PLAINTIFF'S EXHIBIT

CAP-440

To Mr Weaver
from Jim P.

This is an addendum to the Safety and Health Regulations for Construction published by A.G.C. March 14, 1972. This New Sub Part-W on Rollover Protective Structures (ROPS) was promulgated in the Federal Register April 5, 1972.

Subpart W—Rollover Protective Structures; Overhead Protection

Sec.

1926.1000 Rollover protective structures (ROPS) for material handling equipment.

1926.1001 Minimum performance criteria for rollover protective structures for designated scrapers, loaders, dozers, graders, and crawler tractors.

1926.1002 Protective frame (ROPS) test procedures and performance requirements for wheel-type agricultural and industrial tractors used in construction.

Sec.

1926.1003 Overhead protection for operators of agricultural and industrial tractors.

§ 1926.1000 Rollover protective structures (ROPS) for material handling equipment.

(a) *Coverage.* (1) This section applies to the following types of material handling equipment: To all rubber-tired, self-propelled scrapers, rubber-tired front-end loaders, rubber-tired dozers, wheel-type agricultural and industrial tractors, crawler tractors, crawler-type loaders, and motor graders, with or without attachments, that are used in construction work. This requirement does not apply to sideboom pipelaying tractors.

(2) The promulgation of specific standards for rollover protective structures for compactors and rubber-tired skid-steer equipment is reserved pending consideration of standards currently being developed.

(b) *Equipment manufactured on or after September 1, 1972.* Material handling machinery described in paragraph (a) of this section and manufactured on or after September 1, 1972, shall be equipped with rollover protective structures which meet the minimum performance standards prescribed in §§ 1926.1001 and 1926.1002, as applicable.

(c) *Equipment manufactured before September 1, 1972.* (1) All material handling equipment described in paragraph (a) of this section and manufactured or placed in service (owned or operated by the employer) prior to September 1, 1972, shall be fitted with rollover protective structures no later than the dates listed below:

(i) Machines manufactured on or after January 1, 1972, shall be fitted no later than April 1, 1973.

(ii) Machines manufactured between July 1, 1971, and December 31, 1971, shall be fitted no later than July 1, 1973.

(iii) Machines manufactured between July 1, 1970, and June 30, 1971, shall be fitted no later than January 1, 1974.

(iv) Machines manufactured between July 1, 1969, and June 30, 1970, shall be fitted no later than July 1, 1974.

(v) Machines manufactured before July 1, 1969: Reserved pending further study, development, and review.

(2) Rollover protective structures and supporting attachment shall meet the minimum performance criteria detailed in §§ 1926.1001 and 1926.1002, as applicable or shall be designed, fabricated, and installed in a manner which will support, based on the ultimate strength of the metal, at least two times the weight of the prime mover applied at the point of impact.

(i) The design objective shall be to minimize the likelihood of a complete overturn and thereby minimize the possibility of the operator being crushed as a result of a rollover or upset.

(ii) The design shall provide a vertical clearance of at least 52 inches from the work deck to the ROPS at the point of ingress or egress.

(d) *Remounting.* ROPS removed for any reason, shall be remounted with equal quality, or better, bolts or welding as required for the original mounting.

(e) *Labeling.* Each ROPS shall have the following information permanently affixed to the structure:

(1) Manufacturer or fabricator's name and address;

(2) ROPS model number, if any;

(3) Machine make, model, or series number that the structure is designed to fit.

(f) *Machines meeting certain existing governmental requirements.* Any machine in use, equipped with rollover protective structures, shall be deemed in compliance with this section if it meets the rollover protective structure requirements of the State of California, the U.S. Army Corps of Engineers, or the Bureau of Reclamation of the U.S. Department of the Interior in effect on April 5, 1972. The requirements in effect are:

(1) State of California: Construction Safety Orders, issued by the Department of Industrial Relations pursuant to Division 5, Labor Code, § 6312, State of California.

(2) U.S. Army Corps of Engineers: General Safety Requirements, EM-385-1-1 (March 1967).

(3) Bureau of Reclamation, U.S. Department of the Interior: Safety and Health Regulations for Construction, Part II (September 1971).

§ 1926.1001 Minimum performance criteria for rollover protective structures for designated scrapers, loaders, dozers, graders, and crawler tractors.

(a) *General.* This section prescribes minimum performance criteria for rollover protective structures (ROPS) for rubber-tired self-propelled scrapers; rubber-tired front-end loaders and rubber-tired dozers; crawler tractors, and crawler-type loaders, and motor graders. The vehicle and ROPS as a system shall have the structural characteristics prescribed in paragraph (f) of this section for each type of machine described in this paragraph.

(b) The static laboratory test prescribed herein will determine the adequacy of the structures used to protect the operator under the following conditions:

(1) For rubber-tired self-propelled scrapers, rubber-tired front-end loaders, and rubber-tired dozers: Operating between 0 and 10 miles per hour over hard clay where rollover would be limited to a maximum roll angle of 360° down a slope of 30° maximum.

(2) For motor graders: Operating between 0 and 10 miles per hour over hard clay where rollover would be limited to 360° down a slope of 30° maximum.

(3) For crawler tractors and crawler-type loaders: Operating between 0 and 10 miles per hour over hard clay where rollover would be limited to a maximum roll angle of 360° down a slope of 45°.

(c) *Facilities and apparatus.* (1) The following material is necessary:

(i) Material, equipment, and tiedown means adequate to insure that the ROPS and its vehicle frame absorb the applied energy.

(ii) Equipment necessary to measure and apply loads to the ROPS. Adequate means to measure deflections and lengths should also be provided.

(iii) Recommended, but not mandatory, types of test setups are illustrated in Figure W-1 for all types of equipment to which this section applies; and in Figure W-2 for rubber-tired self-propelled scrapers; Figure W-3 for rubber-tired front-end loaders, rubber-tired dozers, and motor graders; and Figure W-4 for crawler tractors and crawler-type loaders.

(2) Table W-1 contains a listing of the required apparatus for all types of equipment described in paragraph (a) of this section.

TABLE W-1

Means to measure	*Accuracy*
Deflection of ROPS, inches.	±5% of deflection measured.
Vehicle weight, pounds.	±5% of the weight measured.
Force applied to frame, pounds.	±5% of force measured.
Dimensions of critical zone, inches.	±0.5 in.

(d) *Vehicle condition.* The ROPS to be tested must be attached to the vehicle structure in the same manner as it will be attached during vehicle use. A totally assembled vehicle is not required. However, the vehicle structure and frame which support the ROPS must represent the actual vehicle installation. All normally detachable windows, panels, or nonstructural fittings shall be removed so that they do not contribute to the strength of the ROPS.

(e) *Test procedure.* The test procedure shall include the following, in the sequence indicated:

(1) Energy absorbing capabilities of ROPS shall be verified when loaded laterally by incrementally applying a distributed load to the longitudinal outside top member of the ROPS, as shown in Figure W-1, W-2, or W-3, as applicable. The distributed load must be ap-

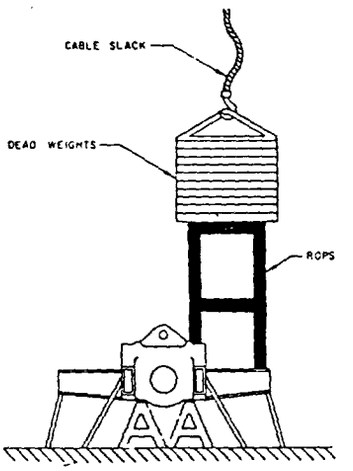

FIGURE W-1—Vertical loading setup for all types of equipment described in § 1518.1001(a).

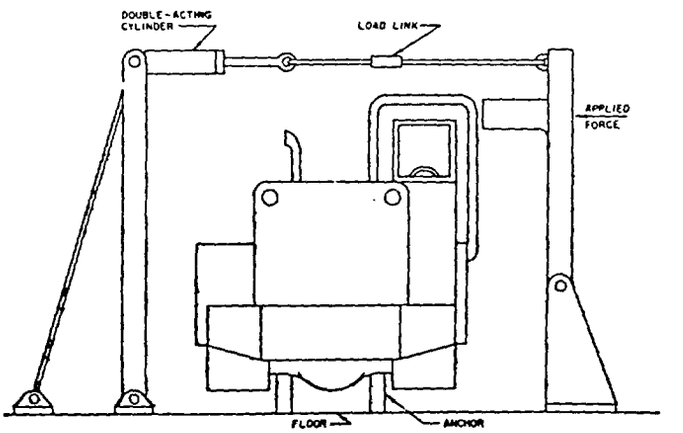

FIGURE W-2—Test setup for rubber-tired self-propelled scrapers.

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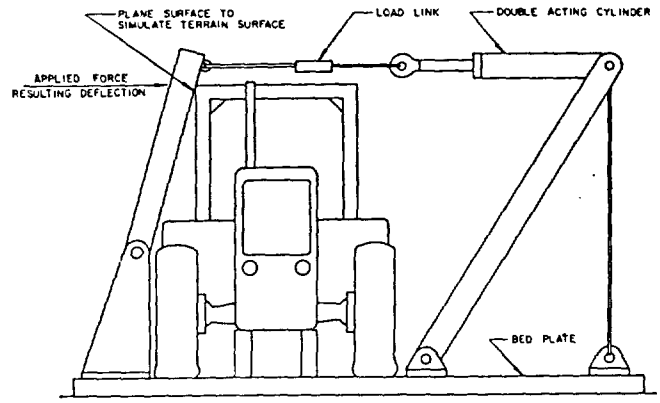


FIGURE W-3—Test setup for rubber-tired front-end loaders, rubber-tired dozers, and motor graders.

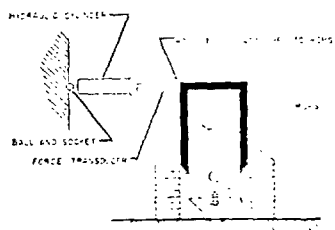
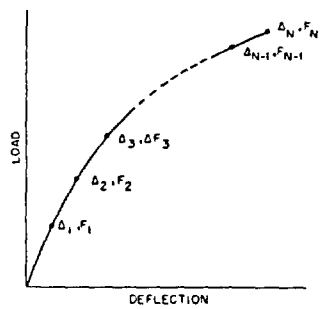


FIGURE W-4—Side-loading setup for crawler tractors and crawler loaders.

plied so as to result in approximately uniform deflection of the ROPS. The load increments should correspond with approximately 0.5 in. ROPS deflection increment in the direction of the load application, measured at the ROPS top edge. Should the operator's seat be off-center, the load shall be applied on the offcenter side. For each applied load increment, the total load (lb.) versus corresponding deflection (in.) shall be plotted, and the area under the load-deflection curve shall be calculated. This area is equal to the energy (in.-lb.) absorbed by the ROPS. For a typical load-deflection curve and calculation method, see Figure W-5.



Δ - TOTAL DEFLECTION
F - FORCE APPLIED

$$\text{AREA} = \frac{\Delta_1 F_1}{2} + (\Delta_2 - \Delta_1)\frac{F_1 + F_2}{2} + (\Delta_3 - \Delta_2)\frac{F_2 + F_3}{2} + \cdots + (\Delta_N - \Delta_{N-1})\frac{F_{N-1} + F_N}{2}$$

FIGURE W-5—Determination of energy area under force deflection curve for all types of ROPS equipment defined in § 1926.1001.

Incremental loading shall be continued until the ROPS has absorbed the amount of energy and the minimum applied load specified under paragraph (f) of this section has been reached or surpassed.

(2) To cover the possibility of the vehicle coming to rest on its top, the support capability shall be verified by applying a distributed vertical load to the top of the ROPS so as to result in approximately uniform deflection (see Figure W-1). The load magnitude is specified in paragraph (f)(2)(iii) of this section.

(3) The low temperature impact strength of the material used in the ROPS shall be verified by suitable material tests or material certification (see paragraph (f)(2)(iv) of this section).

(f) *Performance requirements*—(1) *General performance requirements.* (i) No repairs or straightening of any member shall be carried out between each prescribed test.

(ii) During each test, no part of the ROPS shall enter the critical zone as detailed in SAE J397 (1969). Deformation of the ROPS shall not allow the plane of the ground to enter this zone.

(2) *Specific performance requirements.* (i) The energy requirement for purposes of meeting the requirements of paragraph (e)(1) of this section is to be determined by referring to the plot of the energy versus weight of vehicle (see Figure W-6 for rubber-tired self-propelled scrapers; Figure W-7 for rubber-tired front-end loaders and rubber-tired dozers; Figure W-8 for crawler tractors and crawler-type loaders; and Figure W-9 for motor graders. For purposes of this section, force and weight are measured as pounds (lb.); energy (U) is measured as inch-pounds.

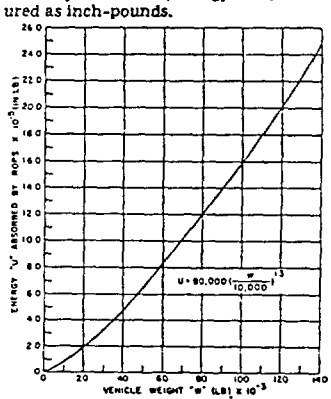


FIGURE W-6—Energy absorbed versus vehicle weight.

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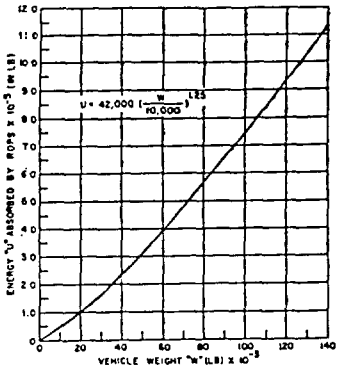

FIGURE W-7—Energy absorbed versus vehicle weight.

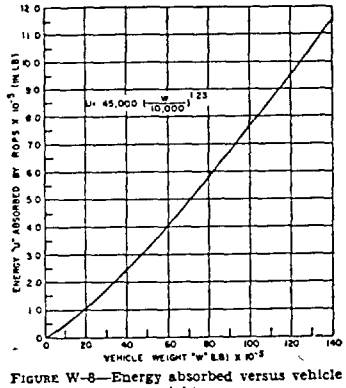

FIGURE W-8—Energy absorbed versus vehicle weight.

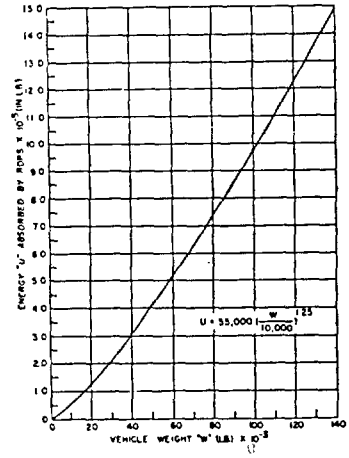

FIGURE W-9—Energy absorbed Versus Vehicle Weight.

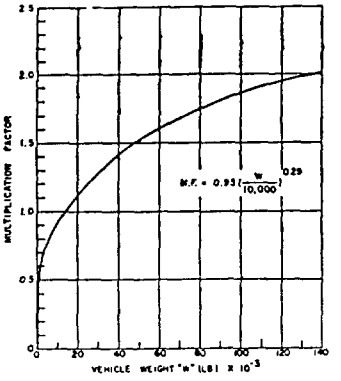

FIGURE W-10—Minimum horizontal load factor for self-propelled scrapers.

(ii) The applied load must attain at least a value which is determined by multiplying the vehicle weight by the corresponding factor shown in Figure W-10 for rubber-tired self-propelled scrapers; in Figure W-11 for rubber-tired front-end loaders and rubber-tired dozers; in Figure W-12 for crawler tractors and crawler-type loaders; and in Figure W-13 for motor graders.

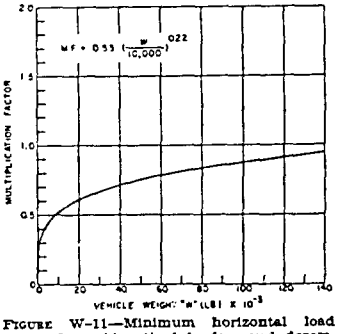

FIGURE W-11—Minimum horizontal load factor for rubber-tired loaders and dozers.

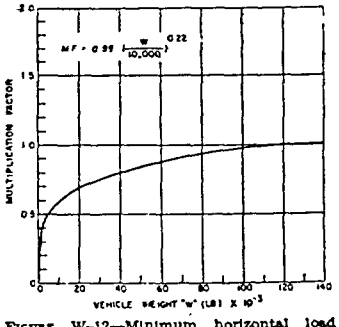

FIGURE W-12—Minimum horizontal load factor for crawler tractors and crawler-type loaders.

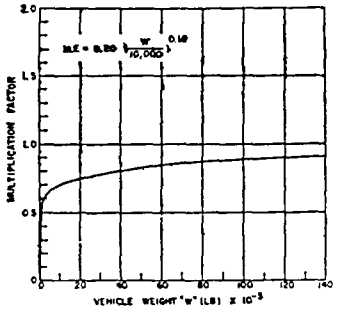

FIGURE W-13—Minimum horizontal load factor for motor graders.

(iii) The load magnitude for purposes of compliance with paragraph (e)(2) of this section is equal to the vehicle weight. The test of load magnitude shall only be made after the requirements of subparagraph (2)(i) of this paragraph are met.

(iv) Material used in the ROPS must have the capability of performing at zero degrees Fahrenheit, or exhibit Charpy V notch impact strength of 8 foot-pounds at minus 20° Fahrenheit. This is a standard Charpy specimen as described in American Society of Testing and Materials A 370, Methods and Definitions for Mechanical Testing of Steel Products (available at each Regional Office of the Occupational Safety and Health Administration). The purpose of this requirement is to reduce the tendency of brittle fracture associated with dynamic loading, low temperature operation, and stress raisers which cannot be entirely avoided on welded structures.

(g) *Definitions.* For purposes of this section, "vehicle weight" means the manufacturer's maximum weight of the prime mover for rubber-tired self-propelled scrapers. For other types of equipment to which this section applies, "vehicle weight" means the manufacturer's maximum recommended weight of the vehicle plus the heaviest attachment.

(h) *Source of standard.* This standard is derived from, and restates, the following Society of Automotive Engineers Recommended Practices: SAE J320a, Minimum Performance Criteria for Roll-Over Protective Structure for Rubber-Tired, Self-Propelled Scrapers; SAE J394, Minimum Performance Criteria for Roll-Over Protective Structure for Rubber-Tired Front End Loaders and Rubber-Tired Dozers; SAE J395, Minimum Performance Criteria for Roll-Over Protective Structure for Crawler Tractors and Crawler-Type Loaders; and SAE J396, Minimum Performance Criteria for Roll-Over Protective Structure for Motor Graders. These recommended practices shall be resorted to in the event that questions of interpretation arise. The recommended practices appear in the 1971 SAE Handbook, which may be examined in each of the Regional Offices of the Occupational Safety and Health Administration.

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§ 1926.1002 Protective frame (ROPS) test procedures and performance requirements for wheel-type agricultural and industrial tractors used in construction.

(a) *General.* (1) The purpose of this section is to set forth requirements for frames for the protection of operators of wheel type agricultural and industrial tractors to minimize the possibility of operator injury resulting from accidental upsets during normal operation. With respect to agricultural and industrial tractors, the provisions of §§ 1026.1001 and 1926.1003 for rubber-tired dozers and rubber-tired loaders may be utilized in lieu of the requirements of this section.

(2) The protective frame which is the subject of this standard is a structure mounted to the tractor that extends above the operator's seat and conforms generally to Figure W-14.

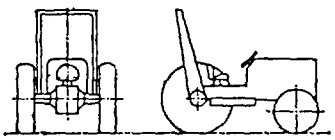

FIGURE W-14—Typical frame configuration.

(3) If an overhead weather shield is attached to the protective frame, it may be in place during tests: *Provided*, That it does not contribute to the strength of the protective frame. If such an overhead weather shield is attached, it must meet the requirements of paragraph (i) of this section.

(4) For overhead protection requirements, see § 1926.1003.

(5) If protective enclosures are used on wheel-type agricultural and industrial tractors, they shall meet the requirements of Society of Automotive Engineers Standard J168 (July 1970), Protective Enclosures, Test Procedures, and Performance Requirements. This standard appears in the 1971 SAE Handbook and may be examined in each Regional Office of the Occupational Safety and Health Administration.

(b) *Applicability.* The requirements of this section apply to wheel-type agricultural tractors used in construction work and to wheel-type industrial tractors used in construction work. See paragraph (j) of this section for definitions of agricultural tractors and industrial tractors.

(c) *Performance requirements.* (1) Either a laboratory test or a field test is required in order to determine the performance requirements set forth in subdivision (i) of this subparagraph.

(2) A laboratory test may be either static or dynamic. The laboratory test must be under conditions of repeatable and controlled loading in order to permit analysis of the protective frame.

(3) A field upset test, if used, shall be conducted under reasonably controlled conditions, both rearward and sideways, to verify the effectiveness of the protective frame under actual dynamic conditions.

(d) *Test procedures—general.* (1) The tractor used shall be the tractor with the greatest weight on which the protective frame is to be used.

(2) A new protective frame and mounting connections of the same design shall be used for each test procedure.

(3) Instantaneous and permanent frame deformation shall be measured and recorded for each segment of the test.

(4) Dimensions relative to the seat shall be determined with the seat unloaded and adjusted to its highest and most rearward latched position provided for a seated operator.

(5) If the seat is offset, the frame loading shall be on the side with the least space between the centerline of the seat and the upright.

(6) The low temperature impact strength of the material used in the protective structure shall be verified by suitable material tests or material certifications in accordance with § 1926.1001 (f) (2) (iv).

(e) *Test procedure for vehicle overturn—(1) Vehicle weight.* The weight of the tractor, for purposes of this section, includes the protective frame, all fuels, and other components required for normal use of the tractor. Ballast must be added if necessary to achieve a minimum total weight of 130 lb. (59 kg.) per maximum power takeoff horsepower at rated engine speed. The weight of the front end must be at least 33 lb. (15 kg.) per maximum power takeoff horsepower. In case power takeoff horsepower is unavailable, 95 percent of net engine flywheel horsepower shall be used.

(2) Agricultural tractors shall be tested at the weight set forth in subparagraph (1) of this paragraph.

(3) Industrial tractors shall be tested with items of integral or mounted equipment and ballast that are sold as standard equipment or approved by the vehicle manufacturer for use with the vehicle where the protective frame is expected to provide protection for the operator with such equipment installed. The total vehicle weight and front end weight as tested shall not be less than the weights established in subparagraph (1) of this paragraph.

(4) The test shall be conducted on a dry, firm soil bank as illustrated in Figure W-15. The soil in the impact area shall have an average cone index in the 0–6 in. (153 mm.) layer not less than 150 according to American Society of Agricultural Engineers Recommendation ASAE R313, Soil Cone Penetrometer (available in each Regional Office of the Occupational Safety and Health Administration). The path of travel of the vehicle shall be 12°±2° to the top edge of the bank.

(5) The upper edge of the bank shall be equipped with an 18 in. (457 mm.) high ramp as described in Figure W-15 to assist in tipping the vehicle.

(6) The front and rear wheel tread settings, where adjustable, shall be at the position nearest to halfway between the minimum and maximum settings obtainable on the vehicle. Where only two settings are obtainable, the minimum setting shall be used.

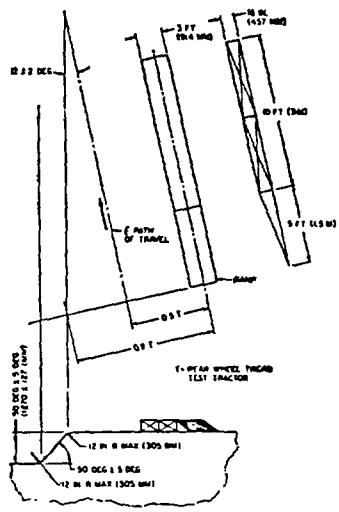

FIGURE W-15.

(7) *Vehicle Overturn Test—Sideways and Rearward.* (i) The tractor shall be driven under its own power along the specified path of travel at a minimum speed of 10 m.p.h. (16 km./hr.) or maximum vehicle speed if under 10 m.p.h. (16 km./hr.) up the ramp as described in subparagraph (5) of this paragraph to induce sideways overturn.

(ii) Rear upset shall be induced by engine power with the tractor operating in gear to obtain 3–5 m.p.h. (4.8–8 km./hr.) at maximum governed engine r.p.m. preferably by driving forward directly up a minimum slope of two vertical to one horizontal. The engine clutch may be used to aid in inducing the upset.

(f) *Other test procedures.* When the field upset test is not used to determine ROPS performance, either the static test or the dynamic test, contained in paragraph (g) or (h) of this section, shall be made.

(g) *Static test—(1) Test conditions.* (i) The laboratory mounting base shall include that part of the tractor chassis to which the protective frame is attached including the mounting parts.

(ii) The protective frame shall be instrumented with the necessary equipment to obtain the required load deflection data at the locations and directions specified in Figures W-16, W-17, and W-18.

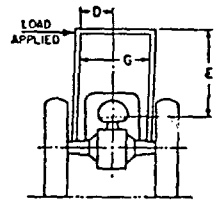

FIGURE W-16—Side load application.

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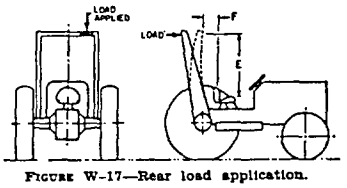

FIGURE W-17—Rear load application.

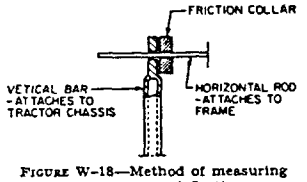

FIGURE W-18—Method of measuring instantaneous deflection.

(iii) The protective frame and mounting connections shall be instrumented with the necessary recording equipment to obtain the required load-deflection data to be used in calculating FSB (see paragraph (j)(3) of this section). The gauges shall be placed on mounting connections before the installation load is applied.

(2) *Test procedure.* (i) The side load application shall be at the upper extremity of the frame upright at a 90° angle to the centerline of the vehicle. The side load "L" shall be applied according to Figure W-16. "L" and "D" shall be recorded simultaneously. The test shall be stopped when:

(a) The strain energy absorbed by the frame is equal to the required input energy (E_{ti}) or

(b) Deflection of the frame exceeds the allowable deflection, or

(c) The frame load limit occurs before the allowable deflection is reached in the side load.

(ii) The L–D diagram, as shown by means of a typical example in Figure W-19, shall be constructed, using the data obtained in accordance with subdivision (i) of this subparagraph.

(iii) The modified L_m–D_m diagram shall be constructed according to subdivision (ii) of this subparagraph and according to Figure W-20. The strain energy absorbed by the frame (E_s) shall then be determined.

(iv) E_{ti}, FER, and FSB shall be calculated.

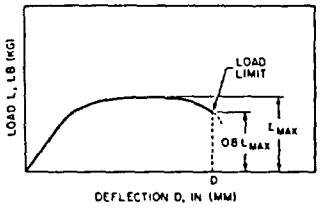

FIGURE W-19—Typical L–D diagram.

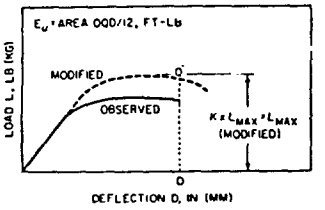

FIGURE W-20—Typical modified L_m–D_m diagram.

(iv) The test procedure shall be repeated on the same frame utilizing L ... input; see Figure W-18) and E_{ti}. Rear load application shall be uniformly distributed along a maximum projected dimension of 27 in. (686 mm.) and a maximum area of 160 sq. in. (1,032 sq. cm.) normal to the direction of load application. The load shall be applied to the upper extremity of the frame at the point which is midway between the centerline of the seat and the inside of the frame upright.

(h) *Dynamic test*—(1) *Test conditions.* (i) The protective frame and tractor shall meet the requirements of paragraphs (e) (2) or (3) of this section, as appropriate.

(ii) The dynamic loading shall be produced by use of a 4,410 lb. (2,000 kg.) weight acting as a pendulum. The impact face of the weight shall be 27 plus or minus 1 in. by 27 plus or minus 1 in. (686+ or −25 mm.) and shall be constructed so that its center of gravity is within 1 in. (25.4 mm.) of its geometric center. The weight shall be suspended from a pivot point 18–22 ft. (5.5–6.7 m.) above the point of impact on the frame and shall be conveniently and safely adjustable for height. (See Figure W-21.)

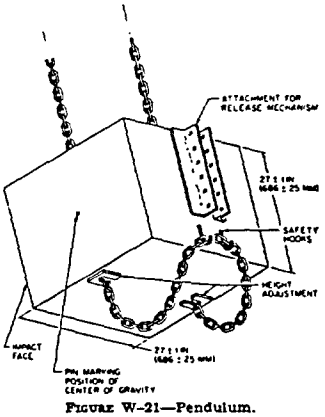

FIGURE W-21—Pendulum.

(iii) For each phase of testing, the tractor shall be restrained from moving when the dynamic load is applied. The restraining members shall be of 0.5–0.63 in. (12.5–16 mm.) steel cable and points of attaching restraining members shall be located an appropriate distance behind the rear axle and in front of the front axle to provide a 15°–30° angle between a restraining cable and the horizontal. The restraining member shall either be in the plane in which the center gravity of the pendulum will swing or more than one restraining cable shall give a resultant force in this plane. (See Figure W-22.)

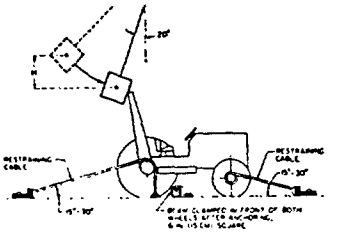

FIGURE W-22—Method of impact from rear.

(iv) The wheel tread setting shall comply with the requirements of paragraph (e) (6) of this section. The tires shall have no liquid ballast and shall be inflated to the maximum operating pressure recommended by the tire manufacturer. With specified tire inflation, the restraining cables shall be tightened to provide tire deflection of 6–8 percent of nominal tire section width. After the vehicle is properly restrained, a wooden beam 6 x 6 in. (15 x 15 cm.) shall be driven tightly against the appropriate wheels and clamped. For the test to the side, an additional wooden beam shall be placed as a prop against the wheel nearest the operator's station and shall be secured to the floor so that it is held tightly against the wheel rim during impact. The length of this beam shall be chosen so that when it is positioned against the wheel rim, it is at an angle of 25°–40° to the horizontal. It shall have a length 20–25 times its depth and a width two to three times its depth. (See Figures W-22 and W-23.)

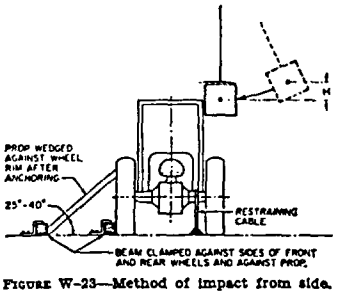

FIGURE W-23—Method of impact from side.

(v) Means shall be provided indicating the maximum instantaneous deflection along the line of impact. A simple friction device is illustrated in Figure W-23.

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(vi) No repair or adjustments may be carried out during the test.

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

(2) *Test procedure*—(i) *General.* The frame shall be evaluated by imposing dynamic loading to rear followed by a load to the side on the same frame. The pendulum dropped from the height (see definition "H" in paragraph (j)(3) of this section) imposes the dynamic load. The position of the pendulum shall be so selected that the initial point of impact on the frame 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, if used, shall not influence the attitude of the block.

(ii) *Impact at rear.* The tractor shall be properly restrained according to subparagraphs (1) (iii) and (iv) of this paragraph. The tractor shall be positioned with respect to the pivot point of the pendulum such that the pendulum is 20° from the vertical prior to impact, as shown in Figure W-22. The impact shall be applied to the upper extremity of the frame at the point which is midway between the centerline of the seat and the inside of the frame upright of a new frame.

(iii) *Impact at side.* The block and restraining shall conform to subparagraphs (1) (iii) and (iv) of this paragraph. The point of impact shall be that structural member of the protective frame likely to hit the ground first in a sideways accidental upset. The side impact shall be applied to the side opposite that used for rear impact.

(j) *Performance requirements*—(1) *General.* (i) The frame, overhead weather shield, fenders, or other parts in the operator area may be deformed but shall not shatter or leave sharp edges exposed to the operator, or violate dimensions as shown in Figures W-16 and W-17 as follows:

D=2 in. (51 mm.) inside of frame upright to vertical centerline of seat.
E=30 in. (762 mm.).
F=Not less than 0 in. and not more than 12 in. (305 mm.), measured at centerline front of seat backrest to crossbar along the line of load application as shown in Figure W-17.
G=24 in. (610 mm.).

(ii) The material and design combination used in the protective structure must be such that the structure can meet all prescribed performance tests at zero degrees Fahrenheit in accordance with § 1926.1001(f)(2)(iv).

(2) *Vehicle overturn performance requirements.* The requirements of this paragraph (j) must be met in both side and rear overturns.

(3) *Static test performance requirements.* Design factors shall be incorporated in each design to withstand an overturn test as prescribed in this paragraph (j). The structural requirements will be generally met if FER is greater than 1 and FSB is greater than K-1 in both side and rear loadings.

(4) *Dynamic test performance requirements.* Design factors shall be incorporated in each design to withstand the overturn test prescribed in this paragraph (j). The structural requirements will be generally met if the dimensions in this paragraph (j) are adhered to in both side and rear loads.

(j) *Definitions applicable to this section.* (1) SAE J333a, Operator Protection for Wheel-Type Agricultural and Industrial Tractors (July 1970) defines "agricultural tractor" as a "wheel-type vehicle of more than 20 engine horsepower designed to furnish the power to pull, carry, propel, or drive implements that are designed for agricultural usage." Since this Part 1926 applies only to construction work, the following definition of "agricultural tractor" is adopted for purposes of this subpart: "Agricultural tractor" means a wheel-type vehicle of more than 20 engine horsepower, used in construction work, which is designed to furnish the power to pull, propel, or drive implements.

(2) "Industrial tractor" means that class of wheeled type tractor of more than 20 engine horsepower (other than rubber-tired loaders and dozers described in § 1926.1001), used in operations such as landscaping, construction services, loading, digging, grounds keeping, and highway maintenance.

(3) The following symbols, terms, and explanations apply to this section:

E_{is}=Energy input to be absorbed during side loading. $E_{is}=723+0.4$ W ft.-lb. ($E'_{is}=100+0.12$ W', m.-kg.).

E_{ir}=Energy input to be absorbed during rear loading. $E_{ir}=0.47$ W ft.-lb. ($E'_{ir}=0.14$ W', m.-kg.).

W=Tractor weight as prescribed in § 1926.1002 (e)(1) and (e)(3), in lb. (W', kg.).

L=Static load, lb. (kg.).

D=Deflection under L, in. (mm.).

L-D=Static load-deflection diagram.

L_m-D_m=Modified static load-deflection diagram (Figure W-20). To account for increase in strength due to increase in strain rate, raise L in plastic range to L x K.

K=Increase in yield strength induced by higher rate of loading (1.3 for hot rolled low carbon steel 1010–1030). Low carbon is preferable; however, if higher carbon or other material is used, K must be determined in the laboratory. Refer to Charles H. Norris, et al., Structural Design for Dynamic Loads (1959), p. 3.

L_{max}=Maximum observed static load.

Load Limit=Point on L-D curve where observed static load is 0.8 L_{max} (refer to Figure W-19).

E_s=Strain energy absorbed by the frame, ft.-lb. (m.-kg.) area under L_m-D_m curve.

FER=Factor of energy ratio, $FER=E_s/E_{ir}$; also $=E_s/E_{is}$.

P_s=Maximum observed force in mounting connection under static load, L, lb. (kg.).

FSB=Design margin for mounting connection $FSB=(P_s/P_b)-1$.

H=Vertical height of lift of 4,410 lb. (2,000 kg.) weight, in. (H', mm.). The weight shall be pulled back so that the height of its center of gravity above the point of impact is defined as follows: $H=4.92+0.00190$ W or ($H'=125+0.107$ W') (Figure W-24).

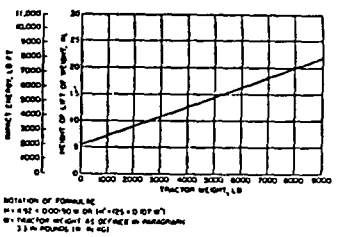

FIGURE W-24—Impact energy and corresponding lift height of 4,410 lb. (2,000 kg.) weight.

(k) *Source of standard.* The standard in this section is derived from, and restates, Society of Automotive Engineers Standard J334a (July 1970), Protective Frame Test Procedures and Performance Requirements. This standard shall be resorted to in the event that questions of interpretation arise. The standard appears in the 1971 SAE Handbook, which may be examined in each of the Regional Offices of the Occupational Safety and Health Administration.

§ 1926.1003 Overhead protection for operators of agricultural and industrial tractors.

(a) *General*—(1) *Purpose.* When overhead protection is provided on wheel-type agricultural and industrial tractors, the overhead protection shall be designed and installed according to the requirements contained in this section. The provisions of § 1926.1001 for rubber-tired dozers and rubber-tired loaders may be used in lieu of the standards contained in this section. The purpose of the standard is to minimize the possibility of operator injury resulting from overhead hazards such as flying and falling objects, and at the same time to minimize the possibility of operator injury from the cover itself in the event of accidental upset.

(2) *Applicability.* This standard applies to wheel-type agricultural tractors used in construction work and to wheel-type industrial tractors used in construction work. See § 1926.1002 (b) and (j). In the case of machines to which § 1926.604 (relating to site clearing) also applies, the overhead protection may be either the type of protection provided in § 1926.604 or the type of protection provided by this section.

(b) *Overhead protection.* When overhead protection is installed on wheel-type agricultural or industrial tractors used in construction work, it shall meet the requirements of this paragraph. The overhead protection may be constructed of a solid material. If grid or mesh is used, the largest permissible opening shall be such that the maximum circle which can be inscribed between the elements of the grid or mesh is 1.5 in. (38 mm.) in diameter. The overhead protection shall not be installed in such a way as to become a hazard in the case of upset.

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(c) *Test procedures—general.* (1) The requirements of § 1926.1002 (d), (e), and (f) shall be met.

(2) Static and dynamic rear load application shall be uniformly distributed along a maximum projected dimension of 27 in. (686 mm.) and a maximum area of 160 in.² (1,032 cm.²) normal to the direction of load application. The load shall be applied to the upper extremity of the frame at the point which is midway between the centerline of the seat and the inside of the frame upright.

(3) The static and dynamic side load application shall be uniformly distributed along a maximum projected dimension of 27 in. (686 mm.) and a maximum area of 160 in.² (1,032 cm.²) normal to the direction of load application. The direction of load application is the same as in § 1926.1002 (g) and (h). To simulate the characteristics of the structure during an upset, the center of load application may be located from a point 24 in. (610 mm.) (K) forward to 12 in. (305 mm.) (K) forward to 12 in. (305 mm.) (L) rearward of the front of the seat backrest to best utilize the structural strength. See Figure W-25.

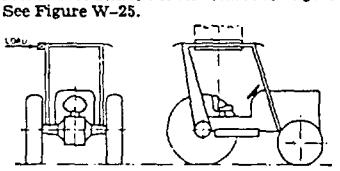

FIGURE W-25—Location for side load.

(d) *Drop test procedures.* (1) The same frame shall be subjected to the drop test following either the static or dynamic test.

(2) A solid steel sphere or material of equivalent spherical dimension weighing 100 lb. (45.4 kg.) shall be dropped once from a height 10 ft. (3,048 mm.) above the overhead cover.

(3) The point of impact shall be on the overhead cover at a point within the zone of protection as shown in Figure W-26, which is furthest removed from major structural members.

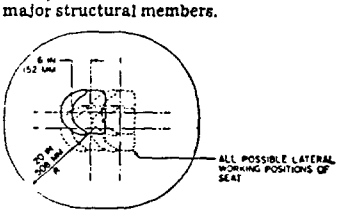

FIGURE W-26—Zone of protection for drop test.

(e) *Crush test procedure.* (1) The same frame shall be subjected to the crush test following the drop test and static or dynamic test.

(2) The test load shall be applied as shown in Figure W-27 with the seat positioned as specified in § 1926.1002(d)(4). Loading cylinders shall be pivotally mounted at both ends. Loads applied by each cylinder shall be equal within 2 percent, and the sum of the loads of the two cylinders shall be two times the tractor weight as set forth in § 1926.1002(e)(1). The maximum width of the beam illustrated in Figure W-27 shall be 6 in. (152 mm.).

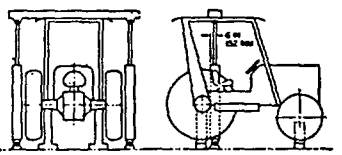

FIGURE W-27—Method of load application for crush test.

(f) *Performance requirements*—(1) *General.* The performance requirements set forth in § 1926.1002(l) (2), (3), and (4) shall be met.

(2) *Drop test performance requirements.* (i) Instantaneous deformation due to impact of the sphere shall not enter the protected zone as illustrated in Figures W-25, W-26, and W-28.

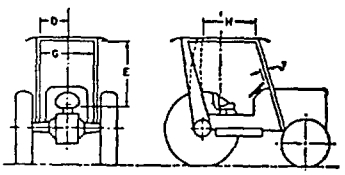

FIGURE W-28—Protected zone during crush and drop tests.

(ii) In addition to the dimensions set forth in § 1926.1002(l)(1)(i), the following dimensions apply to Figure W-28:

H=17.5 in. (444 mm.)
J=2 in. (50.8 mm.) measured from the outer periphery of the steering wheel.

(3) *Crush test performance requirements.* The protected zone as described in Figure W-28 must not be violated.

(g) *Source of standard.* This standard is derived from, and restates, the portions of Society of Automotive Engineers Standard J167 which pertain to overhead protection requirements. The full title of the SAE standard is: Protective Frame with Overhead Protection—Test Procedures and Performance Requirements. The SAE standard shall be resorted to in the event that questions of interpretation arise. The SAE standard appears in the 1971 SAE Handbook, which may be examined in each of the Regional Offices of the Occupational Safety and Health Administration.

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