged prior to completing the stop.

5.2.6 Auxiliary retarders shall not be used in the test unless the retarder is simultaneously actuated by the applicable brake system control.

5.2.7 Maximum allowable operator forces to actuate braking systems as defined in Section 3 are 890 N (200 lb) for a foot operated system, and 535 N (120 lb) for a hand operated system.

TABLE 5—GRADERS—Brake Performance Requirements (SI Units)

Machine Mass, kg	Machine Speed, km/h							
	16	18	22	26	30	34	38	42
	Service Brake Maximum Stopping Distance—Metres (Emergency Brake Maximum Stopping Distance—Metres)							
Up to 16 000	4.2 (12.6)	5.1 (15.3)	6.9 (20.7)	9.0 (27.0)	11.3 (33.9)	13.9 (41.7)	16.7 (50.1)	19.8 (59.4)
Over 16 000 to 32 000	5.2 (15.6)	6.2 (18.6)	8.6 (25.8)	11.4 (34.2)	14.6 (43.8)	18.1 (54.3)	22.0 (66.0)	26.2 (78.6)
Over 32 000	6.4 (19.2)	7.9 (23.7)	11.1 (33.3)	14.8 (44.4)	19.0 (57.0)	23.8 (71.4)	29.2 (87.6)	35.0 (105.0)

Brake Performance Requirements (U.S. Customary Units)

Machine Mass, lb	Machine Speed, mph								
	10	12	14	16	18	20	22	24	26
	Service Brake Maximum Stopping Distance—Feet (Emergency Brake Maximum Stopping Distance—Feet)								
Up to 35 000	14 (42)	19 (57)	24 (72)	29 (87)	35 (105)	42 (126)	49 (147)	56 (168)	65 (195)
Over 35 000 to 70 000	17 (51)	23 (69)	30 (90)	37 (111)	45 (135)	54 (162)	64 (192)	74 (222)	85 (255)
Over 70 000	22 (66)	31 (93)	40 (120)	50 (150)	62 (186)	75 (225)	89 (267)	105 (315)	122 (366)

TABLE 6—CRANES, EXCAVATORS (Class 1 and 2)—Brake Performance Requirements (SI Units)

Machine Mass, kg	Machine Speed, km/h			
	24	32	40	48
	Service Brake Maximum Stopping Distance—Metres (Emergency Brake Maximum Stopping Distance—Metres)			
Up to 32 000	8.2 (20.0)	13.3 (34.2)	19.7 (52.1)	27.3 (73.6)
Over 32 000	9.7 (22.4)	15.5 (37.3)	22.4 (55.8)	30.6 (78.2)

Brake Performance Requirements (U.S. Customary Units)

Machine Mass, lb	Machine Speed, mph			
	15	20	25	30
	Service Brake Maximum Stopping Distance—Feet (Emergency Brake Maximum Stopping Distance—Feet)			
Up to 70 000	27 (66)	44 (113)	65 (172)	90 (243)
Over 70 000	32 (74)	51 (123)	74 (184)	101 (258)

TABLE 7—CRANES, EXCAVATORS (Class 3, 4, and 5)—Brake Performance Requirements (SI Units)

Machine Mass, kg	Machine Speed, km/h			
	24	32	40	48
	Service Brake Maximum Stopping Distance—Metres (Emergency Brake Maximum Stopping Distance—Metres)			
Up to 23 000	10.0 (25.8)	16.7 (44.2)	24.8 (67.6)	34.9 (96.1)
Over 23 000	11.6 (27.9)	18.8 (47.3)	27.6 (71.2)	38.2 (100.6)

Brake Performance Requirements (U.S. Customary Units)

Machine Mass, lb	Machine Speed, mph			
	15	20	25	30
	Service Brake Maximum Stopping Distance—Feet (Emergency Brake Maximum Stopping Distance—Feet)			
Up to 50 000	33 (85)	55 (146)	82 (223)	115 (317)
Over 50 000	38 (92)	62 (156)	91 (235)	126 (332)

ADDENDUM

ed.

MACHINE IDENTIFICATION

A rubber-tired chassis designed exclusively for mounting a revolving upperstructure and its attachments, such as, cranes and excavators, to become an integral unit, and manufactured primarily for use on the job site. The chassis is not designed to transport a payload. The chassis is supported by two or more axles. The chassis frame generally includes an outrigger structure and is designed to take the loadings imposed on it by the upperstructure. Refer to the illustrations for examples of typical chassis configurations for each class.

CLASS 1—A rubber-tired chassis with revolving upperstructure, and attachments, capable of a speed of at least 40 mph (65 km/h), distinguished by the following:

1. Single, steerable front axle with a dynamic capacity of 16 000 lb (7260 kg) or less.
2. Rear tandem axles with a dynamic capacity of 44 000 lb (19 960 kg) or less.
3. Width of 96 in (2440 mm) or less.

Primary chassis controls for travel are located in the chassis cab. These controls usually include a mechanical steering linkage with a power assist. It generally has a wheelbase to track ratio of greater than 2:1.

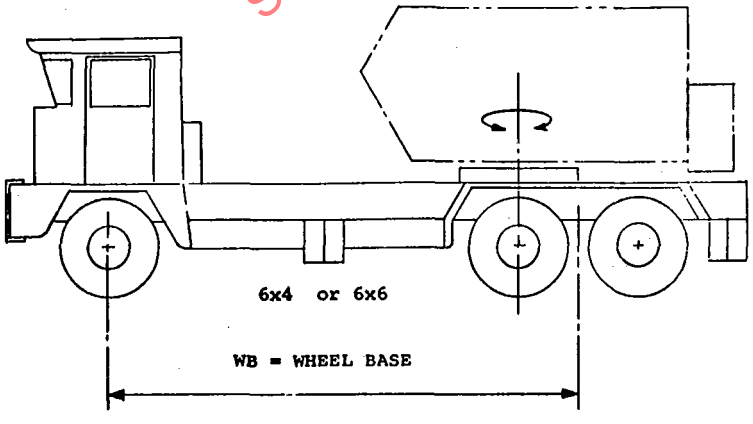

FIG. 1—CLASS 1

CLASS 2—A rubber-tired chassis, rigid or articulated, with revolving upperstructure and attachments, capable of a speed of at least 40 mph (65 km/h), distinguished by one or more of the following:

1. Single, steerable front axle with a dynamic capacity of more than 16 000 lb (7260 kg).
2. Multiple front steering axles.
3. Rear tandem axles with a dynamic capacity of more than 44 000 lb (19 960 kg).
4. Multiple rear axles other than tandem.
5. Width of more than 96 in (2440 mm).

Primary chassis controls for travel are located in the chassis cab. These controls usually include a mechanical steering linkage with a power assist. It generally has a wheelbase to track ratio of greater than 2:1.

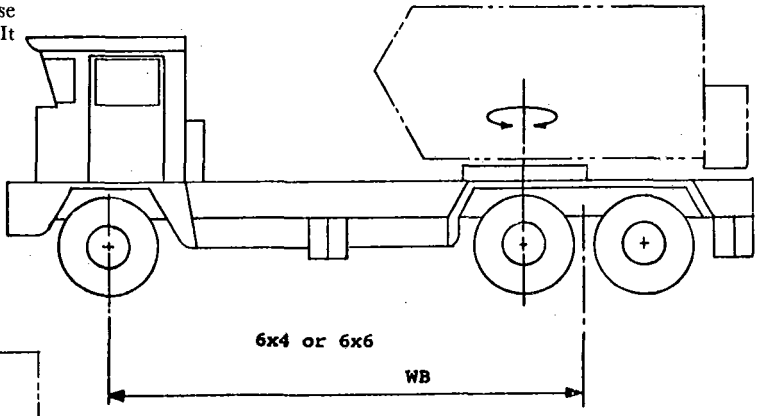

FIG. 2—CLASS 2