



A Product of the
Cooperative Engineering Program

SAE J1194 MAY89

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

SAE Standard
Revised May 1989

S. A. E.
LIBRARY

Submitted for Recognition as
an American National Standard

SAENORM.COM : Click to view the full PDF of j1194_198905

No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise, without the
prior written permission of the publisher.

Copyright 1989 Society of Automotive Engineers, Inc.

**ROLLOVER PROTECTIVE STRUCTURES (ROPS)
FOR WHEELED AGRICULTURAL TRACTORS**

1. SCOPE:

1.1 Fulfillment of the intended purpose requires testing as follows:

- 1.1.1** 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 (6.1) or the dynamic test (6.2) shall be conducted.
- 1.1.2** A crush test to verify the effectiveness of the deformed ROPS in supporting the tractor in an upset attitude.
- 1.1.3** A field upset test under reasonably controlled conditions, both to the rear and side, to verify the effectiveness of the protective system under actual dynamic conditions. (See 6.4.1.1 for requirements for the omission of this test.)
- 1.1.4** In addition to the laboratory and field loading requirements, there is a temperature-material requirement. (See 7.1.2.)
- 1.2** The test procedures and performance requirements outlined in this standard are based on currently available engineering data.

2. PURPOSE:

The purpose of this standard is to establish the test and performance requirements of a rollover protective structure, (ROPS), designed for wheel-type agricultural tractors to minimize the frequency and severity of operator injury resulting from accidental upsets. All self-propelled implements are excluded.

SAE Technical Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

3. DEFINITIONS:

- 3.1 An agricultural tractor, for purposes of this standard, is defined as a 2- or 4-wheel drive type machine of more than 15 kW (20 hp) net engine power as defined by SAE J1349, designed primarily to provide the tractive power to pull, push, carry, propel, and/or provide power to implements designed primarily for agricultural usage.
- 3.2 The tractor mass is defined as the maximum gross machine mass determined by the manufacturer or a minimum ratio of mass-to-maximum power takeoff power at rated engine speed of 67 kg/kW (110 lb/hp), whichever is greater. The mass includes the ROPS, all fuels, and other components required for normal use. (In case power takeoff power is not available, use 95% of net engine flywheel power.)
- 3.3 A rollover protective structure (ROPS) is a cab or frame for the protection of operators of agricultural wheeled tractors to minimize the possibility of serious operator injury resulting from accidental upsets. The protective structure 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. (See Figs. 1, 2, and 3 for typical configurations.)
- 3.4 Seat reference point¹ (SRP in Figs. 4, 5, and 6) is that point where the vertical line tangent to the most forward point at the longitudinal seat centerline of the seat back, and the horizontal line tangent to the highest point of the seat cushion intersect in the longitudinal seat centerline section. The SRP is determined with the seat unloaded and adjusted to the highest and most rearward position provided for seated operation of the tractor.

4. GENERAL REQUIREMENTS:

- 4.1 Batteries, fuel tanks, oil reservoirs, and coolant systems shall be constructed and located or sealed to reduce the possibility of spillage which might be injurious to the operator in the event of upset.
- 4.2 All sharp edges and corners at the operator's station shall be appropriately treated to minimize operator injury in the event of upset.
- 4.3 Glazing shall conform to SAE J674.
- 4.4 Two or more operator exits shall be provided and positioned to reduce the possibility of all exits being blocked by the same accident.

¹Consideration is being given to adopting the ISO definition when it is approved.

- 4.5 Rear input energy tests (static, dynamic, or field upset) need not be performed on ROPS applied to tractors having four driven wheels, and where the static vertical force reaction at the front wheels is greater than the static vertical force reaction at the rear wheels, since this type of tractor is not prone to rearward upset.
- 4.6 The tractor mass used shall be that of the heaviest tractor model on which the ROPS is to be used.
- 4.7 New ROPS and mounting connections of the same design shall be used for conducting the tests as described in the static (6.1), the dynamic (6.2), or the field upset procedure (6.4).
- 4.8 In case of an offset seat, the ROPS loading shall be on the side with the least space between the centerline of the seat and the protective structure.
- 4.9 Accuracy of measurement:

Measurement	Accuracy
Deflections of enclosure	±5% of deflection measured
Tractor mass	±5% of mass measured
Force applied to frame	±5% of forced measured
Dimensions of critical zone	±12.7 mm (0.5 in)

- 4.10 Where movable or normally removable portions of the ROPS add to structural strength, they shall be placed in configurations that contribute least to the structural strength during the test.
- 4.11 If an overhead weather shield is available as an optional attachment to the protective structure, it may be in place during tests, provided it does not contribute to the strength of the protective structure.
- 4.12 If an overhead falling object protective cover is available as an optional attachment to the protective structure, it may be in place during tests provided it does not contribute to the strength of the protective structure.
- 4.13 No repairs or adjustments shall be made during the tests.
- 4.14 The protective structure shall meet the performance requirements established in section 7.

5. SEAT AND SEAT BELT REQUIREMENTS:

- 5.1 ROPS equipped tractors shall be fitted with seat belt assemblies (Type 1) conforming to the following, SAE J114, J117, J140, J141, J339, and J800 except as noted hereafter.
- 5.2 Where a suspended seat is used, the seat belt shall be fastened to the movable portion of the seat to accommodate the ride motion of the operator.

- 5.3 The seat belt anchorage shall be capable of withstanding a static tensile force of 4448N (1000 lbf) at 45 deg to the horizontal equally divided between the anchorages. 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. In addition, the seat mounting shall be capable of withstanding 2224 N (500 lbf) 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. Floor and seat deformation is acceptable provided there is no structural failure or release of the seat adjuster mechanism or other locking device. The seat adjuster or locking device need not be operable after application of the test load.

6. TEST PROCEDURES:

6.1 Static Test: (optional to 6.2).

6.1.1 Test Conditions:

- 6.1.1.1 The ROPS mounting base shall be the tractor chassis or the equivalent for which the ROPS is designed to assure the integrity of the entire system.
- 6.1.1.2 The ROPS shall be instrumented with the necessary equipment to obtain the required load deflection data at the location and direction specified in Figs. 4, 5, and 6. The measuring devices shall be located to record the force and deflection at the point of and along the line of loading. Load and deflection points shall be plotted in increments of deflection no greater than 12.7 mm (0.5 in). The rate of application of deflection (load) shall be such that it can be considered static.

6.1.2 Definition of Terms:

M = tractor mass as defined in 3.2 and 4.6:

Units: M in kg
M' in lb

E_{is} = energy input to be absorbed during side loading:

E_{is} = 980 + 1.2 M units: J and kg
E_{is}' = 8676 + 4.8 M' units: in-lbf and lb

E_{ir} = energy input to be absorbed during rear loading:

E_{ir} = 1.4 M units: J and kg
E_{ir}' = 5.64 M' units: in-lbf and lb

F = static load:

Units: F in N
F' in lbf

6.1.2 (Continued):

D = deflection under F

Units: D in mm
D' in inches

F-D = static force deflection curve.

E_U = strain energy absorbed by the structure.

E_U = area under F-D curve.

Units: E_U in J.
 E_U in inches-lbf

6.1.3 Static Test Procedures:

- 6.1.3.1 Apply the rear load per Fig. 4 or 5 and record F and D simultaneously. Rear load application shall be uniformly distributed along a projected dimension no greater than 686 mm (27 in) and an area no greater than 0.1032 m² (160 in²) normal to the direction of load application. The load shall be applied to the upper extremity of the ROPS at the point which is midway between the center of the ROPS and the inside of the ROPS upright. If no structural cross member exists at the rear of the ROPS, a substitute test beam which does not add strength to the ROPS may be utilized to complete this test procedure. (See 6.4.1.1 if field upset is omitted.) Stop the test when:
- The strain energy absorbed by the structure is equal to or greater than the required input energy E_{I_r} (6.1.2) or
 - deflection of the structure exceeds the allowable deflection (7.1.1).
- 6.1.3.2 Using data obtained in 6.1.3.1, construct the F-D curve as shown typically in Fig. 8 and calculate E_U .
- 6.1.3.3 Apply the side load as shown in Fig. 6 and record F and D simultaneously. Static side load application shall be uniformly distributed along a projected dimension no greater than 686 mm (27 in) and an area no greater than 0.1032 m² (160 in²) normal to the direction of load application. Side load application shall be at a 90 deg angle to the centerline of vehicle. The center of side load application shall be located between a distance 610 mm (24 in) forward, and a distance 305 mm (12 in) rearward of the seat reference point to best utilize the structural strength (see Fig. 6). If the ROPS is a one or two post design, the side load shall be applied in line with the

6.1.3.3 (Continued):

upper crossmember. The side load shall be applied to the longitudinal side farthest from the point of rear load application. (See 6.4.1.1 if field upset is omitted.) Stop the test when:

- a. The strain energy absorbed by the structure is equal to or greater than the required input energy E_{IS} (6.1.2) or,
- b. the deflection of the structure exceeds the allowable deflection (7.1.1).

6.1.3.4 Using data obtained in 6.1.3.3, construct the F-D curve as shown typically in Fig. 8 and calculate E_U .

6.2 Dynamic Test: (optional to 6.1).6.2.1 Test Conditions:

6.2.1.1 The tractor shall be ballasted to achieve the mass, as specified in 3.2, so that the static vertical force reaction at the front wheels shall be at least 33% of the static vertical force reaction at the rear wheels. The wheel tread setting, where adjustable, shall be at the position nearest to halfway between the minimum and maximum settings obtainable on the tractor. Where only two settings are obtainable, the minimum setting shall be used provided the tires do not interfere with structure deflection. The tires shall have no liquid ballast and shall be inflated to the maximum operating pressure recommended by the manufacturer.

6.2.1.2 The dynamic loading shall be produced by use of a 2000 kg (4410 lb) mass acting as a pendulum. The impact face of the mass shall be $686 \pm 25 \times 686 \pm 25$ mm ($27 \pm 1 \times 27 \pm 1$ in) and shall be constructed so that its center of gravity is within 25.4 mm (1 in) of its geometric center. The mass shall be suspended from a pivot point 5.5 - 6.7 m (18 - 22 ft) above the point of impact on the ROPS and shall be conveniently and safely adjustable for height. (See Fig. 9.)

6.2.1.3 For each phase of testing, the tractor shall be restrained from moving when the dynamic load is applied. The restraining members shall have strength no less than, and elasticity no greater than that of a 12.7 mm (0.50 in) diameter steel cable. Points of attaching restraining members shall be located an appropriate distance behind the rear axle and in front of the front axle to provide 15 - 30 deg angle between a restraining cable and the horizontal. For the impact from the rear, the restraining cables shall be located in the plane in which the center of gravity of the pendulum will swing or, alternatively, two sets of symmetrically located cables may be used at convenient lateral locations on the tractor. For the impact from the side, restraining cables shall be used as shown in Figs. 10 and 11.

6.2.1.4 The restraining cable(s) shall be tightened to provide tire deflection of 6 - 8% of nominal tire section width. After the tractor is properly restrained, a beam no smaller than 150 x 150 mm (6 x 6 in) in cross section shall be driven tightly against the appropriate wheels and clamped. For the test to the side, an additional beam of sufficient strength to prevent rim displacement shall be placed as a prop against the wheel rim nearest the operator's station on the side opposite the pendulum impact and shall be secured to the base so it is held tightly against the wheel rim during impact. The length of this beam shall be chosen so that it is at an angle of 25 - 40 deg to the horizontal when it is positioned against the wheel rim. (Figs. 10 and 11.)

6.2.1.5 Means shall be provided for indicating the maximum instantaneous deflection relative to the SRP and parallel to the vertical plane of the pendulum swing. A simple friction device is illustrated in Fig. 13.

6.2.1.6 If any cables, props, or blocking shift or break during the test, the test shall be repeated.

6.2.2 Definition of Terms:

M = tractor mass as defined in 3.2 and 4.6:

Units: M in kg
M' in lb

H = vertical height of the pendulum mass:

Units: H in mm
H' in inches

The pendulum mass shall be 2000 kg (4410 lb).

The pendulum mass shall be pulled back so that the height of its center of gravity above the point of impact is as follows:

$H = 125 + 0.107 M$ Units: mm and kg
 $H' = 4.92 + 0.0019 M'$ Units: in and lb

6.2.3 Dynamic Test Procedures:

6.2.3.1 The ROPS shall be evaluated by imposing dynamic loading from the rear, followed by a load to the side on the same ROPS. The pendulum swinging from the height determined by 6.2.2 imposes the dynamic load. The position of the pendulum shall be so selected that the initial point of impact on the ROPS shall be in line with the arc of travel of the center of gravity of the pendulum. A quick release mechanism should be used but shall not influence the attitude of the pendulum.

6.2.3.2 Impact at Rear: The tractor shall be properly restrained per 6.2.1.3 and 6.2.1.4. The tractor shall be positioned so that the supporting chains of the pendulum are at an angle of 20 deg to the vertical when striking the structure as shown in Fig. 10. If the angle of the cab or

6.2.3.2 (Continued):

frame member at the point of contact is greater than 20 deg forward of the vertical, the angle of the face of the pendulum shall be further adjusted by any convenient means so that the striking face of the pendulum and the cab or frame member are parallel. The impact shall be applied to the upper extremity of the ROPS at the point which is midway between the centerline of the ROPS and the inside of the ROPS upright. If no structural crossmember exists at the rear of the ROPS, a substitute test beam which does not add to the strength of the structure may be utilized to complete the test procedure.

6.2.3.3 Impact at Side: The tractor shall be properly restrained as per 6.2.1.3 and 6.2.1.4. The tractor shall be positioned so that the supporting chains of the pendulum are vertical when striking the structure as shown in Fig. 11. If the structural member at the point of impact is not vertical, the angle of the face of the pendulum shall be adjusted by any convenient means so that the striking face of the pendulum and the cab or frame member are parallel.

The point of impact shall be at the upper extremity of the ROPS at a 90 deg angle to the centerline of the tractor and located between a distance 610 mm (24 in) forward, and a distance 305 mm (12 in) rearward of the seat reference point to best utilize the structural strength. (See Figs. 6 and 11). If the ROPS is a one or two post design, the side impact shall be applied in line with the upper crossmember. The side impact shall be applied to the longitudinal side farthest from the point of rear impact.

6.3 Crush Test Procedure:

6.3.1 After the ROPS has been subjected to either static or dynamic loads, the same ROPS shall be subjected to a static crush test.

6.3.2 The test load shall be 1.5 times the gravity force of the tractor mass as defined and explained in 3.2. The manner of distributing this load on the ROPS shall be such to best utilize those structural members in the fore and aft plane which will support the tractor in an upset position. The resultant of the initial crushing force or load shall be in the vertical direction and shall be in a vertical plane passing through the SRP and parallel to the longitudinal axis of the tractor (Fig. 7). The tractor chassis shall be rigidly supported during this test.

6.4 Field Upset Test:

6.4.1 Test Conditions:

6.4.1.1 The field upset test may be omitted if the ROPS laboratory test (static or dynamic) results indicate compliance at an energy application of 115% or more of the requirements defined in 6.1.2 or 6.2.2 and the ROPS meets the temperature-material requirements (see 7.1.2).

- 6.4.1.2 The tractor shall be ballasted to achieve the mass as specified in 3.2 so that the static vertical force reaction at the front wheels shall be at least 33% of the static vertical force reaction at the rear wheels. The wheel tread setting, where adjustable, shall be at the position nearest to halfway between the minimum and maximum settings of the shortest axles obtainable on the tractor. Where only two settings are obtainable, the minimum setting shall be used provided the tires do not interfere with structure deflection. The tires may have liquid ballast and shall be inflated to the maximum operating pressure recommended by the manufacturer.
- 6.4.1.3 The tests shall be conducted on a firm soil bank as shown in Figs. 14 and 15. The soil in the impact area shall have an average cone index in the 0 - 152 mm (0 - 6 in) layer not less than 150. (Cone index is defined in ASAE R313, Soil Cone Penetrometer.) The path of tractor travel shall be $12 \text{ deg} \pm 2$ to the top edge of the bank. A 457 mm (18 in) high ramp as described and located in Fig. 15 shall be used to assist in upsetting the tractor to its side.
- 6.4.1.4 A means shall be provided for indicating the maximum instantaneous deflection of the structure during upset. A simple friction device is illustrated in Fig. 13.
- 6.4.2 Field Upset Test Procedures:
- 6.4.2.1 Rear Upset: Rear upset shall be induced by engine power with the tractor operating in a gear to obtain 4.8 - 8.0 km/h (3 - 5 mph) at maximum governed engine rpm preferably by driving forward directly up a minimum slope of $60 \text{ deg} \pm 5$ as shown in Fig. 14. The engine clutch may be used to aid in inducing the upset.
- 6.4.2.2 Side Upset: Side upset shall be induced by driving the tractor under its own power along the specified path of travel at a minimum speed of 16 km/h (10 mph) or at maximum tractor speed if under 16 km/h (10 mph) and over the ramp as described in 6.4.1.3. (See Fig. 15.)

7. PERFORMANCE REQUIREMENTS:

7.1 General Requirements:

- 7.1.1 The ROPS overhead weather shield, overhead protection, fenders, cab sheet metal, or related ROPS parts (outside of, but near, the operator area) may be deformed in tests as described in 6.1, 6.2, 6.3 or 6.4, but shall not leave sharp edges exposed to the operator, or intrude on the clearance zone described by the dimensions shown in Figs. 4, 5, and 6 as follows:

- d = 50 mm (2 in) inside of frame upright to vertical centerline of seat.
- c = 760 mm (30 in) at the longitudinal centerline.
- f = no greater than 100 mm (4 in) to rear edge of crossbar measured forward of the SRP.

7.1.1 (Continued):

- g = 610 mm (24 in) min (See Fig. 6).
 h = 445 mm (17.5 in) min (See Fig. 5 cab or four post ROPS).
 j = 50 mm (2.0 in) measured from outer periphery of steering wheel (See Fig. 5).
 m = not greater than 305 mm (12 in) measured from SRP to forward edge of crossbar (See Fig. 4, one or two post ROPS only).

Note: Fig. 12 is a pictorial representation of the clearance zone.

- 7.1.2 The temperature material requirements will be met if the ROPS passes either of the dynamic tests (6.2 or 6.4) at a metal temperature of -18°C (0°F) or below. The temperature-material requirements will also be met if the ROPS passes either the dynamic test (6.2 or 6.4), or the static test (6.1) at ambient temperature provided structural members are from material which exhibit Charpy V-notch impact strengths at -30°C (-20°F) shown in Table 1.

TABLE 1 - Minimum Charpy V-Notch Impact Strengths

Specimen Size, mm	J	ft-lb
10 x 10 ^a	11.0	8.0
10 x 9	10.0	7.5
10 x 8	9.5	7.0
10 x 7.5 ^a	9.5	7.0
10 x 7	9.0	6.5
10 x 6.7	8.5	6.5
10 x 6	8.0	6.0
10 x 5 ^a	7.5	5.5
10 x 4	7.0	5.0
10 x 3.3	6.0	4.5
10 x 3	6.0	4.5
10 x 2.5 ^a	5.5	4.0

^aIndicates preferred size. Specimen size shall be no less than the largest preferred size that the material will permit.

(Reference: ASTM A 370-76, Standard Methods and Definitions for Mechanical Testing of Steel Products.)

7.1.2 (Continued):

Specimens are to be longitudinal and taken from flat stock, tubular, 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 2.6 mm (0.10 in) or less in thickness and the maximum carbon content of 0.20% shall not be exceeded.

- 7.1.3 Fasteners used to attach the ROPS to the tractor frame and to connect structural parts of the ROPS shall be SAE grade 5 - 8 or equivalent (SAE J429 and J995).

- 7.2 Static Test Performance Requirements: The structural requirements will be met if the required rear and side energy input levels are reached or exceeded, and the dimensions of zone of clearance in 7.1.1 are adhered to in rear and side loading.

- 7.3 Dynamic Test Performance Requirements: The structural requirements will be met if the dimensions of the zone of clearance in 7.1.1 are adhered to in both rear and side loading.

- 7.4 Crush Test Performance Requirements: The structural requirements will be met if the dimensions of the zone of clearance in 7.1.1 are adhered to.

- 7.5 Field Upset Performance Requirements: The structural requirements will be met if the dimensions of the zone of clearance in 7.1.1 are adhered to in both rear and side upsets.

The phi (Ø) symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

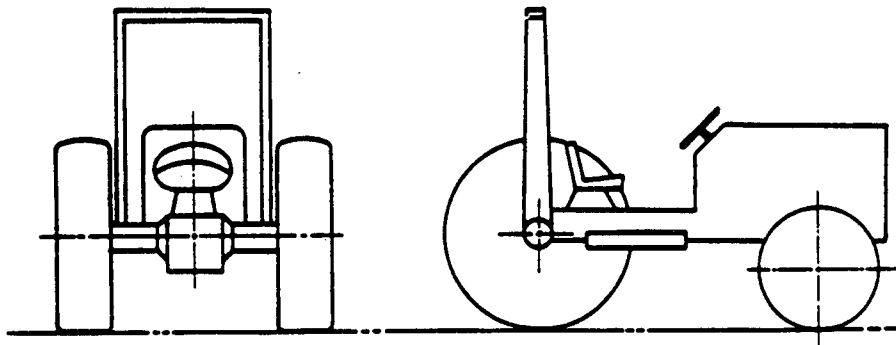


FIGURE 1 - Tractor with Typical Two-Post ROPS

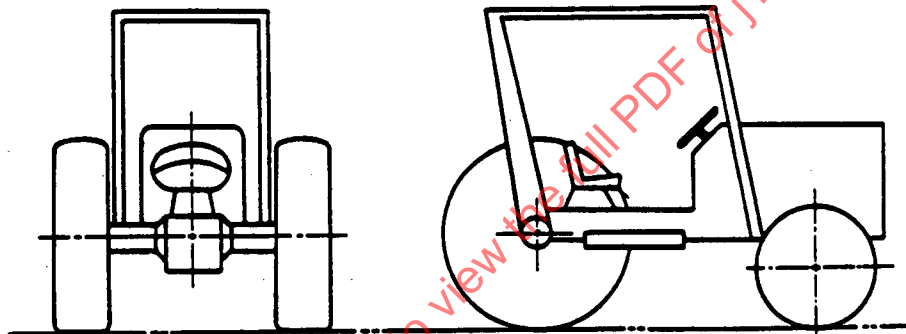


FIGURE 2 - Tractor with Typical Four-Post ROPS

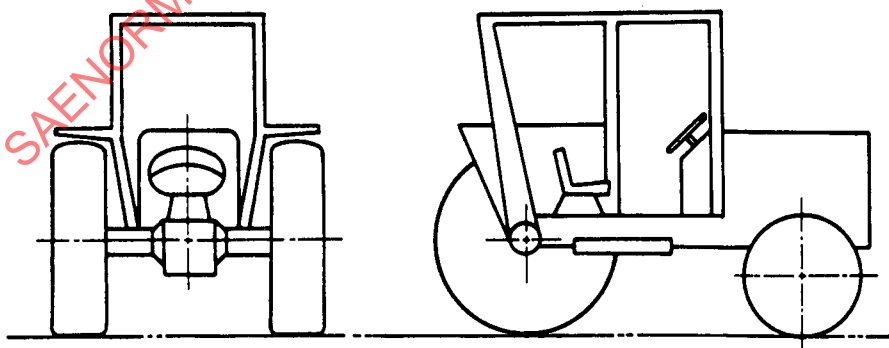


FIGURE 3 - Tractor with Typical Protective Enclosure

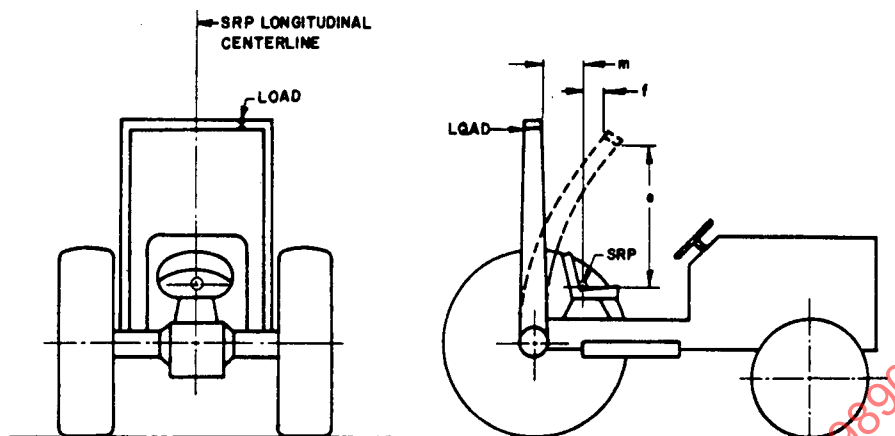


FIGURE 4 - Typical Rear Load Application

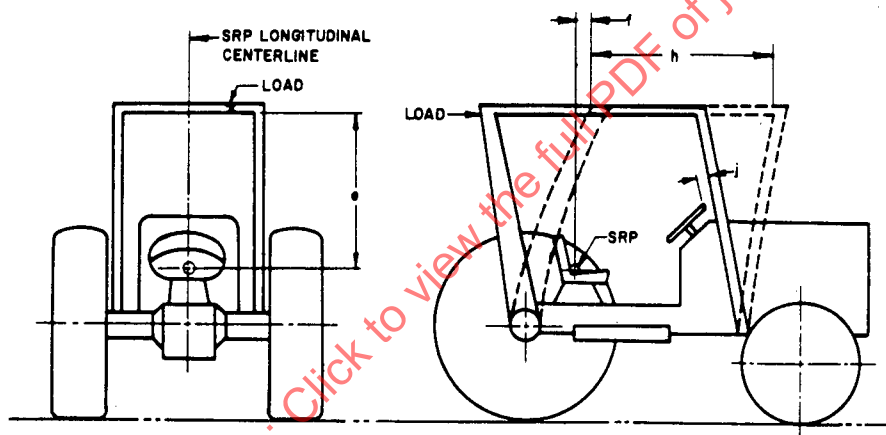


FIGURE 5 - Typical Rear Load Application

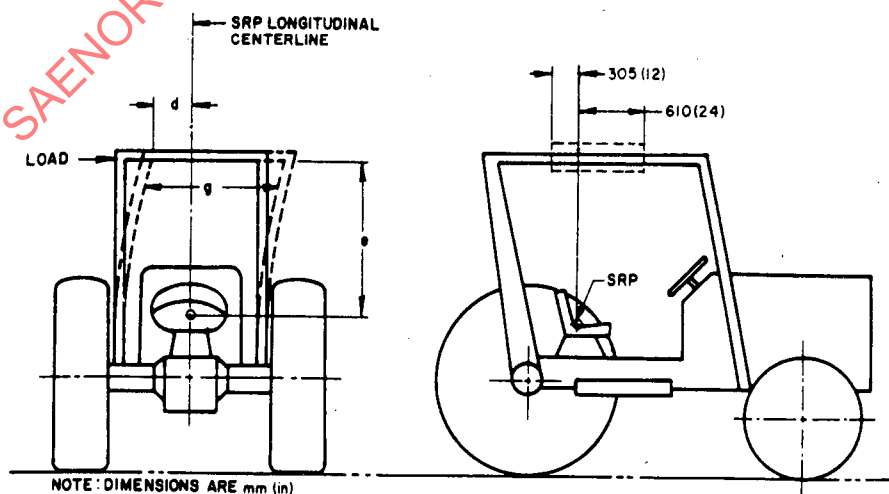


FIGURE 6 - Typical Side Load Application

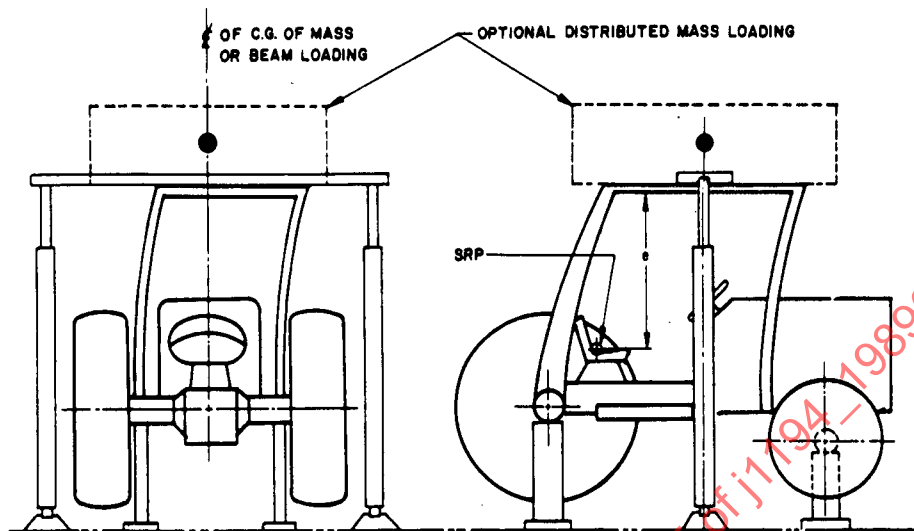


FIGURE 7 - Typical Method of Load Application for Crush Test

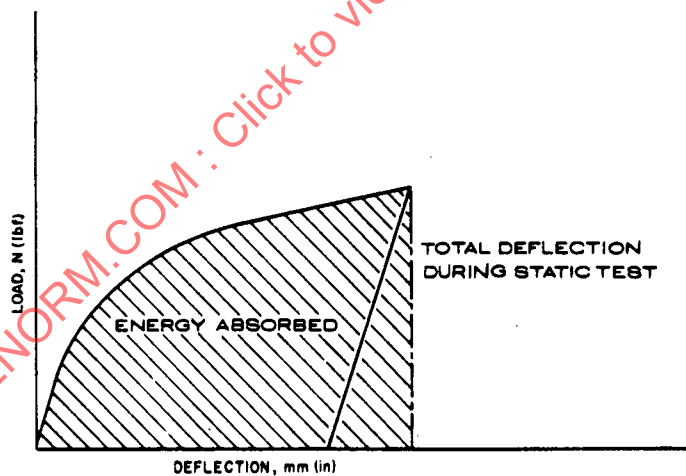


FIGURE 8 - Force Deflection (F-D) Curve

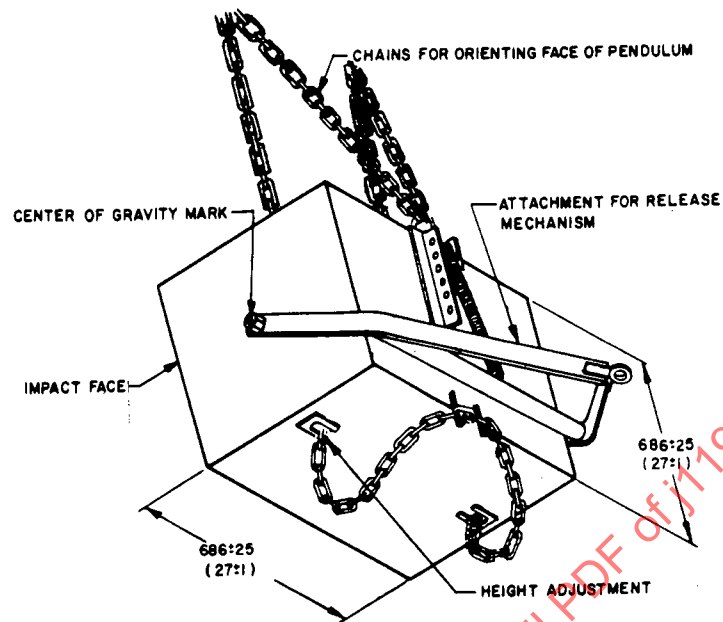


FIGURE 9 - Pendulum

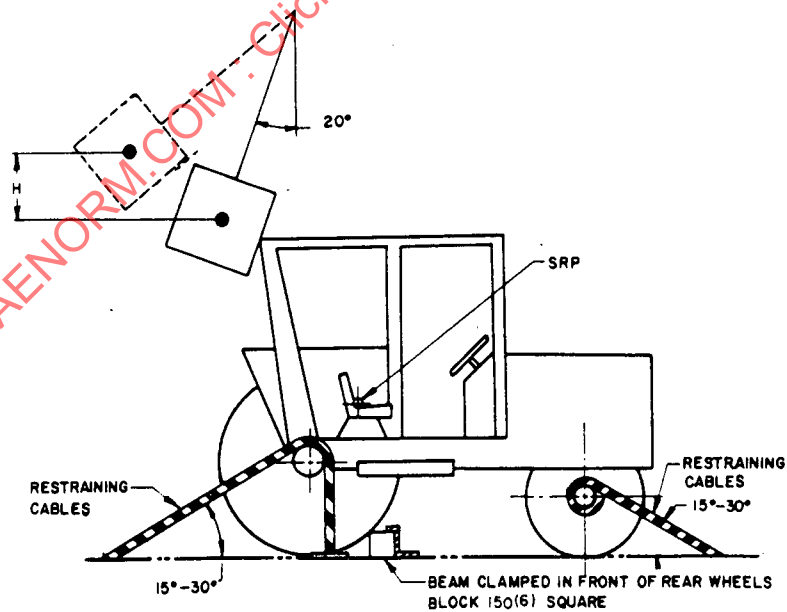


FIGURE 10 - Typical Rear Impact Application