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**Rollover Protective
Structures (ROPS)
for Wheeled
Agricultural Tractors**

SAE Standard
Issued December 1987

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**Submitted for Recognition as
an American National Standard**

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**ROLL-OVER PROTECTIVE STRUCTURES (ROPS)
FOR WHEELED AGRICULTURAL TRACTORS**

1. PURPOSE:

The purpose of this standard 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.

2. SCOPE:

2.1 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 SAE Standard are also met.

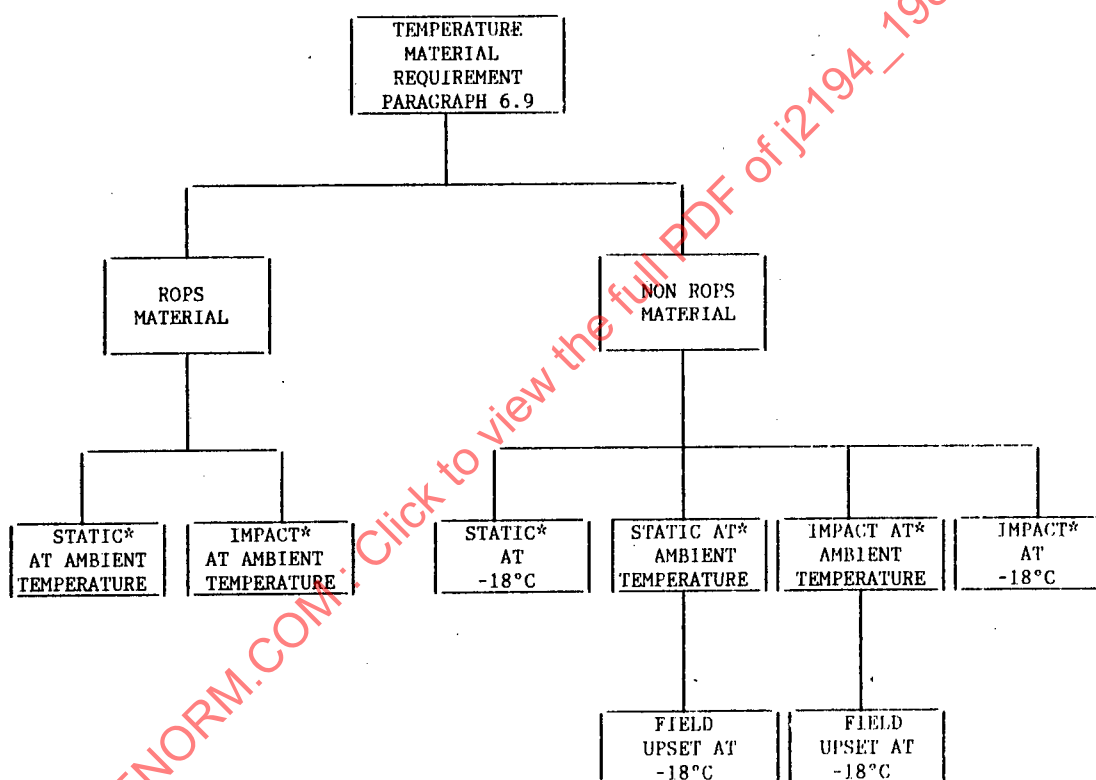
2.2 Fulfillment of the intended purpose requires testing as follows:

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

2.2.2 A laboratory test, under repeatable and controlled loading, to permit analysis of the ROPS for compliance with the performance requirements of this standard. Either the static test sequence (paragraph 7) or the impact test sequence (paragraph 8) shall be conducted.

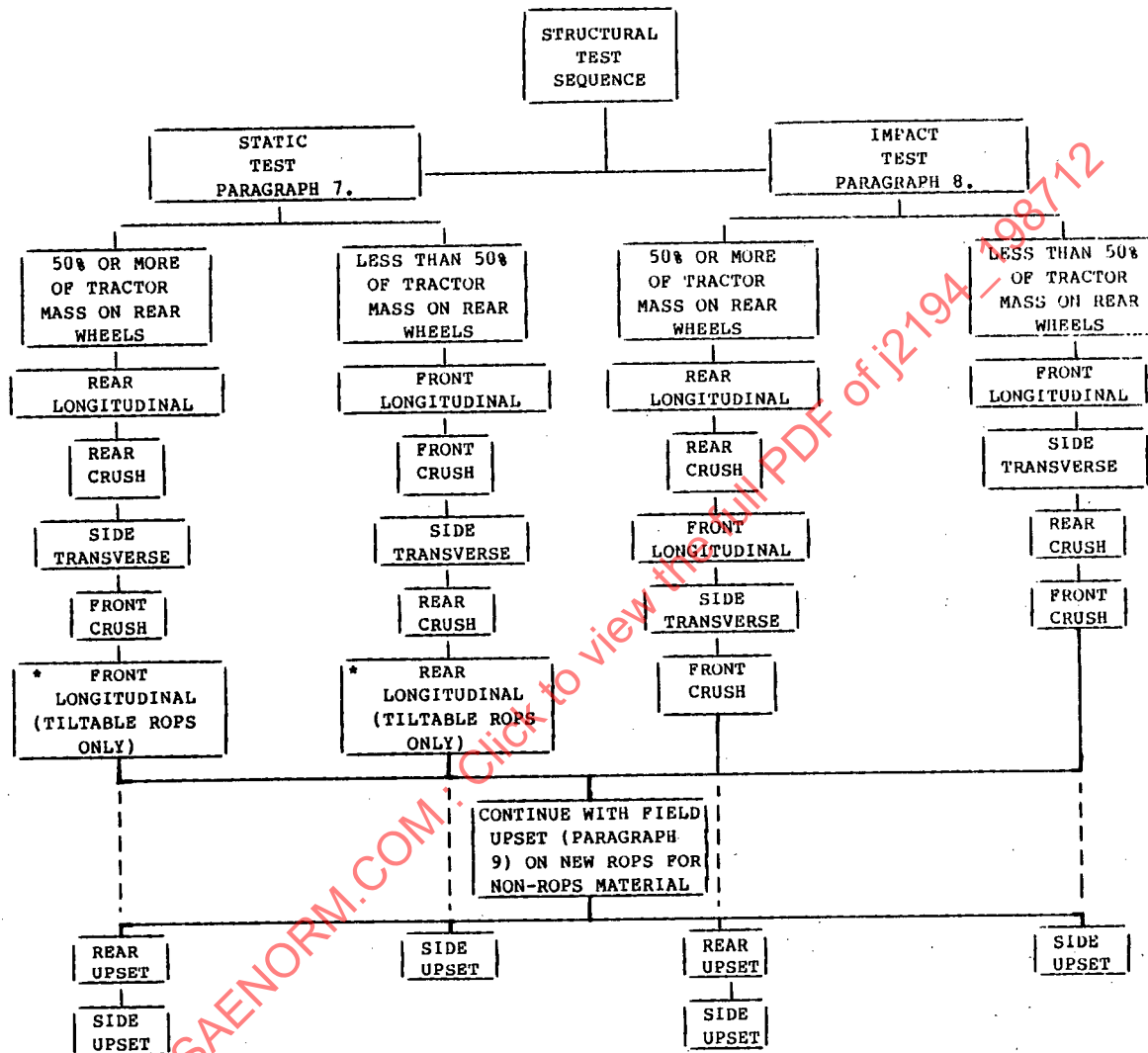
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*See paragraph 3.2 for limitation

FIG. 2.1.1 - TEMPERATURE MATERIAL REQUIREMENT



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

FIG. 2.1.2 - STRUCTURAL TEST SEQUENCE

2.2.3 A seat belt anchorage test (paragraph 10).

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

3. APPLICATIONS:

3.1 This standard applies to wheeled agricultural tractors as defined in paragraph 4.1. It does not preclude the use of extendable or foldable ROPS as long as these ROPS meet the performance requirements of the standard. Tractors used in construction and self propelled implements are excluded.

3.2 Test procedures in this standard are limited by tractor mass (see paragraph 4.3) as follows:

3.2.1 Static Test (paragraph 7): 800 kg min

3.2.2 Impact Test (paragraph 8): 800 kg to 6000 kg

3.2.3 Field Upset Test (paragraph 9): No limitation

3.3 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.

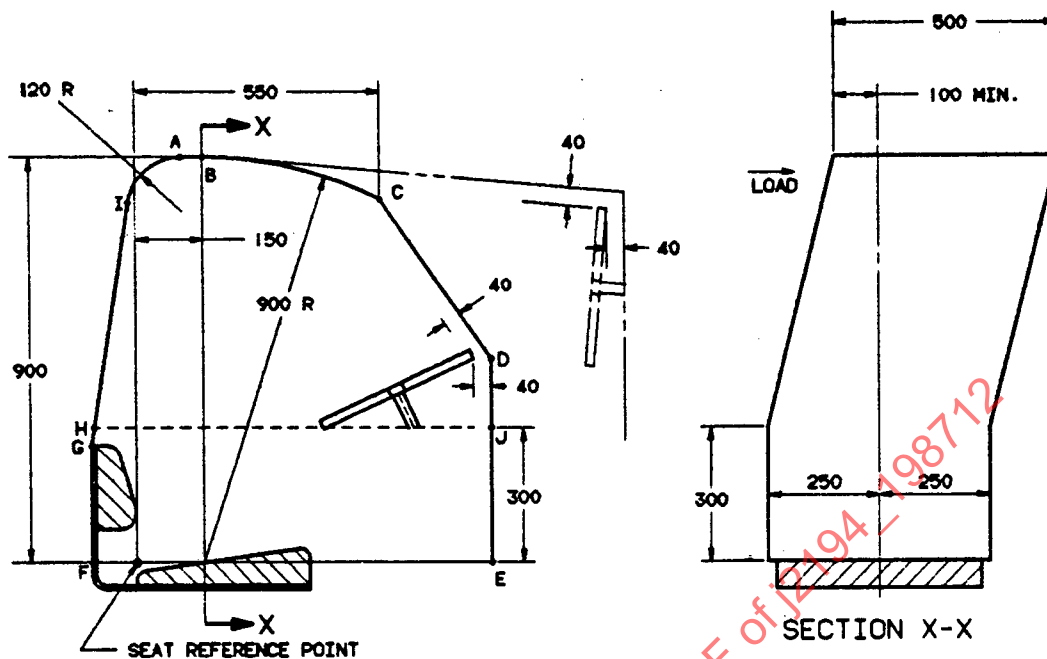
4. DEFINITIONS:

4.1 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 MAR85.

4.2 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.

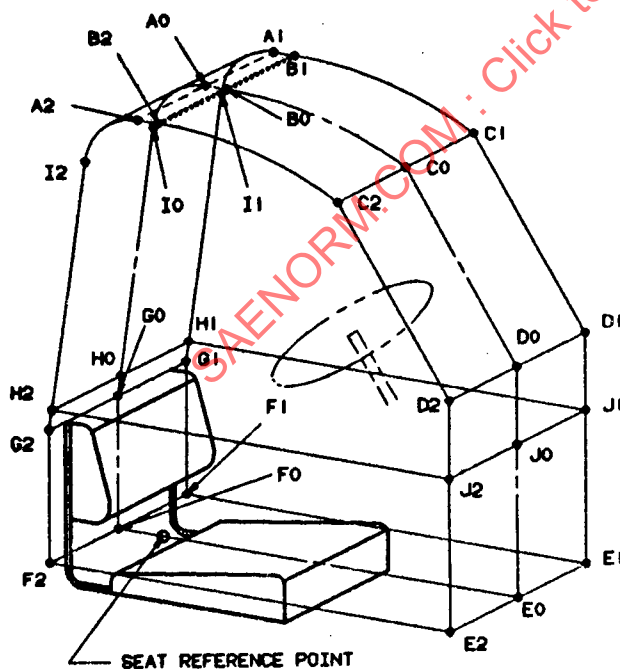
4.3 Tractor Mass: The mass of the unladen tractor in operating order with tanks and radiators full, protective structure with cladding and any wheel equipment or additional front-wheel drive components required to support the tractor static weight. The operator, optional hitch equipment, optional ballast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

- 4.4 Reference Mass: A mass, not less than the tractor mass, selected for calculation of the force and energy inputs to be used during tests.
- 4.5 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 mid-point 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.
- 4.6 Static Test Horizontal Loading: The application of a horizontal static load to the rear, front or side of the ROPS.
- 4.7 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.
- 4.8 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.
- 4.9 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.
- 4.10 ROPS Material: Any material that meets the requirements set forth in paragraph 6.9.1.
- 4.11 Clearance Zone: The clearance zone is illustrated in Figs. 4.11a and 4.11b. 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 mid-position for seated driving.



DIMENSIONS ARE MILLIMETERS.

FIG. 4.11a - 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 F0G0 I0G0 C0D0 E0F0	300 - - - -	Depending on the tractor.

FIG. 4.11b - CLEARANCE ZONE DEFINITION

4.11 (Continued):

Referring to Figure 4.11b,

- 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.) above;
- 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.) above 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.) above 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.) above to the horizontal plane defined in (g.) above following the general direction of, and in contact with, the rear surface of the seat backrest;
- j. 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;

- k. 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.

4.12 Longitudinal Median Plane: See ISO 612, dated March 15, 1978.

4.13 Gross Machine Mass: Tractor mass as described in paragraph 4.3 with the addition of an operator, wheel equipment, ballast weights, hitch equipment and special equipment required for operation.

5. SYMBOLS:

- m = tractor mass, as defined in paragraph 4.3, in kilograms.
- m_t = reference mass, as defined in paragraph 4.4 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.
- $E_{iI.1}$ = energy input to be absorbed during longitudinal loading, in joules.
- $E_{iI.2}$ = 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.

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 paragraph 2.1.2.
- 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 removeable 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 non-symmetrical 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: | |
| At start of test: | +2 deg, all loading |
| During test: | T0 deg above to 20 deg below horizontal, for horizontal loads |
| f. Pendulum lift height: | +6 mm |
| g. Mass of pendulum: | ±20 kg |
| h. Pendulum suspension angle: | ±2 deg |
| 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.

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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 MAR86, J117, J140a, J141, J339 MAR86 and J800 APR86 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 standard.

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 m².

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.

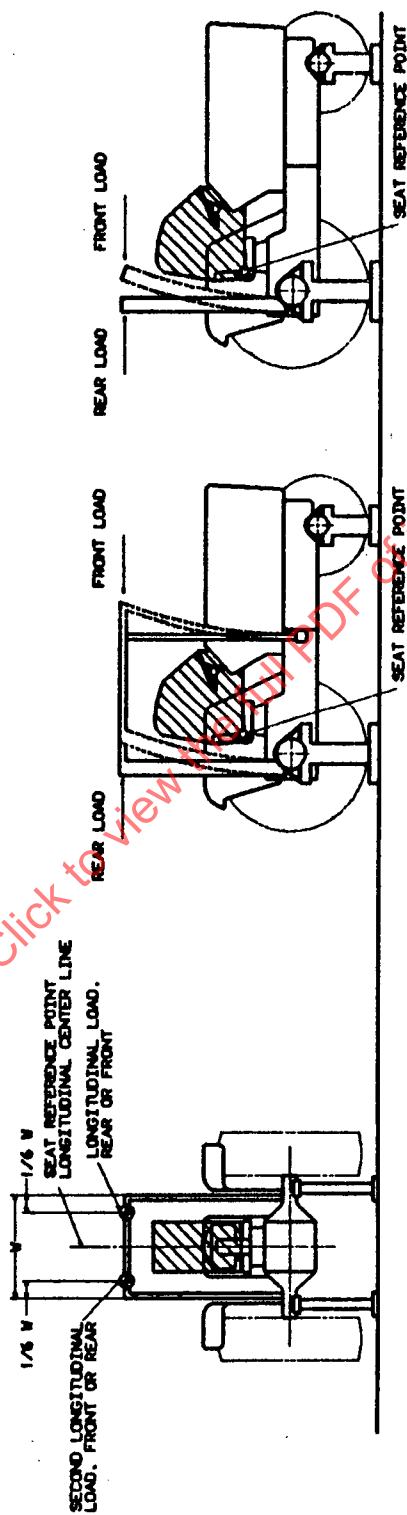


FIG. 7.1.3a - TYPICAL REAR (FRONT) LOAD APPLICATION

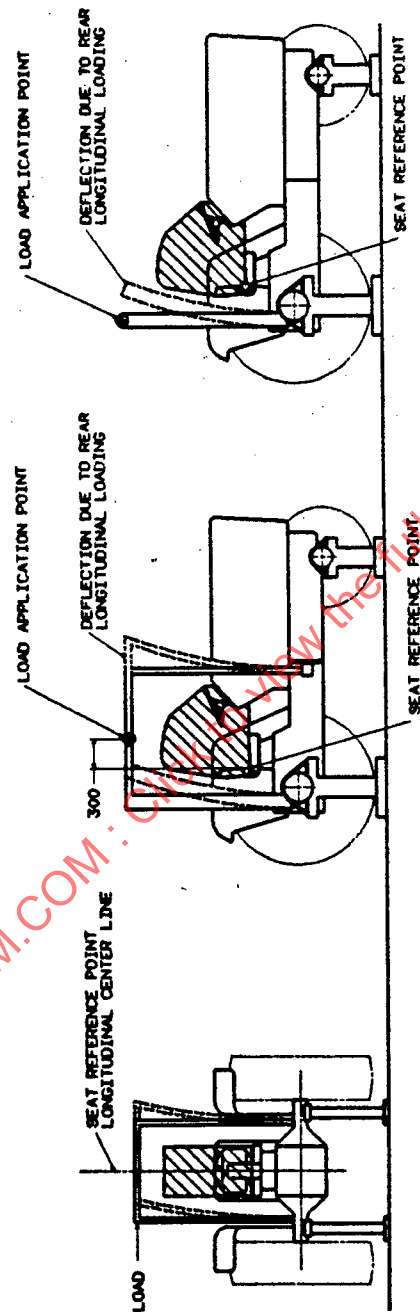


FIG. 7.1.3b - TYPICAL SIDE LOAD APPLICATION

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:

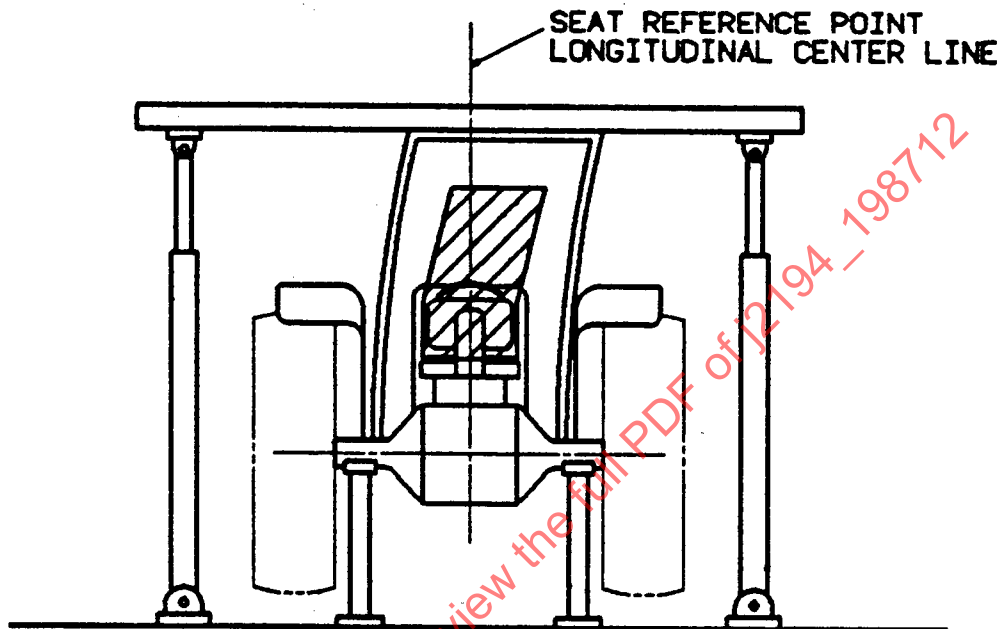


FIG. 7.1.4 - TYPICAL LOAD APPLICATION FOR CRUSH TEST

- 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 Fig. 7.1.4, including a stiff beam with a width of 250 mm.
- 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 Fig. 2.1.2.

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 Fig. 7.1.3). 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.

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 inwards 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: $E_{I.1} = 1.4 m_t$ (joules)

- 7.3.3 Transverse Loading: The side load shall be applied horizontally at 90° 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 paragraph 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: $E_{i1.2} = 0.35 m_t$ (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 Fig. 7.4.1). 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.

- 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.

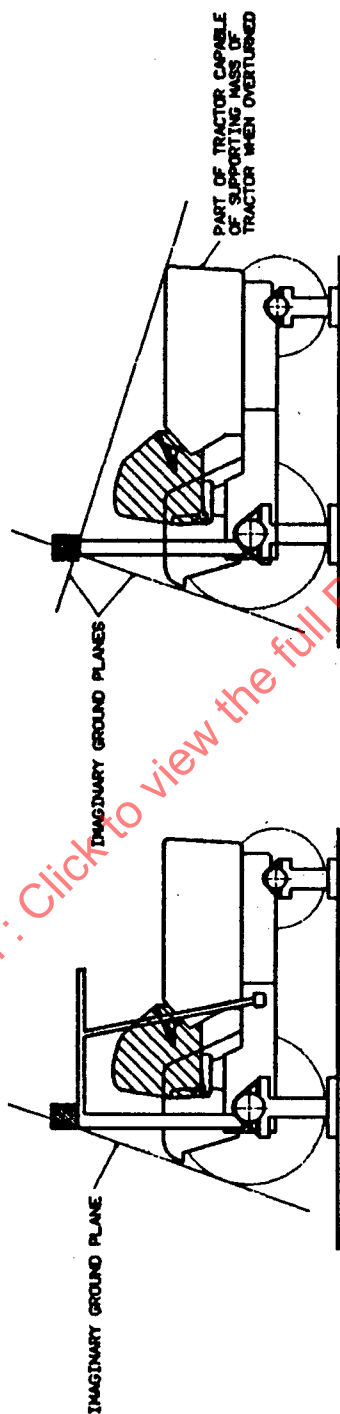


FIG. 7.4.1 - REAR CRUSH

7.4.2 (Continued):

Where the front part of the roof of the ROP 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 Fig. 7.4.2). 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.

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 Fig. 7.5.2).
- 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 Fig. 7.5.3).

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 Fig. 8.1).

The mass of the pendulum block should not include the mass of supporting chains (see Fig. 8.2). The maximum mass of the supporting chains shall be 100 kg.

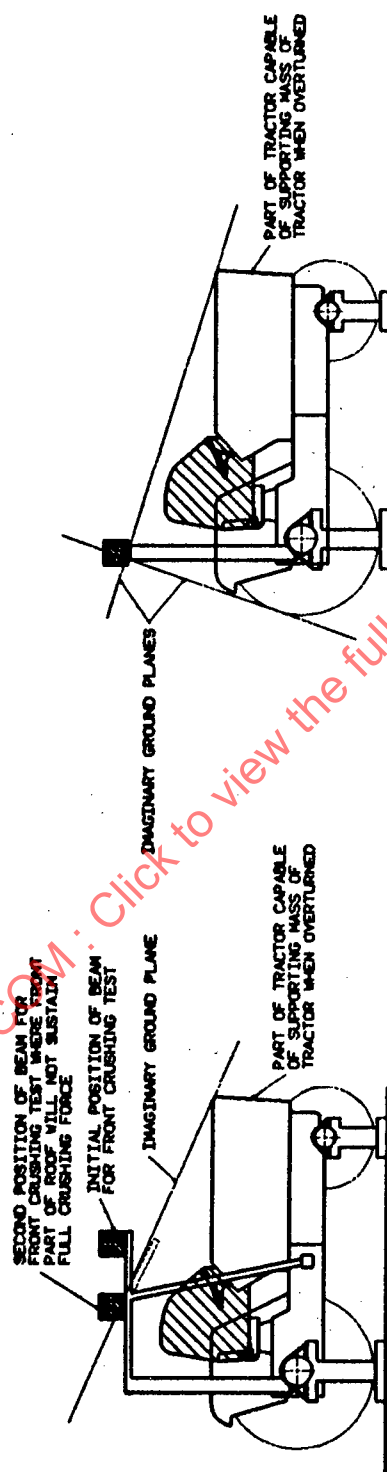
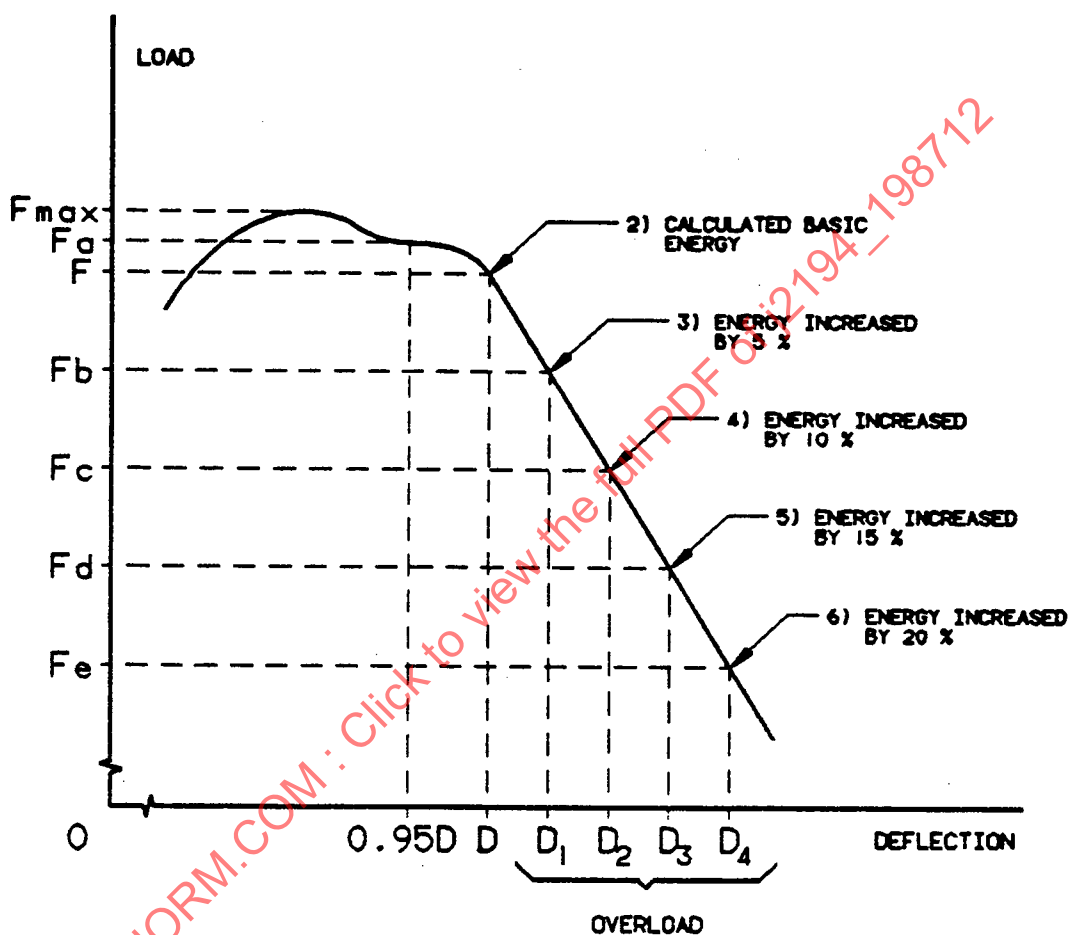


FIG. 7.4.2 - FRONT CRUSH



NOTES

- 1 LOCATE F_a IN RELATION TO $0.95D$.
- 2 OVERLOAD NECESSARY AS $F_a > 1.03F$.
- 3 $F_b < 0.97F$ THEREFORE FURTHER OVERLOAD NECESSARY.
- 4 $F_c < 0.97F_b$ THEREFORE FURTHER OVERLOAD NECESSARY.
- 5 $F_d < 0.97F_c$ THEREFORE FURTHER OVERLOAD NECESSARY.
- 6 OVERLOAD TEST PERFORMANCE SATISFACTORY AS $F_e > 0.8F_{max}$.
- 7 FAILURE AT ANY STAGE WHEN LOAD DROPS BELOW $0.8F_{max}$.

FIG. 7.5.2 - LOAD DEFLECTION DIAGRAM - CONTINUING OVERLOAD TEST

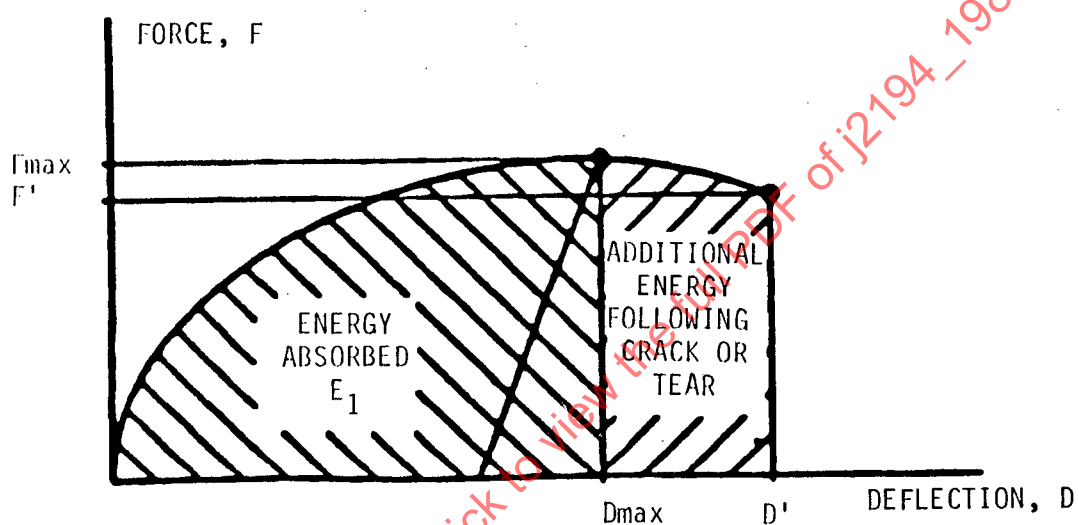


FIG. 7.5.3 - LOAD DEFLECTION CURVE - CONTINUING OVERLOAD TEST

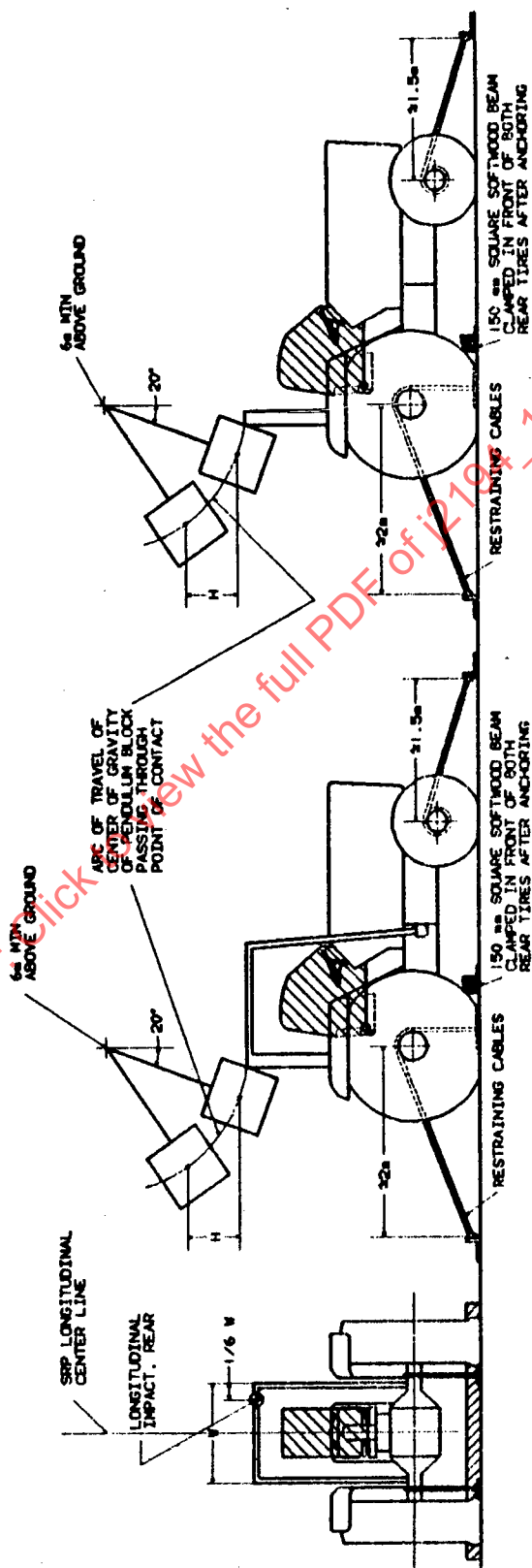


FIG. 8.1a - TYPICAL REAR IMPACT APPLICATION

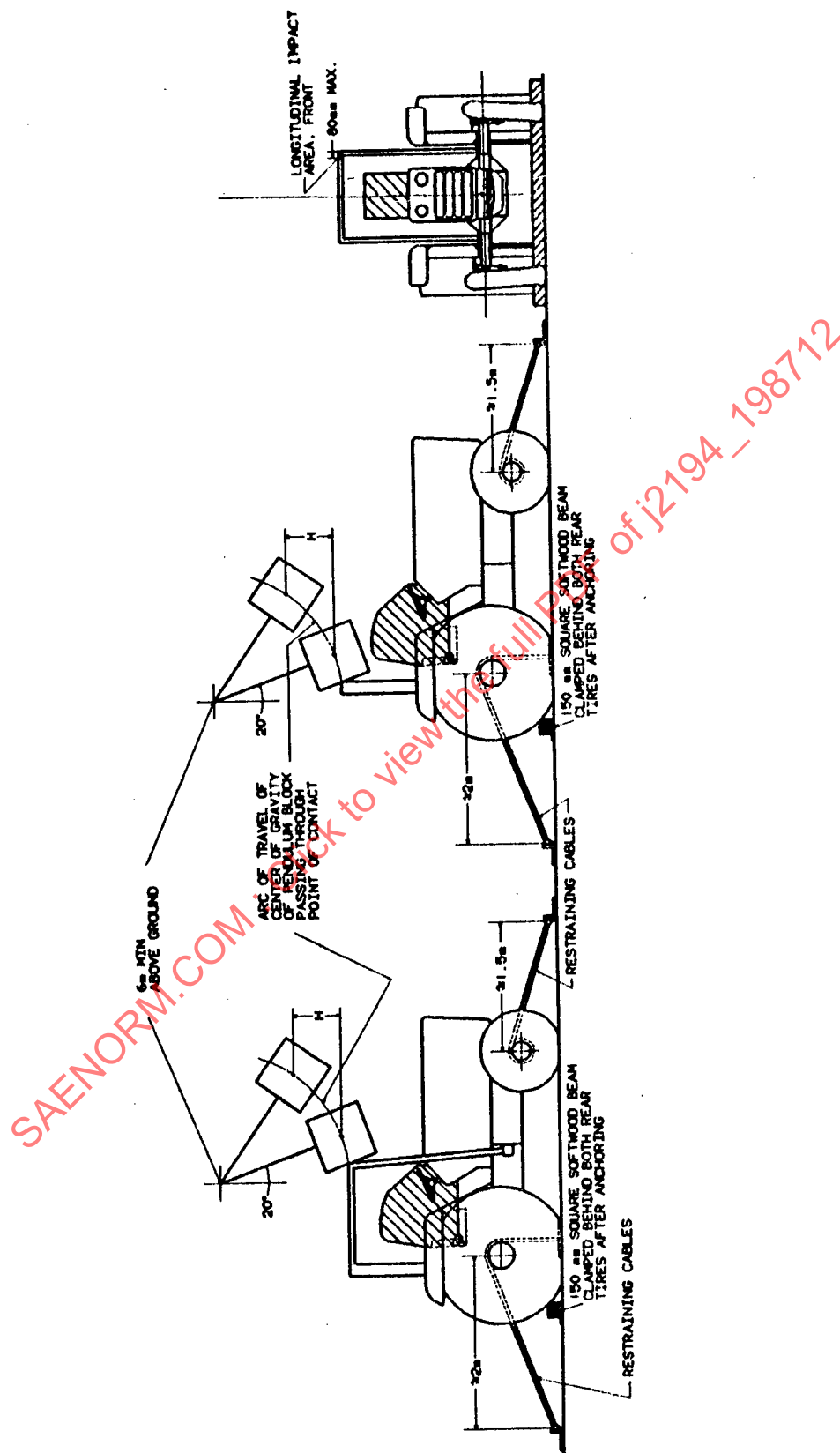


FIG. 8.1b - TYPICAL FRONT IMPACT APPLICATION

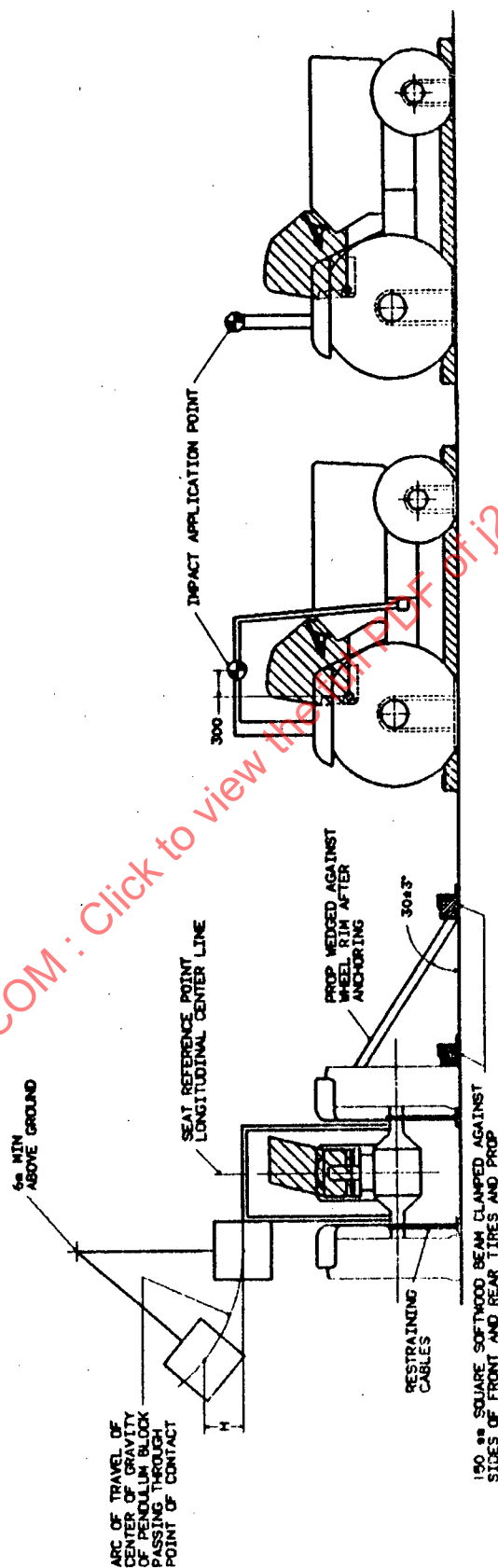


FIG. 8.1c - TYPICAL SIDE IMPACT APPLICATION

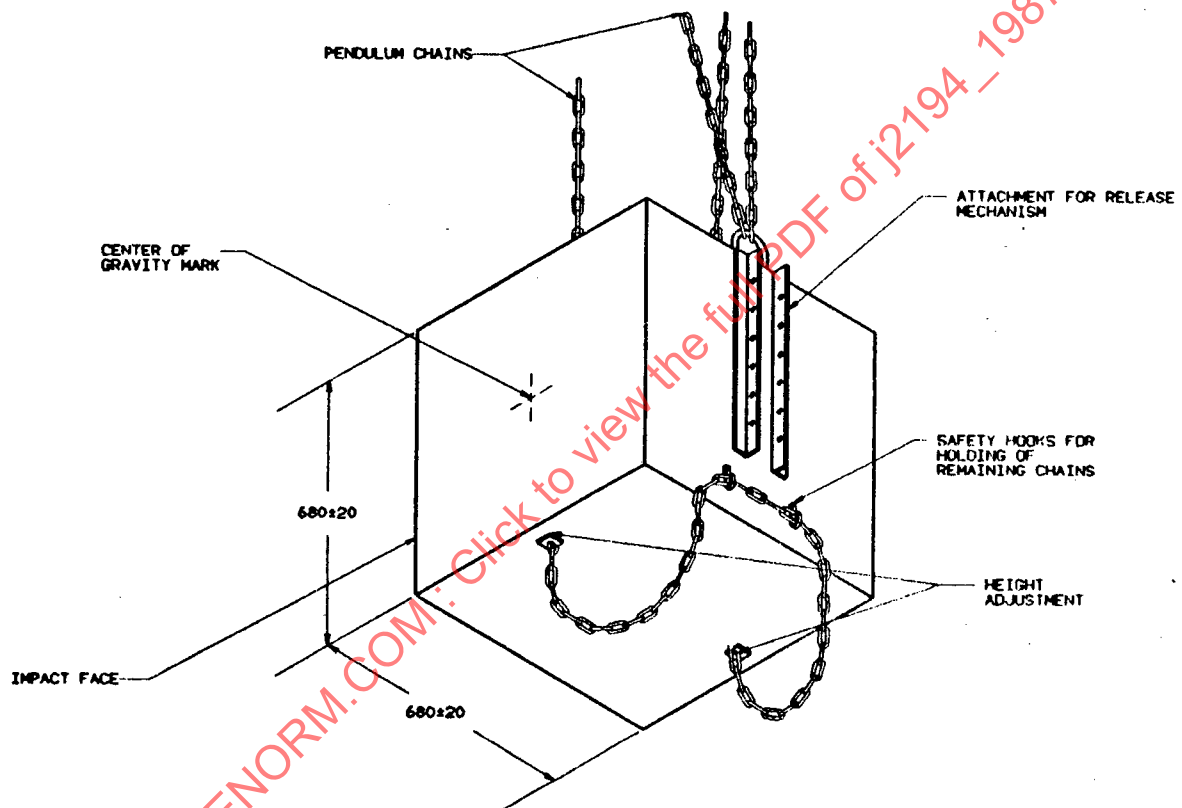


FIG. 8.2 - PENDULUM BLOCK

8.1.2 General apparatus and equipment shall include a:

8.1.2.1 Restrain tractor by means of steel cables (see Table II) 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 Fig. 8.1.

TABLE II - 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 Fig. 8.1.

8.1.2.3 Wooden prop, for restraining the opposite rear wheel when striking from the side as shown in Fig. 8.1b. 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 Fig. 8.1.2.4, in a horizontal plane which coincides with the upper limiting surface of the clearance zone.

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 Fig. 8.4.1, 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 Fig. 2.1.2.

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 Fig. 8.1.

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 III as follows:

TABLE III - IMPACT TESTS - 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 Figs. 8.1a and 8.1b) shall be clamped against the appropriate wheels on the side opposite the pendulum and driven tight against them.

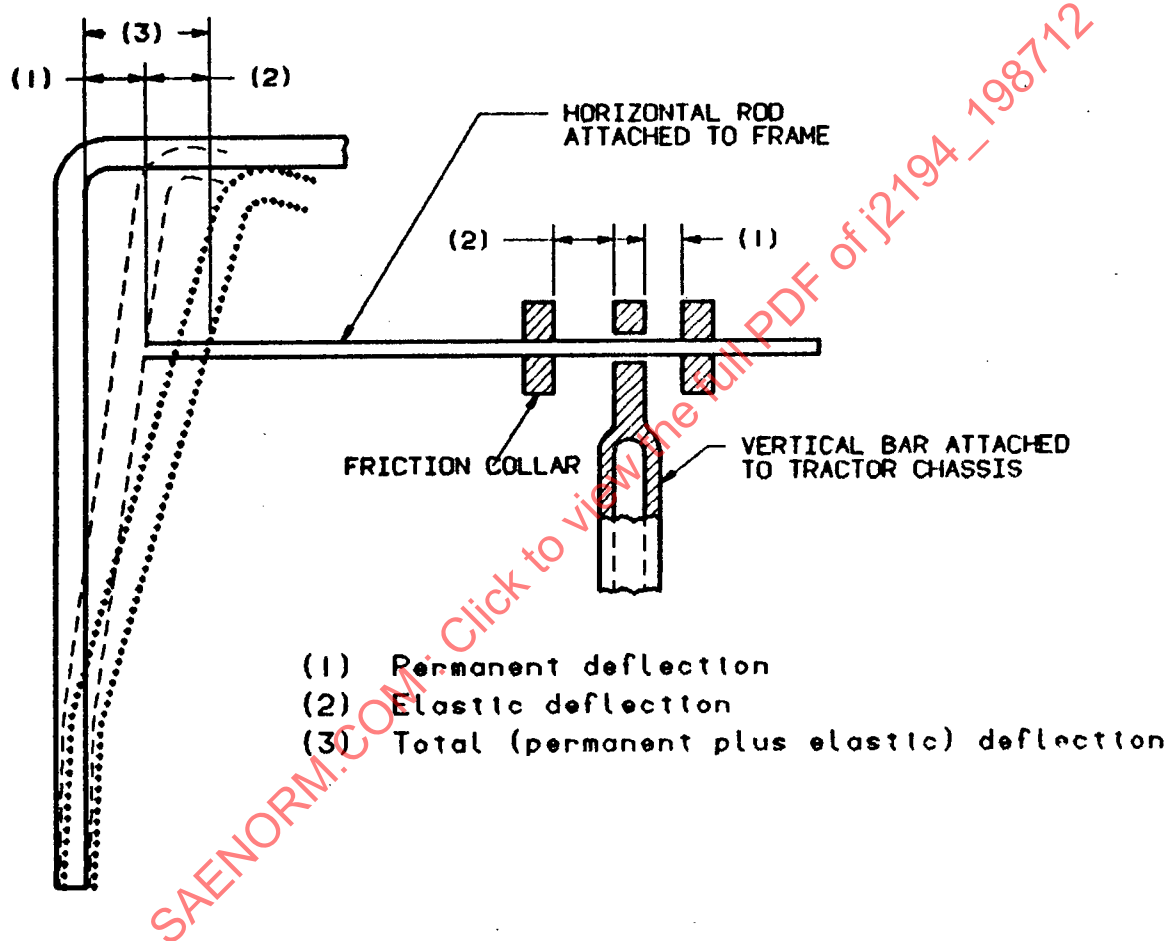


FIG. 8.1.2.4 - TYPICAL METHOD OF MEASURING DEFLECTION

8.3.1.3 Side Impact Test: A beam (see Fig. 8.1c) 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 Fig. 8.1c) 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 $30 \pm 3^\circ$ 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:

$$E = 19.6 H (J)$$

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 deg 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 deg 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 deg to the vertical when the block strikes the ROPS.

Note - In the case of an angle greater than 20 deg, the adjustment of the striking face at the pendulum block 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 median plane on the corner opposite to that on which the side impact (see Section 8.3) is made.

8.3.2.2 (Continued):

The point of application of the load shall be located at one-sixth of the width of the top of the ROPS inwards 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:

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

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

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 Fig. 8.1b).

Note - "As close to the corner as practicable" means 80 mm maximum from a vertical plane parallel to the longitudinal median 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 median plane of the tractor.

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

$$H = 25 + 0.07 m_t \text{ where } m_t = 800 \text{ to } 2000 \text{ kg}$$

$$H = 125 + 0.02 m_t \text{ where } m_t = 2000 \text{ to } 6000 \text{ kg}$$

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 non-vertical 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 median 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:

$$H = 25 + 0.2 m_t \text{ where } m_t = 800 \text{ to } 2000 \text{ kg}$$

$$H = 125 + 0.15 m_t \text{ where } m_t = 2000 \text{ to } 6000 \text{ kg}$$

8.4 Vertical Loadings:

- 8.4.1 Crushing at the Rear: See paragraph 7.4.1.

- 8.4.2 Crushing at the Front: See paragraph 7.4.2.

9. FIELD UPSET TEST:

9.1 Tractor Requirements:

- 9.1.1 The tractor shall be ballasted to a mass greater than the reference mass: the maximum gross machine mass or the mass recommended for normal field operations, whichever is greater. Ballast shall be distributed so that neither axle supports less than 25% of the total mass. Tires may have liquid ballast and shall be inflated to the maximum pressure recommended by the tire manufacturer.
- 9.1.2 Wheel tread settings, where adjustable, shall be at the mid-range setting. Where only two settings are obtainable, the minimum shall be used, provided that tires do not interfere with ROPS deflection. If side upset cannot be achieved with bank height equal to the mid-range wheel tread, the tread may be set to the minimum.
- 9.1.3 A new ROPS shall be used for the start of this test sequence. Repairs and adjustments on the tractor necessary to continue test operation during the test sequences are allowed.
- 9.1.4 The tractor and ROPS shall be instrumented as required to determine that test operation requirements and ROPS performance requirements are met.

9.2 Test Site Requirements:

- 9.2.1 The upset tests shall be conducted on firm soil. The soil in the impact area shall have an average cone index strength not less than 1030 kPa in the 0 to 150 mm layer when tested in accordance with ASAE Recommended Practice R313.1.
- 9.2.2 The rear upset test shall be conducted on a 60 ± 5 deg ramp as specified in Fig. 9.2.2.

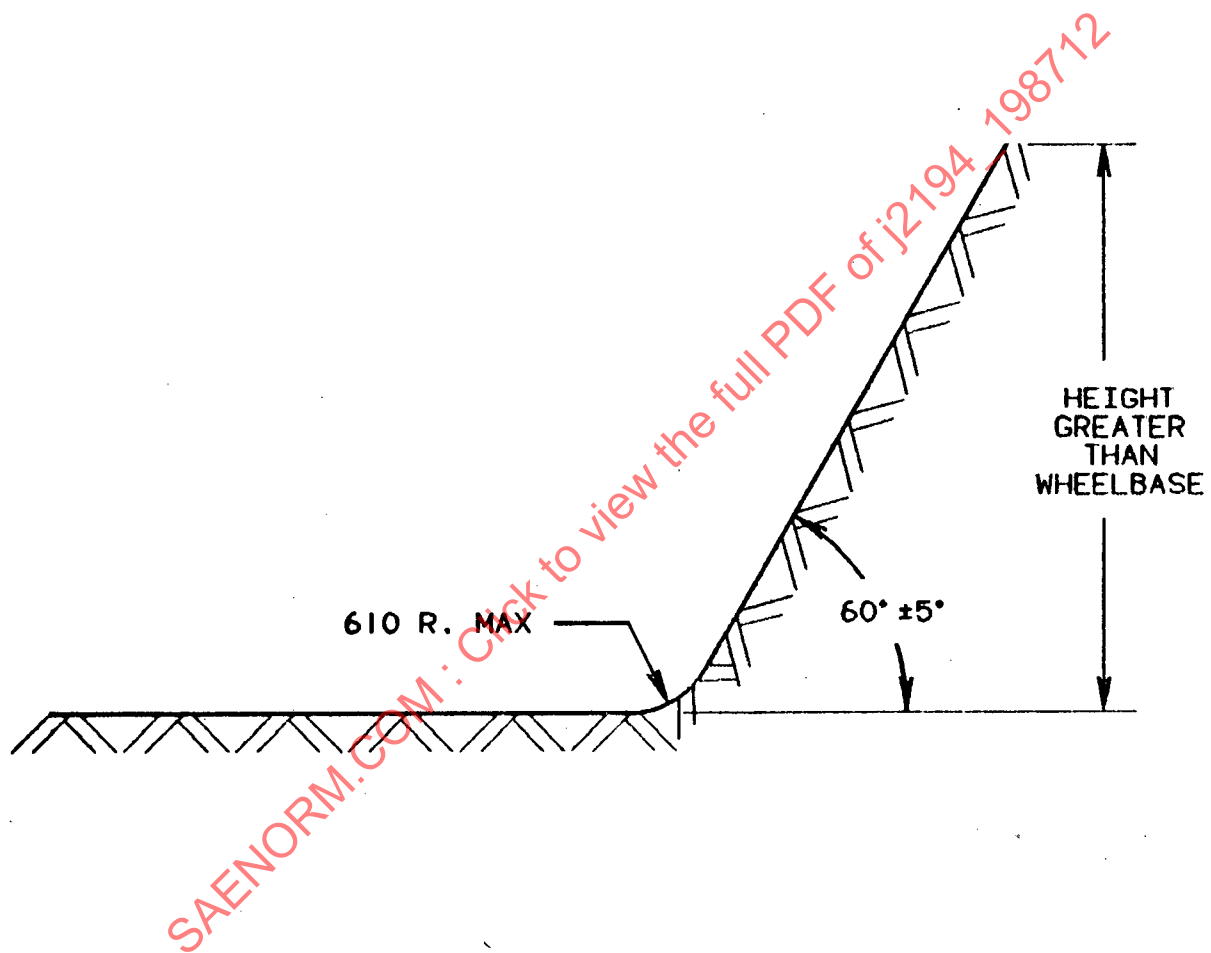


FIG. 9.2.2 - TYPICAL REAR OVERTURN BANK

9.2.3 The side upset test shall be conducted on a test site as specified in Fig. 9.2.3. The direction of roll shall be governed by General Requirement paragraph 6.5. The height of the bank may be increased beyond the 1145 mm to aid in upset, but heights greater than the test tractor wheel tread are not recommended.

9.3 Procedure:

9.3.1 During all tests, a means shall be provided to determine clearance zone infringement. Permanent deflections of the ROPS shall be measured and recorded.

9.3.2 Rear Upset: Rear upset shall be induced by driving the tractor directly forward up the rear upset ramp at 5 to 8 km/h with engine power. The engine speed setting shall be at maximum governed speed. The traction clutch may be used to aid in inducing upset. A rear upset is not required on tractors having 50% or more of the unladen mass on the front wheels.

9.3.3 Side Upset: Side upset shall be induced by driving the tractor forward under engine power over the side upset bank and ramp as specified in Fig. 9.2.3 at a minimum velocity of 16 km/h or at maximum tractor velocity if 16 km/h is not attainable within tractor specifications.

10. SEAT BELT ANCHORAGE TEST PROCEDURE:

10.1 Apply tensile force in an upward, forward direction. The seat belt anchorage shall be capable of withstanding a static tensile force of 4448N at 45 deg to the horizontal. The seat mounting shall be capable of withstanding this force plus a force equal to four times the force of gravity on the mass of all applicable seat components applied 45 deg to the horizontal in a forward and upward direction.

10.2 Apply a second tensile force in an upward, rearward direction. The seat mounting shall be capable of withstanding 2224N belt force, plus two times the force of gravity on the mass of all applicable seat components both applied at 45 deg to the horizontal in an upward and rearward direction.

10.3 Both tensile forces shall be equally divided between the anchorages.

11. CONDITIONS OF ACCEPTANCE:

11.1 General Requirements:

11.1.1 The ROPS, overhead weather shield, overhead protection, cab sheet metal or related ROPS parts outside of but near the operator area may be deformed in tests as described in paragraphs 7, 8, or 9, but shall not leave sharp edges exposed to the operator.

11.1.2 No part in 11.1.1 shall enter the clearance zone or strike the seat during the sequence of tests.