Roll-Over Protective Structures (ROPS) for Wheeled Agricultural Tractors—SAE J1194

SAE Standard
Approved June 1977

THIS IS A PREPRINT AND WILL APPEAR IN THE NEXT EDITION OF THE SAE HANDBOOK

Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

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ROLL-OVER PROTECTIVE STRUCTURES (ROPS) FOR WHEELED AGRICULTURAL TRACTORS—SAE J1194

SAE Standard

Report of Tractor Technical Committee approved June 1977. Conforms to an FIEI and an ASAE report. This report contains information formerly contained in SAE J333b, J334b, and J168a. Rationale statement available.

1. Purpose—The purpose of this standard is to establish the test and performance requirements of a roll-over 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.

2. Scope

2.1 Fulfillment of the intended purpose requires testing as follows:

2.1.1 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 (paragraph 6.1) or the dynamic test (paragraph 6.2) shall be conducted.

2.1.2 A crush test to verify the effectiveness of the deformed ROPS in supporting the tractor in an upset attitude.

2.1.3 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 paragraph 6.4.1.1 for requirements for the omission of this test.)

2.1.4 In addition to the laboratory and field loading requirements, there is a temperature-material requirement. (See paragraph 7.1.2.)

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

3. Definitions

3.1 An agricultural tractor, for the purpose of this standard, is defined as a 2 or 4-wheel drive type machine of more than 15 kW (20 engine hp) 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 maximun power take-off 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 take-off power is not available, use 95% of net engine flywheel power).

3.3 A roll-over protective structure (ROPS) is a cab or frame for the protection of operators of agricultural wheeled tractors in order 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.)

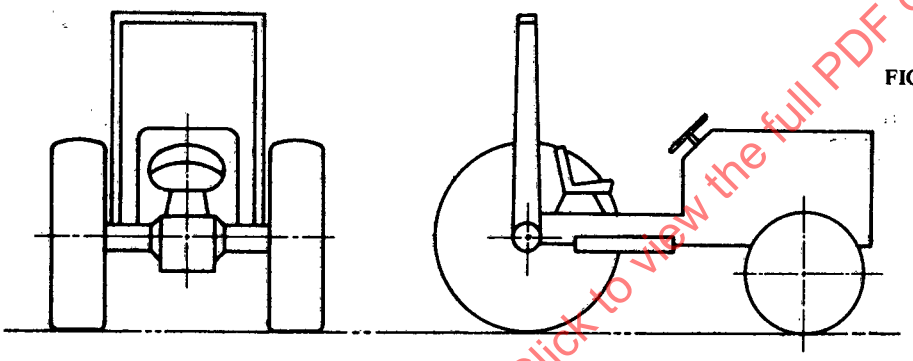

FIG. 1—TRACTOR WITH TYPICAL 2-POST ROPS

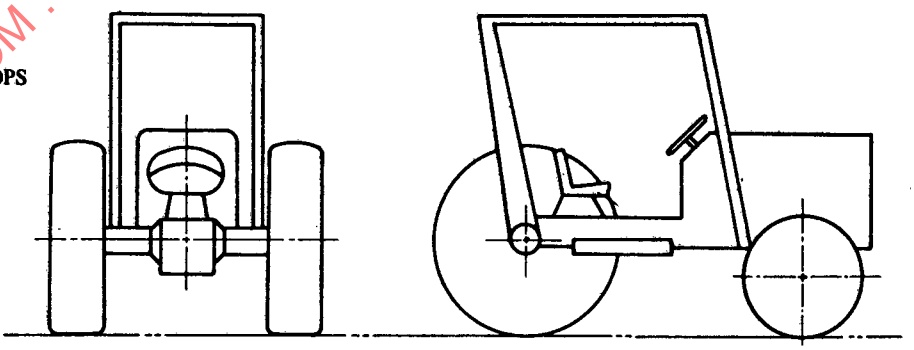

FIG. 2—TRACTOR WITH TYPICAL 4-POST ROPS

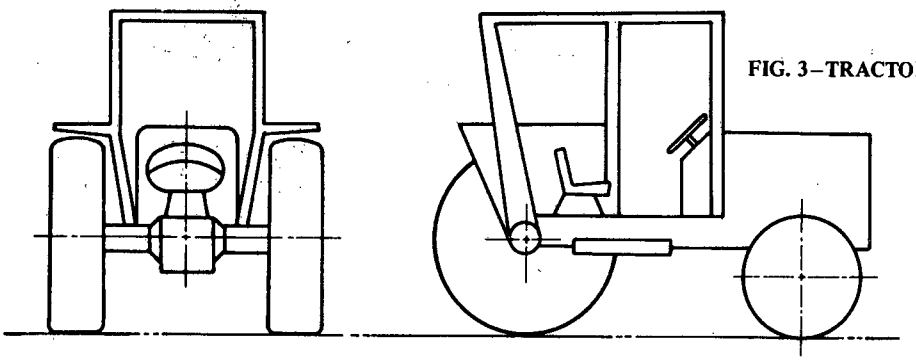

FIG. 3—TRACTOR WITH TYPICAL PROTECTIVE ENCLOSURE

3.4 Seat reference point,[1] (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.

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

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.

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.

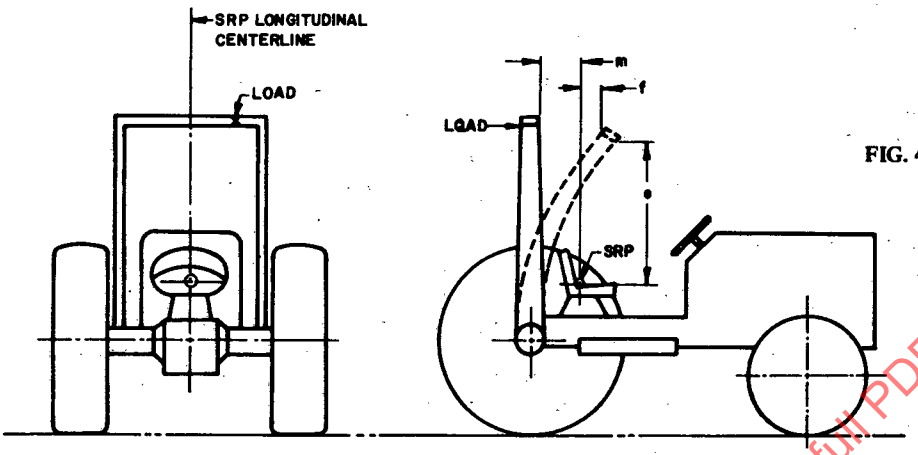

FIG. 4–TYPICAL REAR LOAD APPLICATION

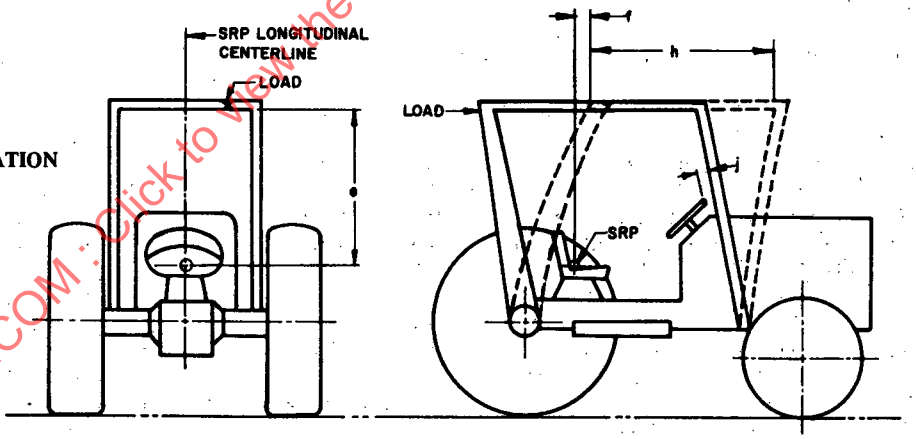

FIG. 5–TYPICAL REAR LOAD APPLICATION

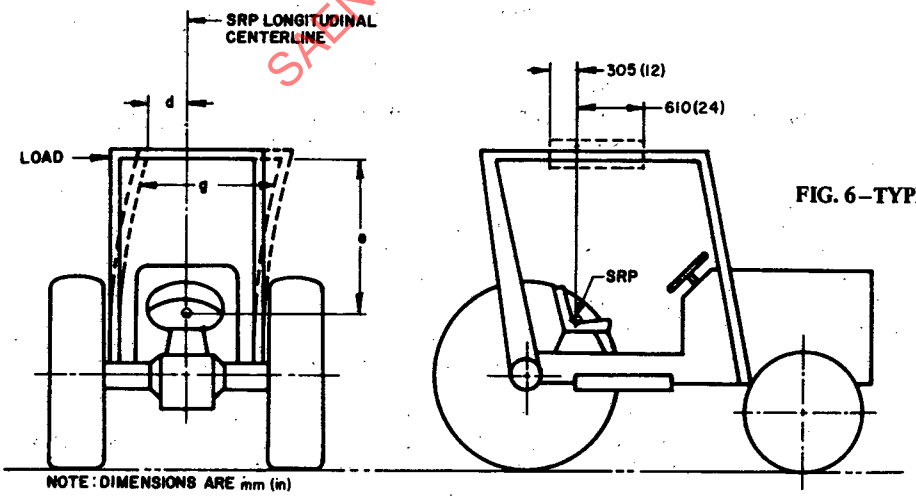

FIG. 6–TYPICAL SIDE LOAD APPLICATION

4.7 New ROPS and mounting connections of the same design shall be used for conducting the tests as described in the static (paragraph 6.1), the dynamic (paragraph 6.2) or the field upset procedure (paragraph 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 force 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, J140a, J141, J339a, and J800c 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 4448 N (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 mechansim 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 paragraph 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 so as 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 paragraphs 3.2 and 4.6:

Units: M in kg
M' in lbs

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

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 m^2 (160 in^2) 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 paragraph 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_{ir} (paragraph 6.1.2) or

b) deflection of the structure exceeds the allowable deflection (paragraph 7.1.1).

6.1.3.2 Using data obtained in paragraph 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 m^2 (160 in^2) 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 upper crossmember. The side load shall be applied to the longitudinal side farthest from the point of rear load application. (See paragraph 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} (paragraph 6.1.2) or

b) deflection of the structure exceeds the allowable deflection (paragraph 7.1.1).

6.1.3.4 Using data obtained in paragraph 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 paragraph 6.1).

6.2.1 Test conditions

6.2.1.1 The tractor shall be ballasted to achieve the mass as specified in paragraph 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.

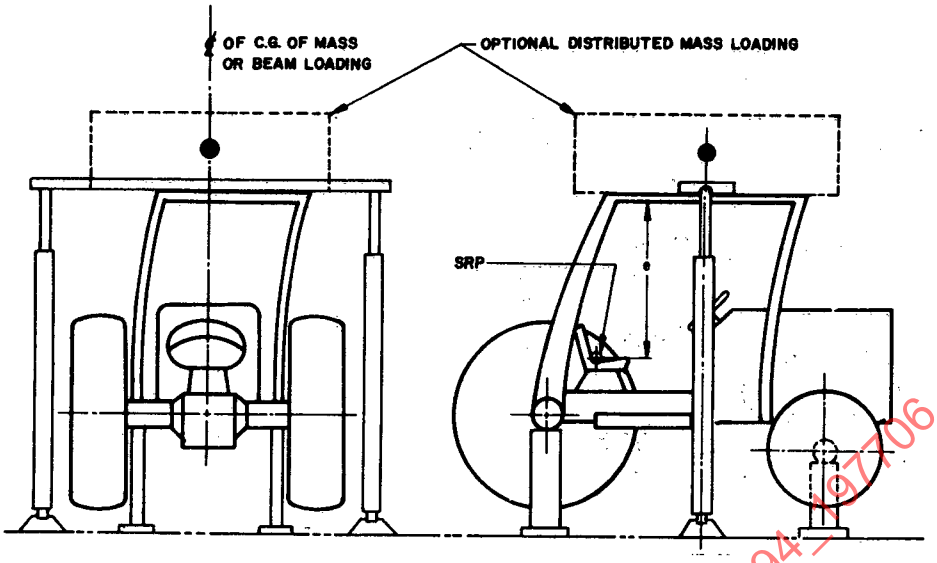

FIG. 7–TYPICAL METHOD OF LOAD APPLICATION FOR CRUSH TEST

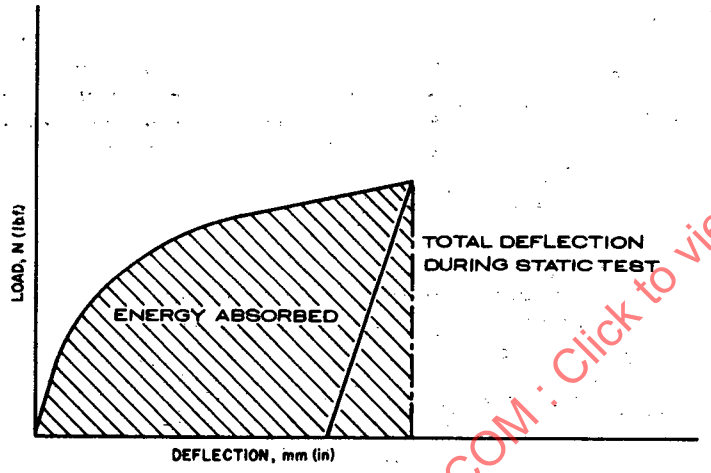

FIG. 8–FORCE DEFLECTION (F-D) CURVE

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 ± 25 mm (27 ± 1 x 27 ± 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 symetrically 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 paragraph 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

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 paragraph 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 mechansim 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 paragraphs 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 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

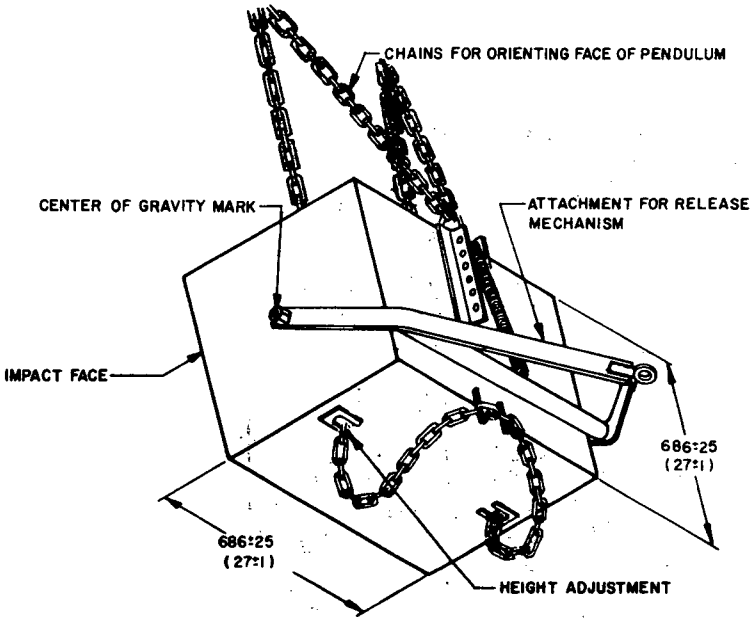

FIG. 9–PENDULUM

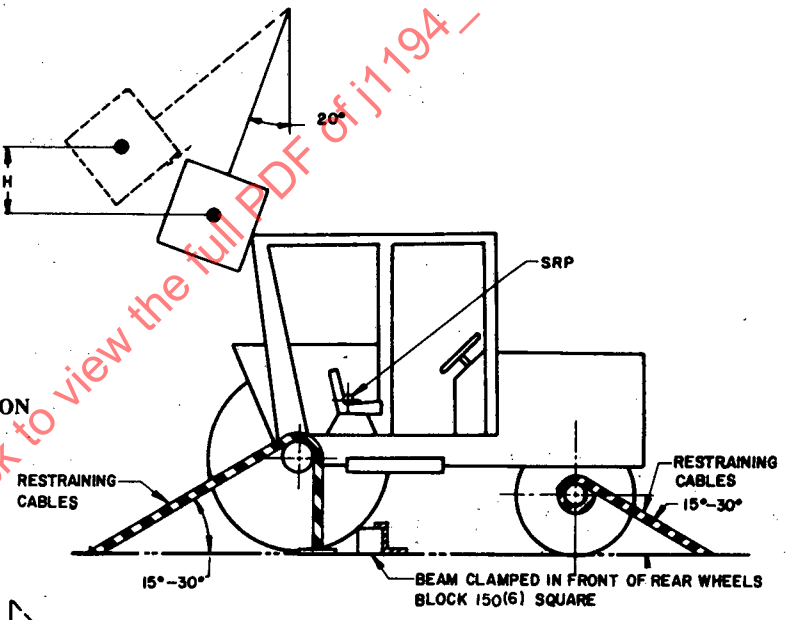

FIG. 10–TYPICAL REAR IMPACT APPLICATION

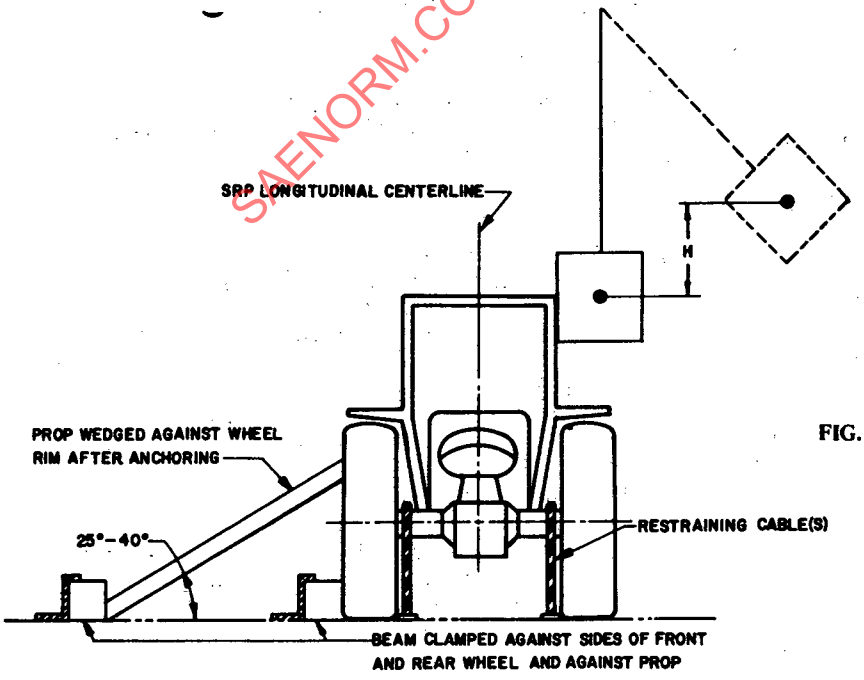

FIG. 11–TYPICAL SIDE IMPACT APPLICATION