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Superseding J2194 AUG2002

Roll-Over Protective Structures (ROPS) for Wheeled Agricultural Tractors

Foreword—There was one editorial change to this document. SAE J117 was cancelled. This has been removed.

1. Scope

1.1 Any ROPS meeting the performance requirement of ISO 5700 (Static ROPS Test Standard) or ISO 3463 (Dynamic ROPS Test Standard) meets the performance requirements of this SAE Standard if the ROPS temperature/material and seat belt requirements of this document are also met.

1.2 Fulfillment of the intended purpose requires testing as follows:

1.2.1 A temperature-material requirement (6.9). This can be satisfied by using the appropriate materials or by performing any of the structural performance tests (Sections 7, 8, or 9) at –18 °C.

1.2.2 A laboratory test, under repeatable and controlled loading, to permit analysis of the ROPS for compliance with the performance requirements of this document. Either the static test sequence (Section 7) or the impact test sequence (Section 8) shall be conducted. See Figure 1.

1.2.3 A seat belt anchorage test (Section 10).

1.3 The test procedures and performance requirements outlined in this document are based on currently available engineering data.

1.4 **Purpose**—The purpose of this document is to establish the test and performance requirements of a roll-over protective structure (ROPS), designed for wheeled agricultural tractors to minimize the frequency and severity of operator injury resulting from accidental tractor upset.

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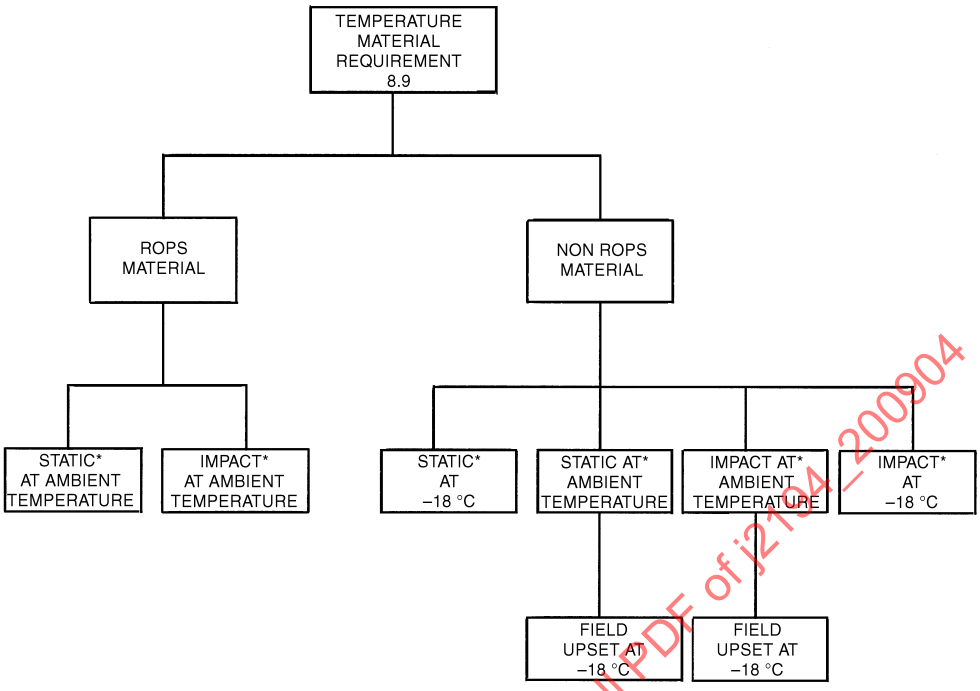


*See 5.2 for limitation.

FIGURE 1—TEMPERATURE MATERIAL REQUIREMENT

2. *References*

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

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

SAE J114—Seat Belt Hardware Webbing Abrasion Performance Requirements
SAE J140—Seat Belt Hardware Test Procedure
SAE J141—Seat Belt Hardware Performance Requirements
SAE J339—Seat Belt Hardware Webbing Abrasion Test Procedure
SAE J800—Motor Vehicle Seat Belt Assembly Installation
SAE J1150—Terminology for Agricultural Equipment
SAE J1194—Rollover Protective Structures (ROPS) for Wheeled Agricultural Tractors

2.1.2 ASAE PUBLICATIONS—Available from the American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph, MI 49085-9659.

ASAE S313—Soil Cone Penetrometer
ASAE S383—Roll-Over Protective Structures (ROPS) for Wheeled Agricultural Tractors

2.1.3 ASTM PUBLICATION—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 370—Standard Methods and Definitions for Mechanical Testing of Steel Products

2.1.4 ISO PUBLICATIONS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO 612—Road vehicles—Dimensions of motor vehicles and towed vehicles—Terms and definitions
ISO 3462—Tractors and machinery for agriculture and forestry—Seat reference point—Method of determination
ISO 3463—Dynamic ROPS test standard
ISO 5700—Static ROPS test standard

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

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

SAE J429—Mechanical and Material Requirements for Externally Threaded Fasteners
SAE J674—Safety Glazing Materials—Motor Vehicles and Motor Vehicle Equipment
SAE J995—Mechanical and Material Requirements for Steel Nuts

3. Definitions

3.1 Agricultural Tractor—A traction machine designed and advertised primarily to supply power to agricultural implements and farmstead equipment. An agricultural tractor propels itself and provides a force in the direction of travel to enable attached soil engaging and other agricultural implements to perform their intended function per SAE J1150.

3.2 Rollover Protective Structure (ROPS)—A cab or frame for the protection of operators of agricultural tractors to minimize the possibility of serious operator injury resulting from accidental upset. The ROPS is characterized by providing space for the clearance zone inside the envelope of the structure or within a space bounded by a series of straight lines from the outer edge of the structure to any part of the tractor that might come in contact with flat ground and is capable of supporting the tractor in that position if the tractor overturns. The mounting structure and fasteners forming the mounting connection with the tractor are part of the ROPS.

3.3 Tractor Mass—The mass of the unladen tractor in operating order with tanks and radiators full, protective structure with cladding and any wheel equipment or additional front wheel drive components required to support the tractor static weight. The operator, optional hitch equipment, optional ballast weights, additional wheel equipment, and other special equipment are not included.

3.4 Reference Mass—A mass, not less than the tractor mass, selected for calculation of the force and energy inputs to be used during tests.

3.5 Seat Reference Point (SRP)—The seat reference point shall be determined in accordance with ISO 3462 with the seat adjusted to its rearmost and uppermost position. For a suspended seat, the seat shall be set to the midpoint of the suspension travel, unless this is contradictory to clearly stated instructions by the manufacturer of the seat. Where special instructions for the seat setting exist, these shall be observed.

3.6 Static Test Horizontal Loading—The application of a horizontal static load to the rear, front, or side of the ROPS.

3.7 Impact Test—The application of a dynamic load to the rear, front, or side of the ROPS produced by a mass acting as a pendulum.

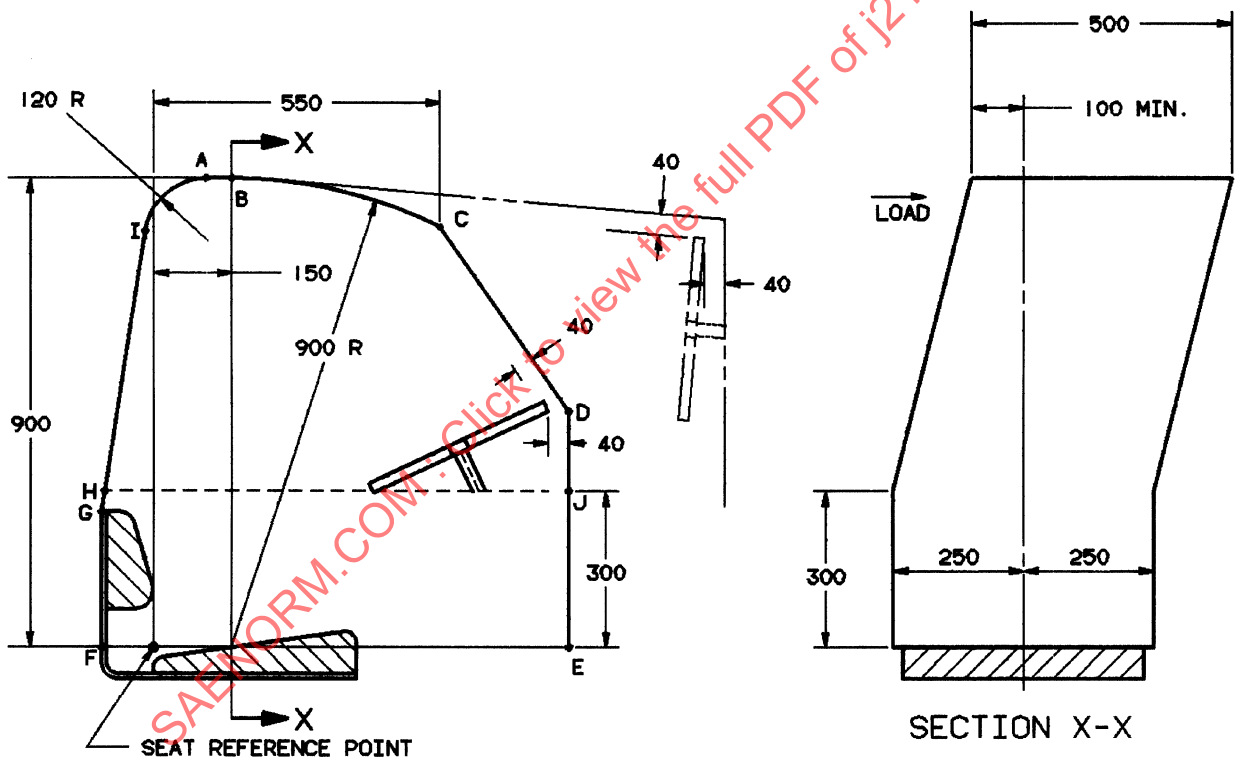
3.8 Crushing Test—The application of a vertical static load through a beam placed laterally across the uppermost members of the ROPS. The resultant of the initial crushing load shall be in the vertical direction and shall be in a vertical reference plane passing through the SRP and parallel to the longitudinal axis of the tractor.

3.9 Vertical Reference Plane—A vertical plane, generally longitudinal to the tractor and passing through the SRP and the center of the steering wheel.

NOTE—Normally the vertical reference plane coincides with the longitudinal median plane of the tractor.

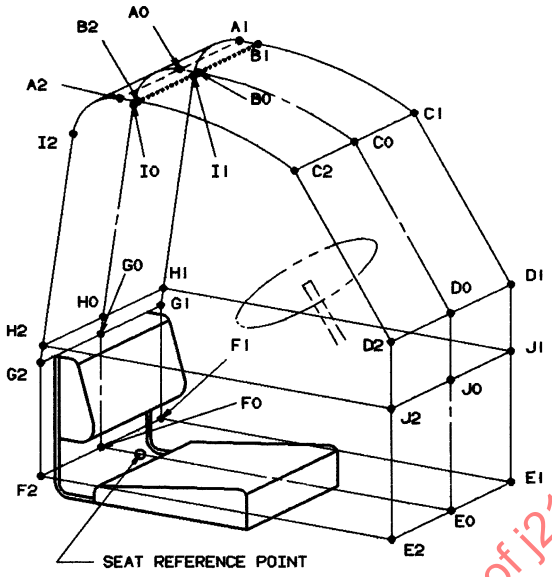
3.10 ROPS Material—Any material that meets the requirements set forth in 6.9.1.

3.11 Clearance Zone—The clearance zone is illustrated in Figures 2A and 2B. Referring to the figures, the zone is defined in relation to the vertical reference plane. This reference plane shall be assumed to move horizontally with the seat and steering wheel during loading and to remain perpendicular to the tractor or the floor of the protective structure. The clearance zone is defined when the tractor is standing on its wheels on a horizontal surface and, where applicable, the steering wheel is adjusted to the midposition for seated driving.



DIMENSIONS ARE MILLIMETERS.

FIGURE 2A—CLEARANCE ZONE FROM THE SIDE



DIMENSIONS	mm	REMARKS
A1A0, B1B0	100	Minimum
A1A2, B1B2, C1C2	500	
D1D2, E1E2	500	Minimum or equal to the diameter of the steering wheel plus 80mm, whichever is the greater.
F1F2, G1G2, H1H2, I1I2, J1J2	500	
E1E0, E2E0	250	Minimum or equal to the radius of the steering wheel plus 40mm, whichever is the greater.
J0E0	300	
F0G0	-	Depending on the tractor.
I0G0	-	
C0D0	-	
E0F0	-	

FIGURE 2B—CLEARANCE ZONE DEFINITION

NOTE—Referring to Figure 2B:

a. A horizontal plane ($A_1B_1B_2A_2$) 900 mm above the seat reference point.
b. An inclined plane ($G_1G_2I_2I_1$) perpendicular to the reference plane and including the rearmost point of the seat backrest and the extension of which passes through a point 900 mm directly above the seat reference point
c. A cylindrical surface ($A_1A_2I_2I_1$) perpendicular to the reference plane, with a radius of 120 mm tangential to the planes defined in (a) and (b)
d. A cylindrical surface ($B_1C_1C_2B_2$) perpendicular to the reference plane, having a radius of 900 mm extending forward for 400 mm from and tangential to the plane defined in (a) at a point 150 mm forward of the seat reference point
e. An inclined plane ($C_1D_1D_2C_2$) perpendicular to the reference plane, joining the surface defined in (d) at its forward edge and passing 40 mm from the rim of the steering wheel

f. A vertical plane ($D_1E_1E_2D_2$) perpendicular to the reference plane 40 mm forward of the rim of the steering wheel
g. A horizontal plane ($E_1F_1F_2E_2$) through the seat reference point
h. A surface ($G_1F_1F_2G_2$), curved if necessary, from the bottom limit of the plane defined in (b) to the horizontal plane defined in (g) following the general direction of, and in contact with, the rear surface of the seat backrest
i. Vertical planes ($J_1E_1F_1G_1H_1$ and $J_2E_2F_2G_2H_2$) not less than 250 mm on either side of the reference plane;
The distance E_1E_2 shall be equal to the diameter of the steering wheel plus 40 mm on each side of the rim of the wheel or 500 mm, whichever is greater
j. Parallel planes ($A_1B_1C_1D_1J_1H_1I_1$ and $A_2B_2C_2D_2J_2H_2I_2$) inclined so that the upper edge of the plane on the side on which the load is applied is at least 100 mm from the reference plane

3.12 Longitudinal Median Plane—See ISO 612.

3.13 Gross Machine Mass—Tractor mass as described in 3.3 with the addition of an operator, wheel equipment, ballast weights, hitch equipment, and special equipment required for operation.

4. Symbols

m = Tractor mass, as defined in 3.3, in kilograms
m_t = Reference mass, as defined in 3.4, in kilograms
D = Deflection of the ROPS at the point of and in line with the load application, in millimeters
D_{max} = Total deflection of the ROPS during static test corresponding to E_i, in millimeters
D′ = Deflection of the ROPS for the calculated energy required, in millimeters
F = Static load force, in newtons
F_{max} = Maximum static load force occurring during loading, with the exception of the overload, in newtons
F′ = Force for the calculated energy required, in newtons
E_{is} = Energy input to be absorbed during side loading, in joules
F-D = Force-deflection curve
$E_{il.1}$ = Energy input to be absorbed during longitudinal loading, in joules
$E_{il.2}$ = Energy input to be absorbed during a second longitudinal loading, in joules
F_r = Applied force at rear in the crushing test, in newtons
F_f = Applied force at front in the crushing test, in newtons
E_i = Energy absorbed by the ROPS area under F-D curve at the point where D = D_{max}, in joules
E'_i = Total energy absorbed by the ROPS structure after static overload test, in joules
H = Height of pendulum at start of impact test, in millimeters
L = Reference wheelbase, which shall be not less than the maximum wheelbase, in millimeters
I = Reference moment of inertia about the rear axle, excluding the rear wheels which shall be not less than the maximum moment of inertia in kilogram meters squared

5. Applications

5.1 This document applies to wheeled agricultural tractors as defined in 3.1. It does not preclude the use of extendable or foldable ROPS as long as these ROPS meet the performance requirements of the document. Tractors used in construction and self-propelled implements are excluded.

5.2 Test procedures in this document are limited by tractor mass (see 3.3) as follows:

5.2.1 STATIC TEST (SECTION 7)—800 kg min.

5.2.2 IMPACT TEST (SECTION 8)—800 to 6000 kg.

5.2.3 FIELD UPSET TEST (SECTION 9)—No limitation.

5.3 The minimum tread of the rear wheels should generally be greater than 1150 mm. This Standard Code may not apply to some designs of tractors, for example, lawn mowing tractors, narrow vineyard tractors, low profile tractors used in buildings with limited overhead clearance or orchards, and stilt tractors (high clearance). For specialized applications, SAE J1194 (ASAE S383) may be used.

6. General Requirements

6.1 The ROPS shall be to production specifications. Where a number of tractor models form a family and use the same ROPS, testing may be performed based on the largest tractor mass within the family. New ROPS and mounting connections shall be used for conducting the test sequence described in Figure 4.

6.2 A tread setting for the wheels, if present, shall be chosen such that no interference exists with the ROPS during the tests.

6.3 Moveable ROPS sections, such as windows, or removable sections, such as doors, which may add to structural strength, shall be removed or placed in configurations that contribute least to strength during a test. All normally moveable glazing shall be removed before tests; however, glazing material that is permanently affixed or is designed as a structural component need not be removed.

6.4 If an overhead weather shield or overhead falling object protective cover is available as an optional attachment to the ROPS, it may be in place during tests, provided it does not contribute to the strength of the ROPS.

6.5 In case of an offset seat and/or nonsymmetrical strength of the ROPS structure, the side loading shall be on the side more likely to lead to infringement of the clearance zone.

6.6 Repairs or adjustments to the ROPS shall not be made during the test sequence.

6.7 Accuracy of Measurement

a. Dimensions: ±3 mm
b. Deflections: ±3 mm
c. Tractor Mass: ±20 kg
d. Loads and Forces: ±2%
e. Direction of Loading:
    1. At start of test: ±2 degrees, all loading.
    2. During test: 10 degrees above to 20 degrees below horizontal, for horizontal loads
f. Pendulum lift height: ±6 mm
g. Mass of pendulum: ±20 kg
h. Pendulum suspension angle: ±2 degrees
i. Moment of inertia: ±5%

6.8 If any fixturing used to restrain the tractor breaks or shifts during any test, the test shall be repeated.

6.9 Material Requirements

6.9.1 The temperature material requirements will be met:

a. If the ROPS passes any of the structural performance tests (Sections 7, 8, or 9) at a metal temperature of –18 °C or below, or
b. If the structural members are from material which exhibits Charpy V-notch impact strengths at –30 °C shown in Table 1.

TABLE 1—MINIMUM V-NOTCH IMPACT STRENGTHS[1]

Specimen Size (mm)	Impact Strength (J)
10 x 10[2]	11.0
10 x 9	10.0
10 x 8	9.5
10 x 7.5[2]	9.5
10 x 7	9.0
10 x 6.7	8.5
10 x 6	8.0
10 x 5[2]	7.5
10 x 4	7.0
10 x 3.3	6.0
10 x 3	6.0
10 x 2.5[2]	5.5

1. Reference: ASTM A 370.
2. Indicates preferred size. Specimen size shall be no less than the largest preferred size that the material will permit.

Specimens are to be "longitudinal" and taken from flat stock, tubular sections, or structural sections before forming or welding for use in the ROPS. Specimens from tubular or structural sections are to be taken from the middle of the side of greatest dimension, not to include welds. There is no Charpy requirement for steel 2.5 mm or less in thickness and a maximum carbon content of 0.20%.

6.9.2 Fasteners used to attach the ROPS to the tractor frame and to connect structural parts of the ROPS shall be metric grade 8.8 or 10.9, SAE grade 5 through 8 or equivalent.

6.9.3 All welding electrodes used in the fabrication of structural members and mountings shall be compatible with material requirements given in 6.9.1.

6.10 Seat and Seat Belt Requirements

6.10.1 ROPS equipped tractors shall be fitted with seat belt assemblies (Type 1) conforming to the following: SAE J114, J140a, J141, J339, and J800 except as noted hereafter.

6.10.2 Where a suspended seat is used, the seat belt shall be fastened to the moveable portion of the seat to accommodate the ride motion of the operator.

6.11 Labeling—Each ROPS shall have a label, permanently affixed to the structure, which states:

a. ROPS model number, if any
b. Manufacturer's or fabricator's name and address
c. Tractor makes, models, or series numbers that the structure is designed to fit
d. That the ROPS model was tested in accordance with the requirements of this document

7. Static Tests

7.1 Apparatus and equipment needed to perform the static test includes:

7.1.1 The ROPS mounting base; a tractor chassis or the equivalent for which the ROPS is designed to assure the integrity of the entire system. If a tractor is utilized, it shall be supported independent of the tires.

7.1.2 The ROPS mounting base anchorage; the assembly shall be secured to the bedplate so that the members connecting the assembly and the bedplate do not deflect significantly in relation to the protective structure under load. The assembly shall not receive any support under load other than that due to the initial attachment.

7.1.3 MEANS FOR APPLYING HORIZONTAL FORCE

7.1.3.1 Provision shall be made so that the load can be uniformly distributed normal to the direction of loading and along a beam of length not less than 250 mm nor more than 700 mm. Projected area shall be no greater than 0.10 m^2.

7.1.3.2 The edges of the beam in contact with the protective structure shall be curved with a maximum radius of 50 mm.

7.1.3.3 Universal joints or the equivalent shall be incorporated to ensure that the loading device does not constrain the protective structure in rotation or translation in any direction other than the direction of loading.

7.1.3.4 Where the straight line defined by the appropriate beam on the protective structure is not normal to the direction of application of load, the space shall be packed so as to distribute the load over the full length.

7.1.4 MEANS FOR APPLYING VERTICAL FORCE

7.1.4.1 When in position for the crushing test, the tractor shall be supported under the axles so that the load applied is not carried on the wheels.

7.1.4.2 A means shall be provided for applying a downward force on the ROPS, such as shown in Figure 3, including a stiff beam with a width of 250 mm.

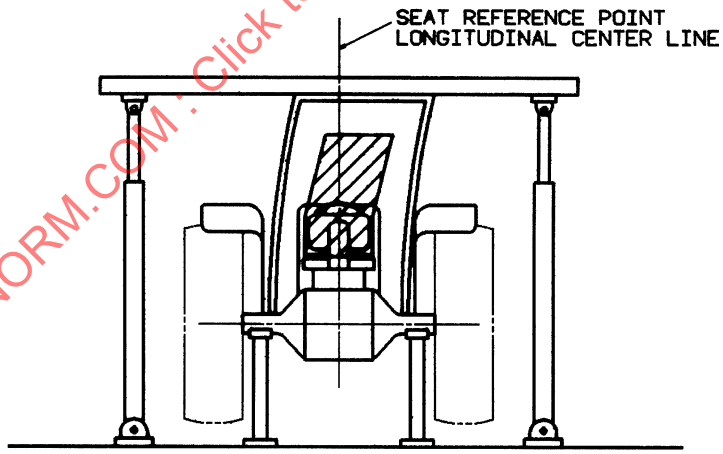


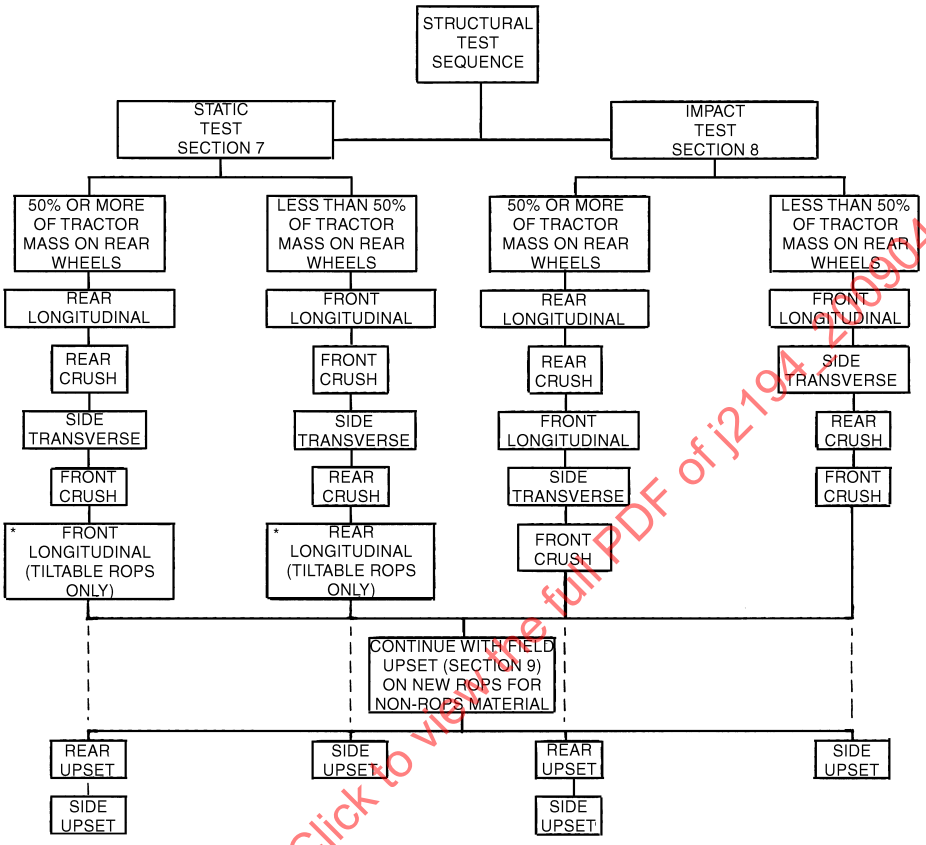
FIGURE 3—TYPICAL LOAD APPLICATION FOR CRUSH TEST

7.1.5 Equipment for measuring force and deflection in the load direction, relative to the tractor chassis. To ensure accuracy, measurements should be taken as continuous readings. The measuring devices shall be located so as to record the force and deflection at the point of, and along the line of, loading.

7.1.6 Means for proving that the zone of clearance has not been entered during the test.

7.2 Test Procedure

7.2.1 SEQUENCE OF TESTS—Refer to Figure 4.



* REQUIRED ONLY IF FIRST LONGITUDINAL LOAD WAS NOT IN THE TILT DIRECTION

FIGURE 4—STRUCTURAL TEST SEQUENCE

7.2.2 During all tests, maximum and permanent deflections of the ROPS shall be measured and recorded.

7.3 Horizontal Loadings from the Rear, Front, and Side

7.3.1 General provisions for horizontal loading tests.

7.3.1.1 The loads applied to the ROPS shall be distributed uniformly by means of a stiff beam, normal to the direction of load application (see Figures 5A and 5B). The stiff beam may be equipped with a means of preventing its sideways displacement. As the load is applied, force and deflection shall be recorded as a continuous record to ensure accuracy. Once the initial application has commenced, the load shall not be reduced until the test has been completed.

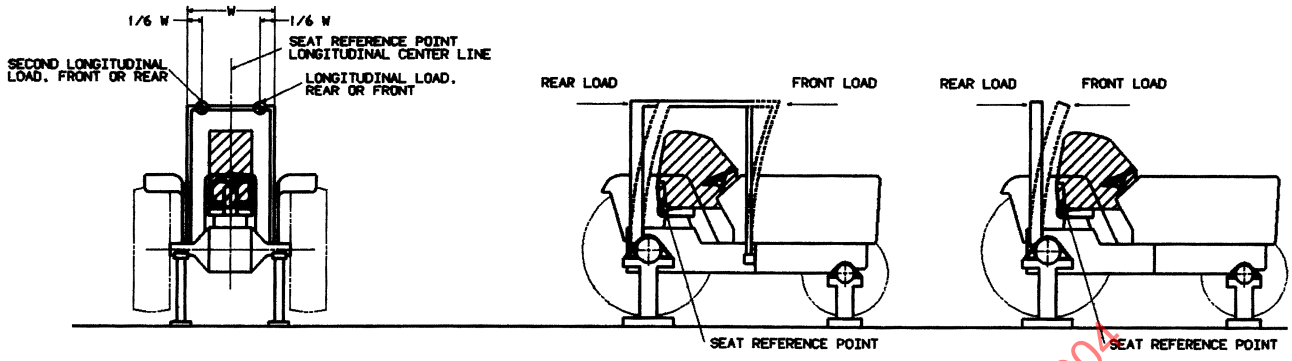


FIGURE 5A—TYPICAL REAR (FRONT) LOAD APPLICATION

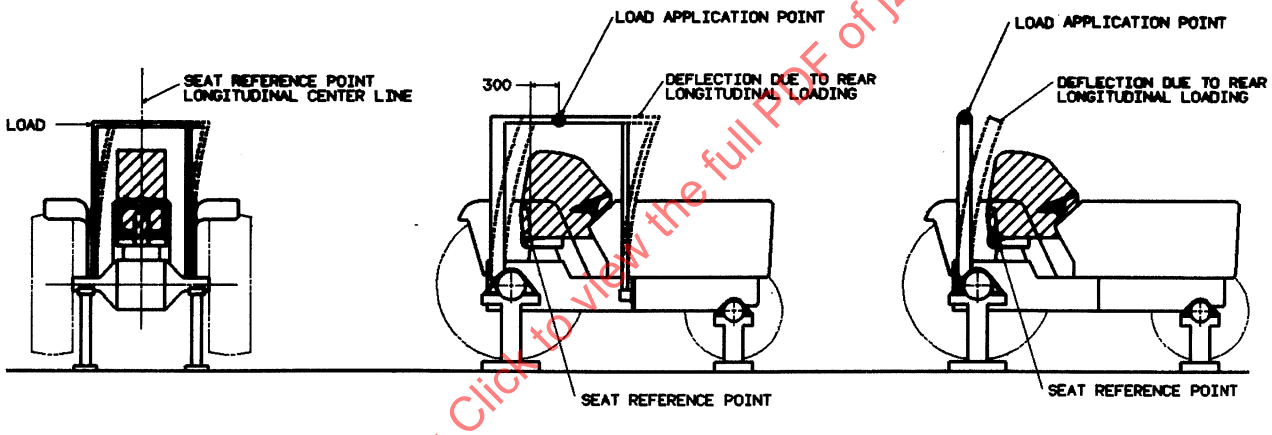


FIGURE 5B—TYPICAL SIDE LOAD APPLICATION

7.3.1.2 The rate of load application to be considered static means that the rate of deflection under loading shall not be greater than 5 mm/s.

7.3.1.3 If no structural cross member exists at the point of load application, a substitute test beam, which does not add strength to the structure, shall be utilized.

7.3.2 FIRST LONGITUDINAL LOADING—The load shall be applied horizontally and parallel to the longitudinal median plane of the tractor. If the load is applied from the rear, the longitudinal load and the lateral load shall be applied on different sides of the median longitudinal plane of the ROPS. If the longitudinal load is applied from the front, it shall be on the same side as the side load.

The rear load is not required on tractors having 50% or more of the unballasted weight on the front wheels.

The load shall be applied to the uppermost traverse structural member of the ROPS (that is, that part which would be likely to strike the ground first in an overturn).

The point of application of the load shall be located at one-sixth of the width of the top of the ROPS inward from the outside corner. The width of the protective structure shall be taken as the distance between two lines parallel to the longitudinal median plane of the tractor touching the outside extremities of the ROPS in the horizontal plane touching the top of the uppermost transverse structural members.

The length of the load distribution device shall be not less than one-third of the width of the ROPS and not more than 49 mm greater than this minimum.

The required energy is: $E_{il.1} = 1.4\ m_t$ (joules)

7.3.3 TRANSVERSE LOADING—The side load shall be applied horizontally at 90 degrees to the longitudinal median plane. It shall be applied to the upper extremity of the ROPS at a point 300 mm forward of the seat reference point. If it is certain that any particular part of the ROPS side will touch the ground first when the tractor overturns sideways, the loading shall be applied at that point, provided that this permits uniform distribution of the load as specified in 7.3.1.1. In the case of a two-post ROPS, side loading shall be applied at the structural member uppermost on the side, regardless of the seat reference point position.

The load distribution beam shall be as long as practicable, subject to a maximum of 700 mm.

The required energy is: $E_{is} = 1.75\ m_t$ (joules)

7.3.4 SECOND LONGITUDINAL LOADING—The load shall be applied in the opposite direction to and at the corner furthest from the point of application of the first longitudinal load.

The required energy is: $E_{il.2} = 0.35\ m_t$ (joules)

7.4 Vertical Loadings

7.4.1 CRUSHING AT THE REAR—The beam shall be positioned across the rear uppermost structural members and the resultant crushing forces shall be located in the vertical reference plane. The force $F_R = 20\ m_t$ (N) shall be applied.

Where the rear part of the ROPS roof will not sustain the full crushing force, the force shall be applied until the roof is deflected to coincide with the plane joining the upper part of the ROPS with that part of the rear of the tractor capable of supporting the vehicle's mass when overturned (see Figure 6). The force shall then be moved and the tractor or loading force repositioned so that the beam is over that point of the ROPS which would then support the rear of the tractor when completely overturned and the full force applied.

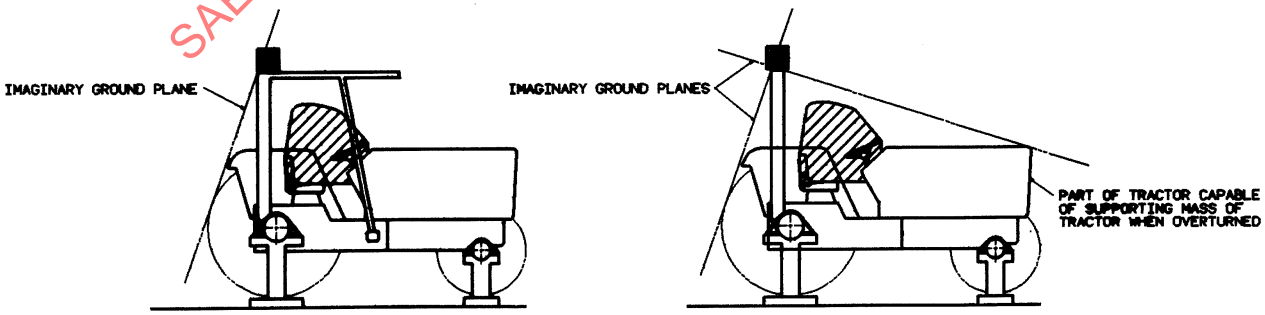


FIGURE 6—REAR CRUSH

7.4.2 CRUSHING AT THE FRONT—The beam shall be positioned across the front uppermost structural members and the resultant crushing forces shall be located in the vertical reference plane. The force $F_F = 20\ m_t$ (N) shall be applied.

Where the front part of the roof of the ROPS will not sustain the full crushing force, the force shall be applied until the roof is deflected to coincide with the plane joining the upper part of the ROPS with that part of the front of the tractor capable of supporting the vehicle mass when overturned (see Figure 7). The force shall then be removed and the tractor or loading force repositioned so that the beam is over that part of the ROPS which would then support the front of the tractor when completely overturned and the full force applied.

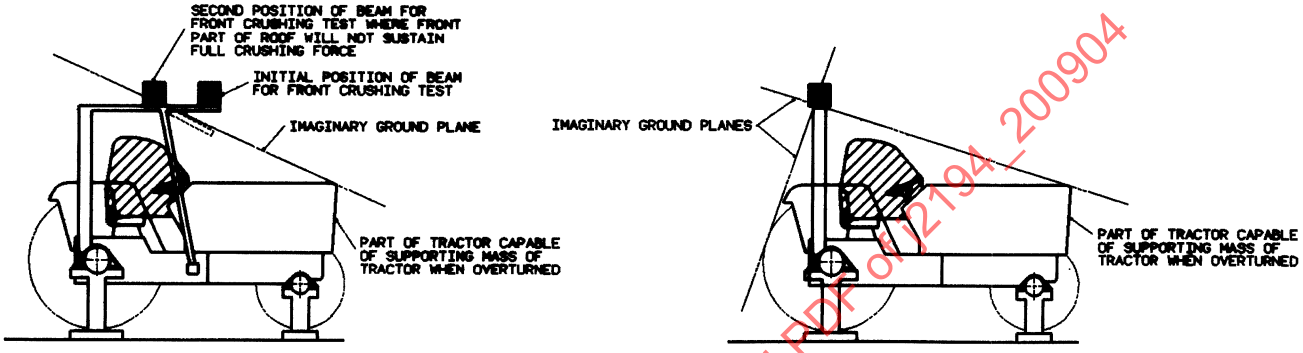


FIGURE 7—FRONT CRUSH

7.5 Overload Test

7.5.1 An overload test to determine the residual strength of the ROPS after a horizontal loading test which may have caused cracks, tears, bending, or buckling may be required to assure adequate strength.

7.5.2 An overload test shall be required if the applied force decreases by more than 3% over the last 5% of the deflection attained when the energy required is absorbed by the structure (see Figure 8).

7.5.3 An overload test shall consist of continuing the horizontal loading in increments of 5% of the original required energy, up to a maximum of 20% additional energy (see Figure 9).

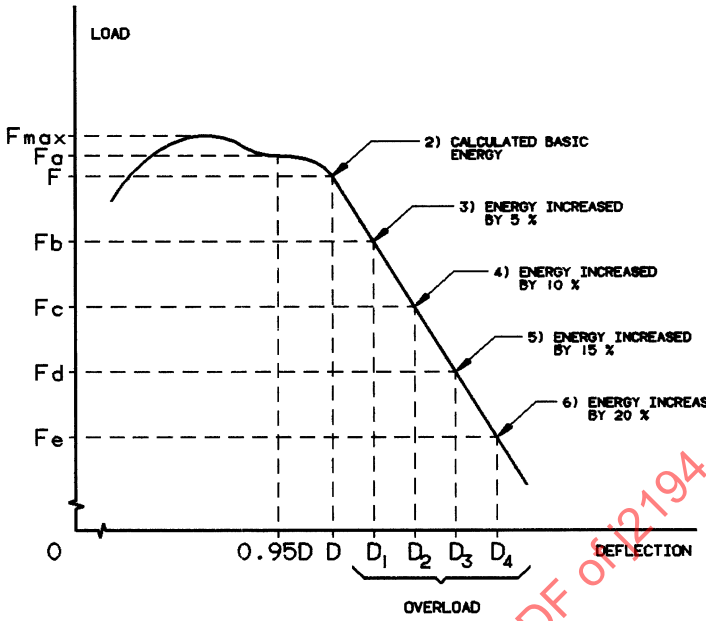


FIGURE 8—LOAD DEFLECTION DIAGRAM—CONTINUING OVERLOAD TEST

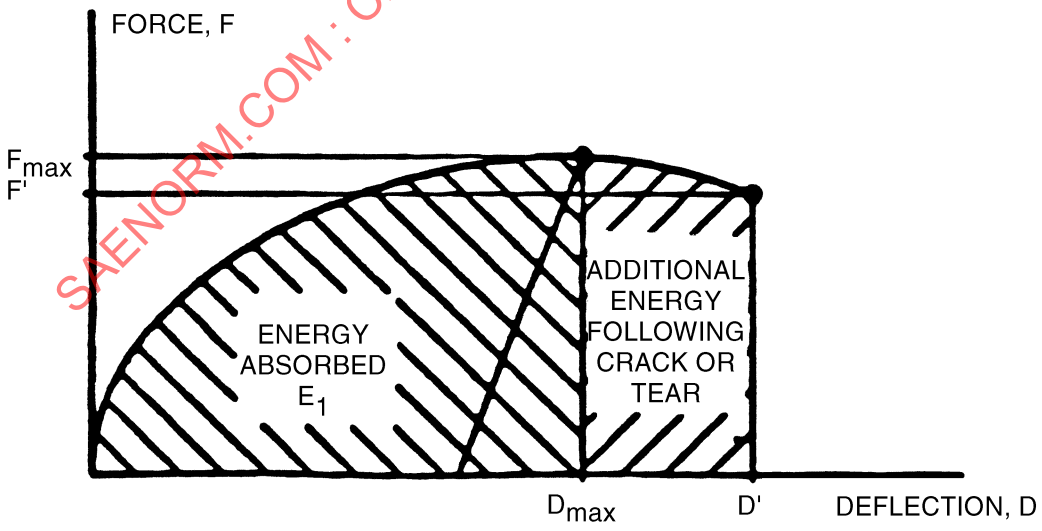


FIGURE 9—LOAD DEFLECTION CURVE—CONTINUING OVERLOAD TEST

8. Impact Tests

8.1 Apparatus and Equipment

8.1.1 The dynamic loading shall be produced by use of a 2000 kg mass acting as a pendulum. The impact face of the mass shall be 680 mm ± 20 mm x 680 mm ± 20 mm and shall be constructed so that its center of gravity is within 25.4 mm of its geometric center. The mass shall be suspended from a pivot point 6 m or more above ground level and shall be conveniently and safely adjustable for height (see Figures 10A through 10C).

The mass of the pendulum block should not include the mass of supporting chains (see Figure 11). The maximum mass of the supporting chains shall be 100 kg.

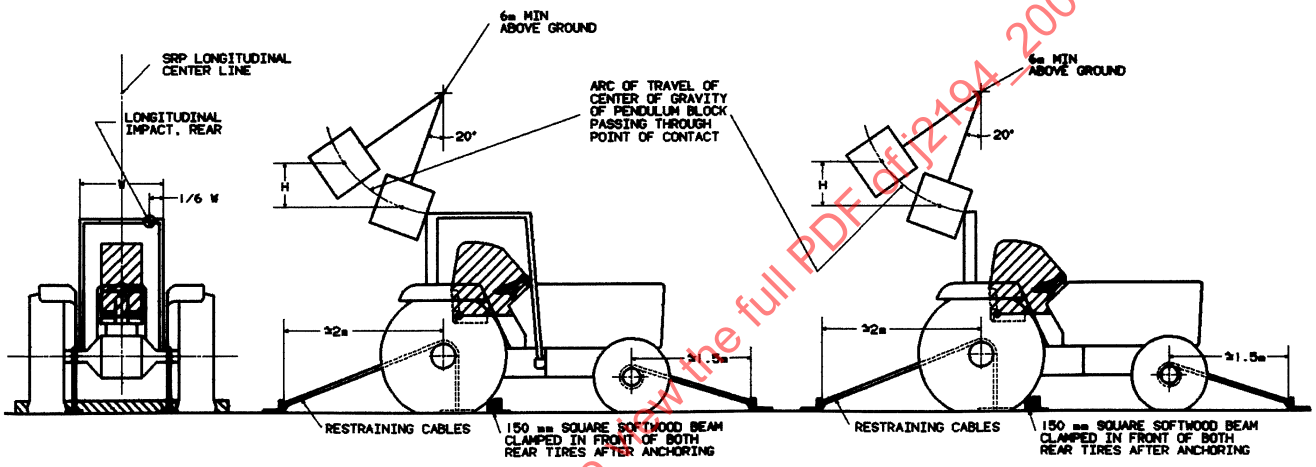


FIGURE 10A—TYPICAL REAR IMPACT APPLICATION

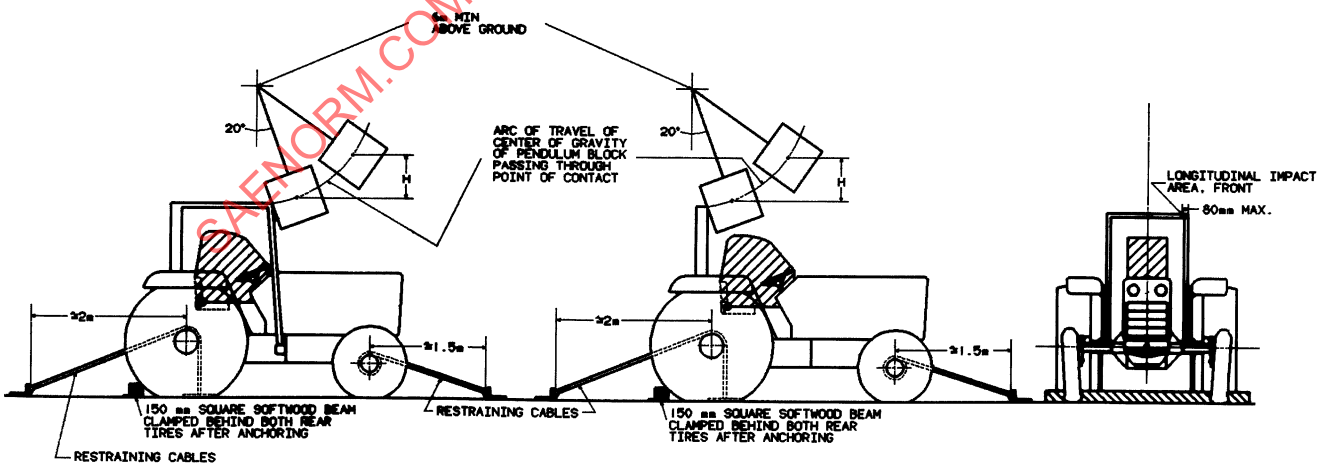


FIGURE 10B—TYPICAL FRONT IMPACT APPLICATION

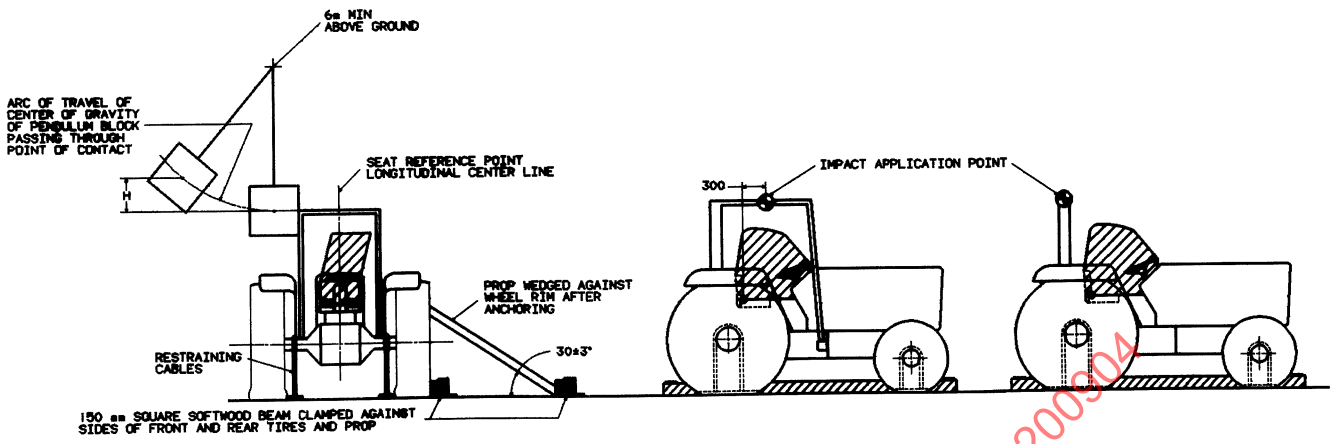


FIGURE 10C—TYPICAL SIDE IMPACT APPLICATION

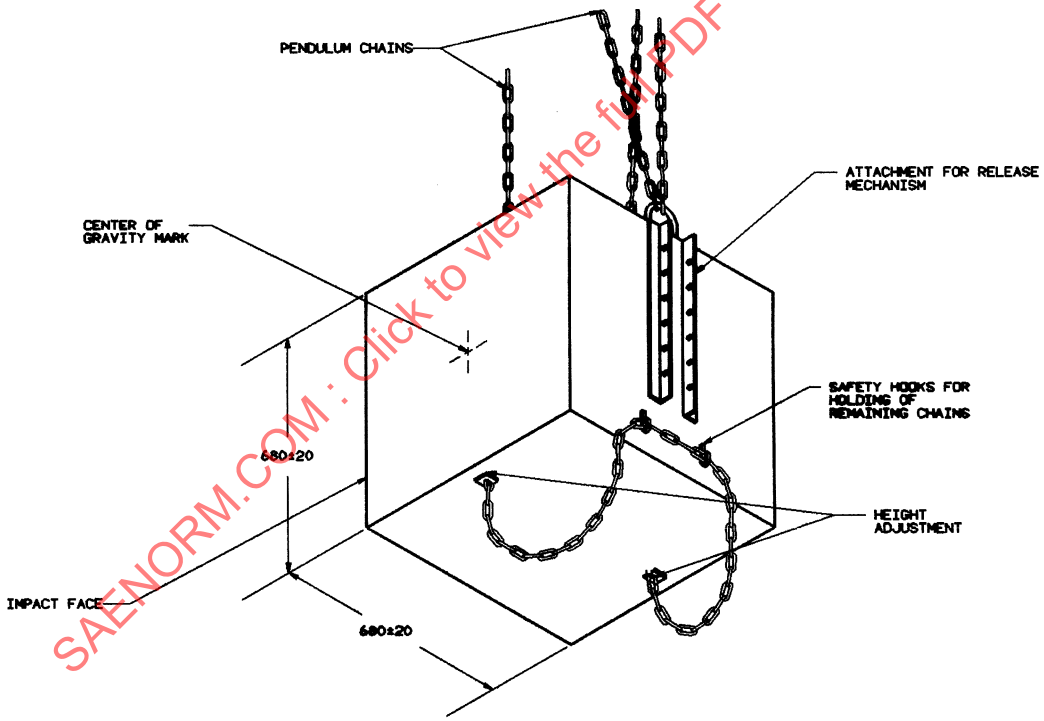


FIGURE 11—PENDULUM BLOCK

8.1.2 General apparatus and equipment shall include a:

8.1.2.1 Restrain tractor by means of steel cables (see Table 2) incorporating tensioning devices. These cables are attached to ground rails which should preferably be spaced approximately 600 mm apart throughout the area immediately below the pendulum pivot points. The ground rails should extend for approximately 9 m along the axis of the pendulum block and approximately 1.8 m to either side. Details of the arrangements are given in Figures 10A through 10C.

TABLE 2—NOMINAL DIAMETER OF RESTRAINING CABLES

Tractor Mass (kg)	Rope Diameter (mm)
Less than 5000	13
5000 or greater	16

8.1.2.2 Softwood beam, of cross-section 150 x 150 mm, for restraining the rear wheels when striking from the front and rear, and for clamping against the side of the front and rear wheels when striking from the side, as shown in Figures 10A through 10C.

8.1.2.3 Wooden prop, for restraining the opposite rear wheel when striking from the side as shown in Figure 10B. Its length shall be 20 to 25 times and its width 2 to 3 times its thickness.

8.1.2.4 Device for measuring elastic deflection, such as that shown in Figure 12, in a horizontal plane which coincides with the upper limiting surface of the clearance zone.

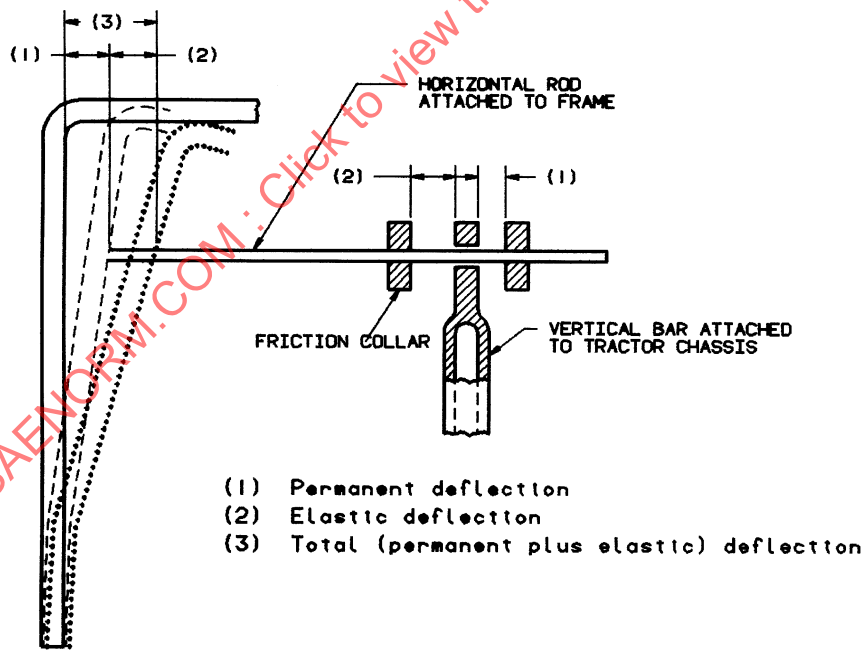


FIGURE 12—TYPICAL METHOD OF MEASURING DEFLECTIION

8.1.3 MEANS FOR APPLYING VERTICAL FORCE

8.1.3.1 When in position for the crushing test, the tractor shall be supported under the axles so that the load applied is not carried on the wheels.

8.1.3.2 A means shall be provided for applying a downward force on the ROPS, such as shown in Figure 3, including a stiff beam with a width of 250 mm.

8.1.3.3 A means shall be provided for continuous recording of force applied to and deflection of the ROPS.

8.2 Test Procedure

8.2.1 SEQUENCE OF TESTS—Refer to Figure 4.

8.2.2 During all tests, maximum instantaneous and permanent deflections of the ROPS shall be measured and recorded.

8.3 Impact Tests

8.3.1 GENERAL PROVISIONS

8.3.1.1 The position of the block and its supporting chains shall be selected so that the point of the impact will be at the upper edge of the ROPS and in line with the arc of travel of the center of gravity of the block.

The tractor shall be positioned and held securely in the area beneath the pivots as shown in Figures 10A through 10C.

The points of attachment of the cables shall be approximately 2 m behind the rear axle and 1.5 m in front of the front axle.

The tires of the tractor shall be inflated for different types of tractor (no water ballast being used), and the cables tightened to give deflections appropriate to the type of tractor and tire as shown in Table 3 as follows:

TABLE 3—IMPACT TEST—DEFLECTIONS

Type of Tractor	Tire Pressure (kPa)	Deflection (mm)
Four-wheel drive with front and rear wheels of the same size:		
Front	100	25
Rear	100	25
Four-wheel drive with front wheels smaller than rear wheels:		
Front	150	20
Rear	100	25
Two-wheel drive:		
Front	200	15
Rear	100	25

8.3.1.2 *Front and Rear Impact Tests*—The restraining cables shall be one on each side of both axles giving a resultant force in the plane in which the center of gravity of the block will swing.

After the restraining cables have been tightened for the front and rear blows, a beam (see Figures 10A and 10B) shall be clamped against the appropriate wheels on the side opposite the pendulum and driven tight against them.

8.3.1.3 *Side Impact Test*—A beam (see Figure 10C) shall be clamped against the side of the front and rear wheels opposite the pendulum and driven hard against the tires. After tightening the restraining cables, a beam (see Figure 10C) shall be placed as a prop against the rear wheel rim and secured to the ground so that it is held tight against the rim during the impact. The length of the beam shall be chosen so that when in position against the rim, it is at an angle of 30 degrees ± 3 degrees to the horizontal.

8.3.1.4 If a protruding member would present an inadequate area for the pendulum block, a steel plate of appropriate thickness and depth and about 300 mm in length shall be fastened to the member in such a manner that the strength of the ROPS is not affected.

8.3.1.5 The energy input to be absorbed by the protective structure is calculated by the formula:

$$E = 19.6\ H\ (J) \qquad \text{(Eq. 1)}$$

8.3.2 IMPACT FROM THE REAR AND FRONT

8.3.2.1 *Positioning of the Tractor*—For the impact tests to the rear and front, the tractor shall be positioned so that the supporting chains and the face of the pendulum block are at an angle of 20 degrees to the vertical when striking the ROPS. If the angle of the ROPS member at the point of contact at maximum deflection during impact will be greater than 20 degrees to the vertical, the angle of the block shall be further adjusted so that the striking face and the ROPS member are parallel at the point of impact and maximum deflection, the supporting chains being 20 degrees to the vertical when the block strikes the ROPS.

NOTE—In the case of an angle greater than 20 degrees, the adjustment of the striking face at the pendulum blocks has to be based on estimated maximum deformation.

8.3.2.2 *Impact From the Rear*—The rear impact is not required on tractors having 50% or more of the unballasted weight on the front wheels.

The load shall be applied to the uppermost traverse structural member of the ROPS (that is, that part which would be likely to strike the ground first in an overturn).

The rear blow shall be struck in a vertical plane parallel to the longitudinal medium plane on the corner opposite to that on which the side impact (see 8.3) is made.

The point of application of the load shall be located at one-sixth of the width of the top of the ROPS inward from the outside corner. The width of the protective structure shall be taken as the distance between two lines parallel to the longitudinal median plane of the tractor touching the outside extremities of the ROPS in the horizontal plane touching the top of the uppermost transverse structural members. However, if the back of the ROPS is curved and the curve starts at less than one-sixth the frame width, the impact shall be at the beginning of that curve, that is, at the point where this curve is tangential to a line at right angles to the median plane of the tractor.

The height of the lift of the pendulum block shall be calculated by choosing either of the following formulae:

$$\text{Alternative 1: } H\ (\text{mm}) = 2.165 \times 10^{-8} m\ L^2 \qquad \text{(Eq. 2)}$$

$$\text{Alternative 2: } H\ (\text{mm}) = 5.74 \times 10^{-2} I \qquad \text{(Eq. 3)}$$

8.3.2.3 *Impact From the Front*—The general provisions for this test are similar to those for the impact from the rear. The blow shall be struck as close to the corner of the top of the ROPS as is practicable on the same side as the side impact (see Figure 10B).

NOTE—"As close to the corner as practicable" means 80 mm max from a vertical plane parallel to the longitudinal medium plane of the tractor touching the outside extremity of the top of the ROPS. However, if the front of the ROPS is curved and the curve starts at a longer distance than 80 mm inside this vertical plane, the impact shall be administered at the beginning of the curve, that is, at the point where this curve is tangential to a line at right angles to the medium plane of the tractor.

The lift height of the pendulum block shall be calculated from the following formulae:

$$H = 25 + 0.07\ m_t \text{ where } m_t = 800 \text{ to } 2000 \text{ kg} \qquad \text{(Eq. 4)}$$

$$H = 125 + 0.02\ m_t \text{ where } m_t = 2000 \text{ to } 6000 \text{ kg} \qquad \text{(Eq. 5)}$$

8.3.3 IMPACT FROM EITHER SIDE

8.3.3.1 *Positioning of the Tractor*—For the side impact test, the direction of the impact shall be horizontal.

The tractor shall be positioned so that the supporting chains and the striking face of the pendulum block are vertical when striking the ROPS. If the angle of the protective structure member at the point of contact is not vertical, the striking face of the pendulum block and ROPS members shall be set parallel at the point of impact at maximum deflection by one additional support. The supporting chains shall remain vertical at the point of impact.

NOTE—In the case of nonvertical structural members, the adjustment of the striking face at the pendulum block has to be based on estimated maximum deformation.

8.3.3.2 *Impact From the Side*—If it is certain that any particular structural member will take the initial impact when the tractor overturns sideways, the impact shall be struck against this member. Otherwise, the impact shall be struck against an uppermost side member and in the vertical plane perpendicular to the longitudinal medium plane and 300 mm forward of the seat reference point.

The height of the lift of the pendulum block shall be calculated from the following formulae:

$$H = 25 + 0.2\ m_t \text{ where } m_t = 800 \text{ to } 2000 \text{ kg} \qquad \text{(Eq. 6)}$$

$$H = 125 + 0.15\ m_t \text{ where } m_t = 2000 \text{ to } 6000 \text{ kg} \qquad \text{(Eq. 7)}$$

8.4 Vertical Loadings

8.4.1 CRUSHING AT THE REAR—See 7.4.1.

8.4.2 CRUSHING AT THE FRONT—See 7.4.2.