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SURFACE VEHICLE RECOMMENDED PRACTICE

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Cab Roof Strength Evaluation—Dynamic Loading Heavy Trucks

1. ***Scope***—This SAE Recommended Practice describes the test procedures for conducting dynamic cab roof strength tests for heavy-truck applications. Its purpose is to establish recommended test procedures which will standardize the procedure for heavy trucks. Descriptions of the test set-up, test instrumentation, photographic/video coverage, and the test fixtures are included.

2. ***References***

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

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

SAE J211-1—Instrumentation for Impact Test—Part 1: Electronic Instrumentation
SAE J211-2—Instrumentation for Impact Test—Part 2: Photographic Instrumentation
SAE CRP-9—"Heavy Truck Crashworthiness (Statistics, Accident Reconstruction, Occupant Dynamics Simulation)", March 1995.
SAE CRP-13—"Heavy Truck Crashworthiness (Phase III)," April 1997.

3. ***Definitions***

3.1 Platen—A structurally stiff, flat plate.

3.2 Cab Mount—The component or components used to connect the cab to the chassis frame rails.

3.3 Static Stability Position—The roll position at which a vehicle would be statically balanced on either left- or right-side wheels.

4. ***Test Configuration***—The cab roof strength test is designed to evaluate the resistance of a heavy truck cab in a 180-degrees rollover. The loading is divided into two phases, a dynamic pre-load that simulates the side loading on the upper cab as the vehicle rolls past 90 degrees, and a roof loading that simulates the loading on the cab when the vehicle is inverted. Both phases are conducted on a cab attached to actual or simulated frame rails with its standard cab mounts. The loading is applied to the cab with a platen. The loading for both phases is generated with the inertia of the platen and the structure carrying it.

To assist with the description of the platen orientation and direction of motion, a reference system is defined for the cab and chassis relative to its original orientation on the vehicle. This is illustrated in Figure 1.

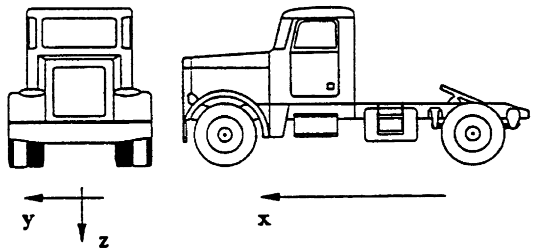

FIGURE 1—REFERENCE FRAME

5. ***Dynamic Pre-Load***—In the dynamic pre-load, the platen impacts one side of the cab, with the cab mounted at an angle so that the platen initially contacts the upper portion of the cab. The platen is oriented vertically, and aligned parallel to the chassis's longitudinal axis. Either side of the cab may be loaded, depending on whether a driver side or passenger side leading rollover is to be simulated. The chassis of the test cab shall be affixed to the ground at a roll angle of 20 degrees. The longitudinal axis of the chassis shall be perpendicular to the direction of travel of the platen. The pre-load configuration is shown in Figure 2. The target speed of the platen and its supporting structure is computed as described in the following sections.

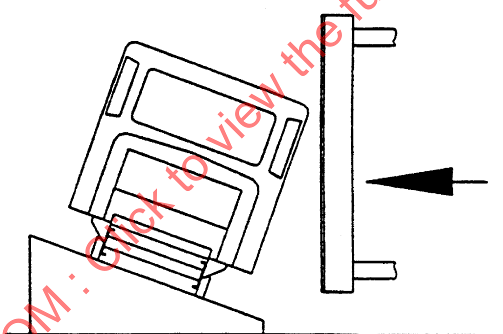

FIGURE 2—DYNAMIC PRE-LOAD CONFIGURATION

5.1 Pre-Load Energy Computation—The energy to pre-load the cab comes from the kinetic energy of the platen and its supporting structure. For the pre-load phase of the test, the target energy level is 1.6 times a reference energy level up to a maximum recommended target level of 17 625.6 J (13 000 ft-lb). The recommended maximum is based upon the limited testing performed to evaluate this test procedure and to produce cab damage consistent with rollover accidents. Manufacturers can, at their discretion, exceed this maximum. The reference energy level is an approximation of the kinetic energy developed when a vehicle is tipped from its static stability position to a rest position on its side. Both positions are illustrated in Figures 3 and 4.

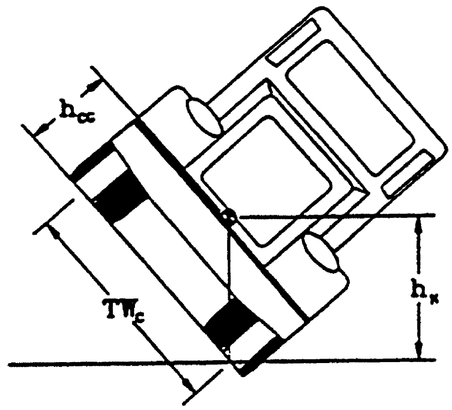

FIGURE 3—STATIC STABILITY POSITION

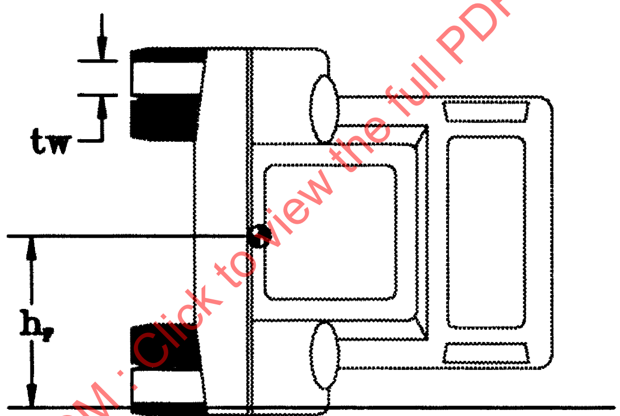

FIGURE 4—90-degree ROLL POSITION

The calculation assumes that all the potential energy at the static stability position is converted to kinetic energy at the ground contact point. Basic dimensions, weight, and the center of gravity (cg) height of the vehicle are needed for this calculation. This computed energy level shall be used in the following sections in determining the platen impact speed.

$$TW_c = \frac{(TW_F + TW_R)}{2} \qquad \text{(Eq. 1)}$$

$$h_n = \sqrt{\left(\frac{TW_c}{2}\right)^2 + h_{cg^2}}$$

$$h_f = \frac{(TW_c + tw)}{2}$$

$$KE = mg*(h_N - h_F)$$

where:

TW_F = Trackwidth of front wheels
TW_R = Trackwidth of the rear wheels, in the case of dual wheels, use the outermost wheels
TW_c = Trackwidth representation at the cg location
tw = tire tread width
h_{cg} = Center of gravity height of level vehicle
h_N = Height of the cg at the static stability position
h_F = Height of the cg at the ground contact position
KE = Reference kinetic energy level
TE = Target impact energy
mg = weight of vehicle

5.2 Platen—A rigid platen shall be used to simulate ground contacting the side of the cab. The platen shall be sufficiently large and positioned such that the cab will only be in contact with the interior of the platen, not the outer edge. The face of the platen is to be covered with a 19 mm (3/4 in) thick layer of plywood.

For the dynamic pre-load phase of the test, the platen and structure that carries it shall have a mass of 2268 to 6803.9 kg (5000 to 15 000 lb). Two recommended methods for supporting the platen are described in the following sections.

5.3 Carriage Option—With this option the, platen is attached to the front of a carriage. The carriage is then towed to a target impact speed and released to roll into the cab. Ballast shall be added as necessary to the rear of the carriage to stabilize it and obtain the target mass. The platen impact speed to obtain the desired pre-load energy level is computed with Equation 2:

$$V_{PL} = \sqrt{\frac{2*TE}{M}} \quad \text{(Eq. 2)}$$

where:

M = Mass of the platen and carriage
TE = The smaller value of either 17 625.6 J (13 000 ft-lb) or (1.6 * KE)
V_{PL} = Target speed for the pre-load test

5.4 Pendulum Option—With this option, the platen is attached to a pendulum. The pendulum is then pulled back to a height determined to obtain the target impact speed and released to swing into the cab. Ballast shall be added as necessary to the pendulum to reach the target mass. The pendulum should be positioned relative to the cab so that the platen is vertical at impact. The distance from the bottom of the platen to the pivot point should be at least 610 cm (20 ft) to ensure that the there is relatively little vertical motion of the platen during the crush phase of the test. This will also ensure that the platen's orientation remains nearly vertical throughout the impact. The platen impact speed to obtain the desired pre-load energy level is computed from the following equations. With a simple pendulum, the system has rotational as well as linear kinetic energy. All of the kinetic energy can be accounted for with a simple computation if the moment of inertia is calculated at the pivot axis.

$$\omega_{PL} = \sqrt{\frac{2*TE}{J_{PIVOT}}} \quad \text{(Eq. 3)}$$

where:

J_{PIVOT} = Moment of inertia of pendulum and platen about the pivot axis
TE = The smaller value of either 17 625.6 J (13 000 ft-lb) or (1.6 * KE)
w_{PL} = Target rotational speed for the pre-load test

For comparison purposes, the impact speed should be computed as the pendulum speed at the mid-height of the cab side window.

$$V_{PL} = R*\omega_{PL} \qquad \text{(Eq. 4)}$$

where:

R = Vertical distance from the pivot axis to the mid-height of the side window
V_{PL} = Target speed for the pre-load test

A bifilar pendulum design may be used to constrain the platen in a vertical orientation. For a bifilar pendulum, the arms of the pendulum have rotational kinetic energy, but the mass at the end of the pendulum, including the platen, only has linear kinetic energy.

$$V_{PL} = \sqrt{\frac{2*TE}{M + n*J_{ARM}/L^2}} \qquad \text{(Eq. 5)}$$

where:

M = Mass at the end of the bifilar pendulum, including the platen, ballast, and supporting structure
J_{ARM} = Moment of inertia of pendulum arms about the pivot axis
L = Length of each arm from the upper to the lower pivot
n = Number of pendulum arms
TE = The smaller value of either 17 625.6 J (13 000 ft-lb) or (1.6 * KE)
V_{PL} = Target speed for the pre-load test

6. ***Dynamic Roof Load***—In this phase, a platen that is parallel to the xy plane of the chassis is impacted into the roof of the cab, while traveling parallel to the vertical axis of the chassis. This can be implemented by affixing the chassis to ground, with it rotated so that the longitudinal axis of the chassis is horizontal and the lateral axis is vertical. With the side of the cab that was impacted in the pre-load phase oriented downward, a vertical platen would then travel horizontally into the roof. This roof loading configuration is shown in Figure 5.

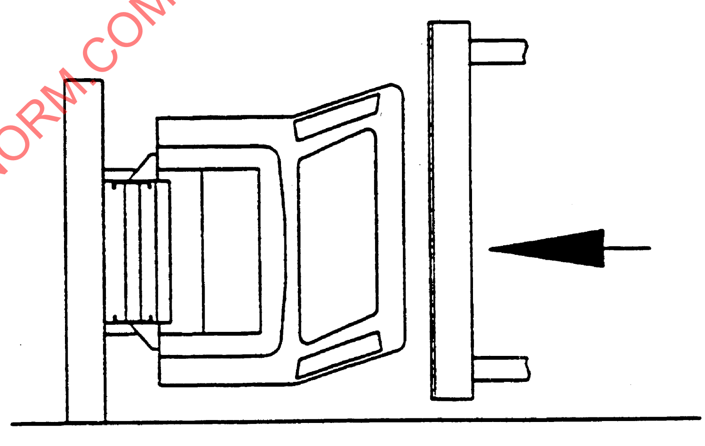

FIGURE 5—DYNAMIC ROOF LOAD CONFIGURATION

6.1 **Platen—**A rigid platen shall be used to simulate ground contacting the roof of the cab. The platen must be sufficiently large and positioned such that the cab will contact only the interior of the platen, not the edges.

A linear-bearing system shall be included between the platen and its supporting structure to allow for lateral motion of the cab roof away from the side that was impacted in the pre-load phase. In the recommended configuration described previously, the platen weight would tend to oppose this motion, thus the weight must be less than 25% of the chassis cab vehicle.

The combined weight of the platen and structure that carries it shall be 2268 to 6803.9 kg (5000 to 15 000 lb). Two recommended methods for supporting the platen are described in the following sections. Either method could be used for both phases of the test, with the addition of the linear bearing between the platen and supporting structure for the roof load phase.

6.2 **Carriage Option—**With this option, the platen is attached to the front of a carriage. The carriage is then towed to a target impact speed and released to roll into the cab. Ballast shall be added as necessary to the rear of the carriage to stabilize it and obtain the target mass.

6.3 **Pendulum Option—**With this option, the platen is attached to a pendulum. The pendulum is then pulled back to a height determined to obtain the target impact speed and released to swing into the cab. Ballast shall be added as necessary to the pendulum to reach the target mass. The pendulum should be positioned relative to the cab so that the platen is vertical at impact. The distance from the bottom of the platen to the pivot point should be at least 610 cm (20 ft) to ensure that there is relatively little vertical motion of the platen during the crush phase of the test. This will also ensure that the platen's orientation remains nearly vertical throughout the impact. A bifilar pendulum design may be used to constrain the platen in a vertical orientation.

7. ***Cab Mounting—***The cab shall be evaluated with its standard cab mounts. The cab mounts shall either be mounted to the vehicle's stock frame rails or to a simulated chassis that locates the cab mounts in their standard location and orientation. If testing is conducted using actual frame rails, the frame rails shall be rigidly attached to the ground. If a simulated chassis is used, it shall not deform during the test. Hardware used to attach the cab mounts to the simulated chassis shall be the same type and strength as the standard hardware used to attach the cab mounts to the standard chassis.

Cab mounts employing pneumatic ride control should be pressurized to produce the manufacturer recommended ride height.

8. ***Instrumentation—***To record the load applied to the cab structure, load cells shall be installed between the platen and its supporting structure. Measured load must be scaled to obtain the load applied to the cab as follows:

$$F_{CAB} = F_{MEASURED} * \left(\frac{W_{TOTAL}}{W_{SUPPORT}}\right) \quad \text{(Eq. 6)}$$

where:

F_{CAB} = Load applied to the cab
$F_{MEASURED}$ = Measured load
W_{TOTAL} = Combined weight of the platen and supporting structure
$W_{SUPPORT}$ = Total weight minus the platen weight

The displacement of the platen shall also be measured and recorded. One method for measuring platen motion is to attach accelerometers to the platen or supporting structure. Displacement of the platen during the crush phase of the test is determined by twice integrating the acceleration data. All measurements should be recorded and filtered according to the most recent version of SAE J211-1 and SAE J211-2.