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SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J1981

REV. MAY2002

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Superseding J1981

(R) Road Hazard Impact Test for Wheel and Tire Assemblies (Passenger Car, Light Truck, and Multipurpose Vehicles)

Foreword—This SAE Recommended Practice provides a uniform test procedure for evaluating the effect, on wheel and tire assemblies, of impacting a road hazard such as a pothole. Since this document was first issued comparative testing with instrumented wheels has shown that an improved simulation of a pothole impact can be achieved by setting the striker at an angle. For this reason, the document has been revised to show a striker that can be set to impact the wheel and tire assembly at angles between ±6 degrees at 1 degree increments. The method of articulating the striker is optional but the geometry and mass distribution of the pendulum must be as specified. The equipment can now be used to more closely simulate the conditions of a vehicle pothole test or can be used to evaluate inboard and outboard tire and rim damage separately. Threshold conditions at which damage first occurs can be determined accurately.

1. Scope—The test is designed to evaluate the frontal impact resistance of wheel and tire assemblies used with passenger cars, light trucks and multi-purpose vehicles. The test is specifically related to vehicle pothole tests that are undertaken by most vehicle manufacturers. The scope has been expanded to allow the use of a striker that can be angled to preferentially impact the inboard and outboard wheel flange. For side impact of the outboard rim flange only, please refer to SAE J175. This SAE Recommended Practice does not provide standards of performance.

2. References

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

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

SAE J175—Wheels—Impact Test Procedure—Road Vehicles
SAE J1982—Wheels for Passenger Cars and Light Trucks

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this specification.

2.2.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Dr. Warrendale, PA 15096-0001.

SAE Technical Paper 940534—Development of the SAE J1981 Road Hazard Impact Test for Wheel and Tire Assemblies. Authors Trevor Brown and Rick Wallace – 1994

2.2.2 ISO PUBLICATIONS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO 7141—Road vehicles—Wheels—Impact procedures
ISO 3991— Wheel/rim for pneumatic tyres—Nomenclature, designation and marking

3. Definitions—For terms and definitions specific to passenger car, light truck and multi-purpose vehicle wheels please refer to SAE J1982.

3.1 Frontal Impact Test Fixture—Test fixture for evaluating the frontal (radial) impact performance of a wheel and tire assemblies.

3.2 Drop Mass—The mass acting through the striker.

3.3 Striker—The shaped projection bolted to the pendulum that impacts the wheel and tire assembly.

3.4 Drop Height—The falling height of the drop mass. (The height of the striker mass center above the wheel hub center).

3.5 Drop Angle—The angle through which the pendulum falls before striking the rim flange. (Using an angle transducer on the pendulum is the best way to calculate the drop height, particularly when the striker is set at an angle.)

3.6 Striker Mass Center—The intersection of the vertical axis through the fulcrum and the horizontal axis through the striker nose center with the pendulum hanging freely.

3.7 Wheel Holding Fixture—Fixture used to securely hold the wheel/tire assembly during testing.

3.8 Pendulum—The swing arm having a fulcrum at one end and the striker at the other end.

3.9 Bed Plate—A substantial member used to locate and securely clamp the wheel holding fixture.

3.10 Frame—A substantial member used to support the fulcrum of the pendulum.

3.11 Catcher—A mechanism that drops into place, after impact, to prevent a second hit.

4. Test Procedure

4.1 Wheels and Tires for Test—Only fully processed new wheels and tires intended for use on passenger cars, light trucks and multi-purpose vehicles should be used. (The test wheels should not subsequently be used on a vehicle).

4.2 Equipment—Road hazard test fixture (Figure 1) consisting of:

a. A 1828.8 mm (6ft) pendulum having a drop mass of 54 kg as shown in (Figure 2).
b. A rigid frame to support the pendulum.
c. A device for raising and releasing the pendulum.
d. A device (catcher) for limiting the impact to one hit.
e. A very low friction (self-aligning ball bearing) fulcrum.
f. Striker (Figure 3).
g. Striker Bracket (Figure 4) that allows the Striker to be set for inboard and outboard flange testing or for pothole simulation testing.
h. Striker Assembly (Figure 5) with angle adjustment of ±6 degrees. Bolt sizes are optional but should be substantial enough to resist all impact loads.
i. Bed Plate for rigid support of the frame and wheel holding fixture

j. A wheel holding fixture having a spindle height that matches the height of the striker nose when the pendulum is hanging freely. The stiffness of this fixture is very important; it should very closely approximate the stiffness of the fixture shown in Figure 6.

k. Gage for measuring the drop height or drop angle.

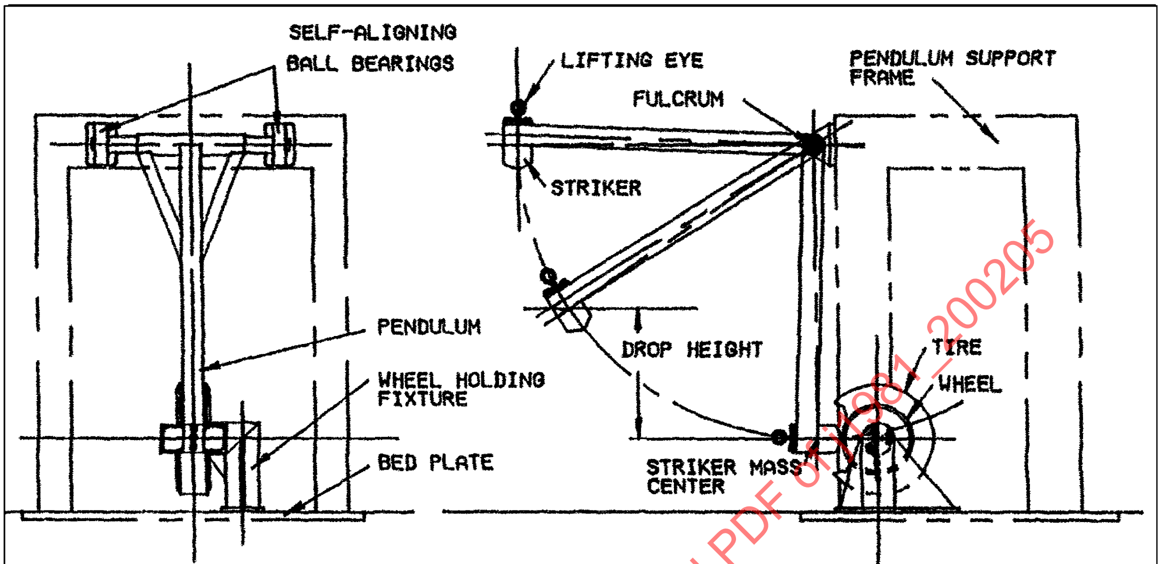

FIGURE 1—SAE J1981 ROAD HAZARD TEST FIXTURE

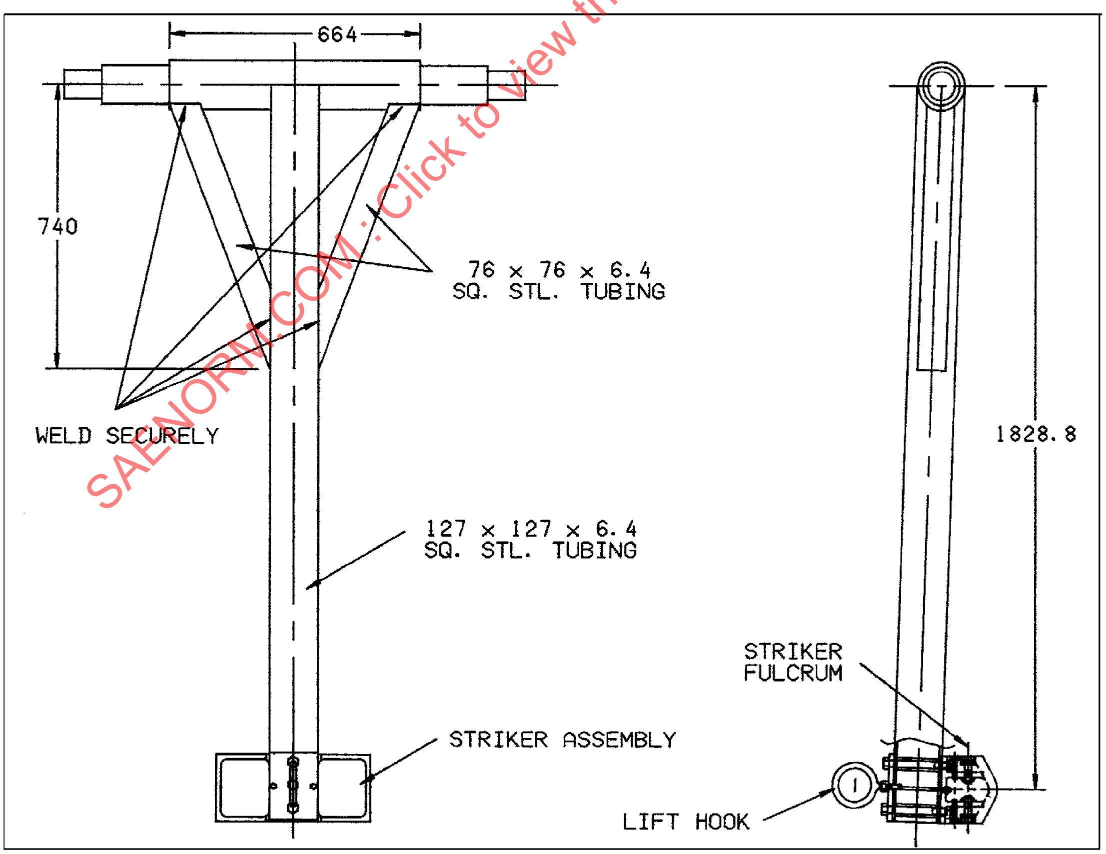

FIGURE 2—SAE J1981 PENDULUM

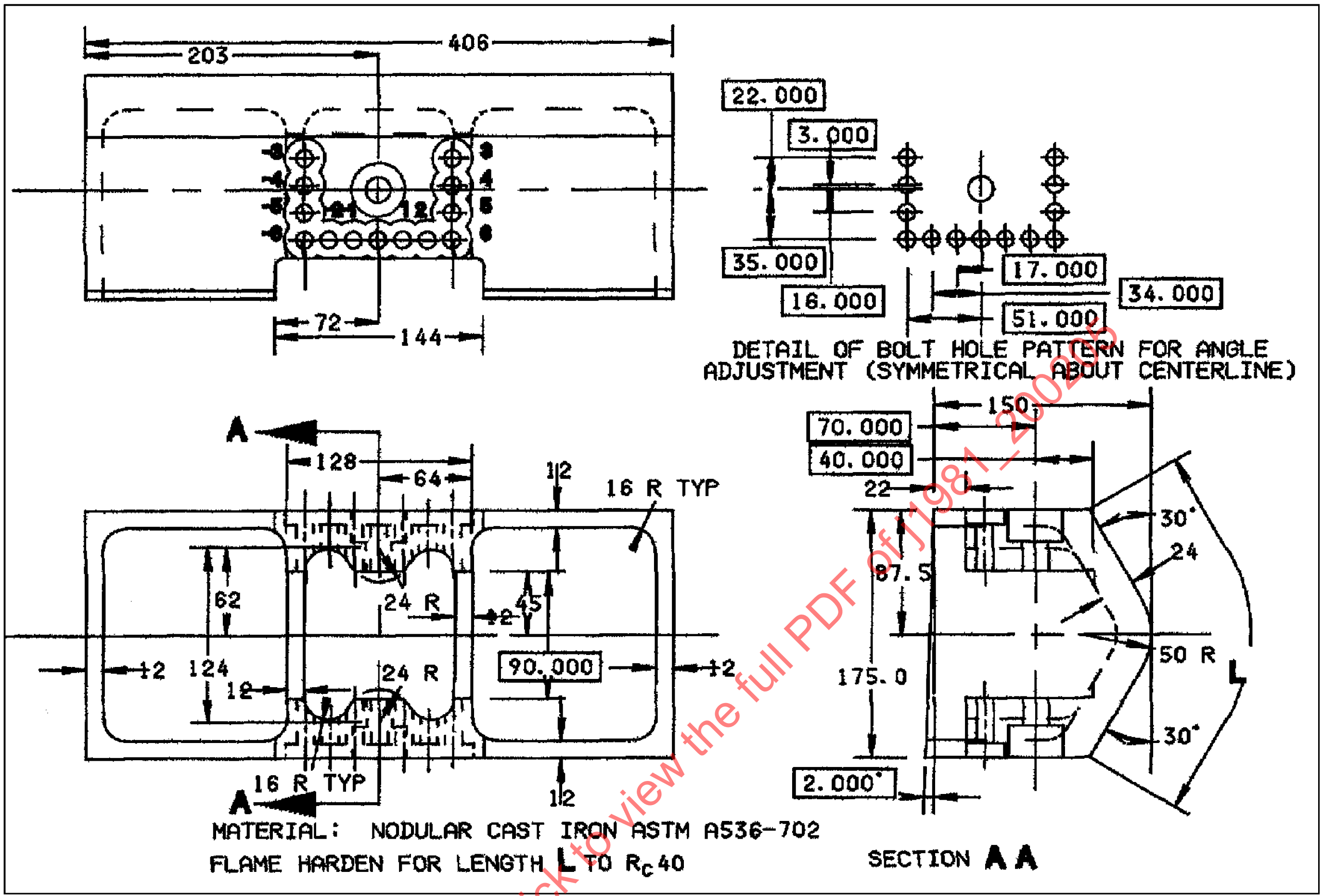

FIGURE 3— SAE J1981 STRIKER

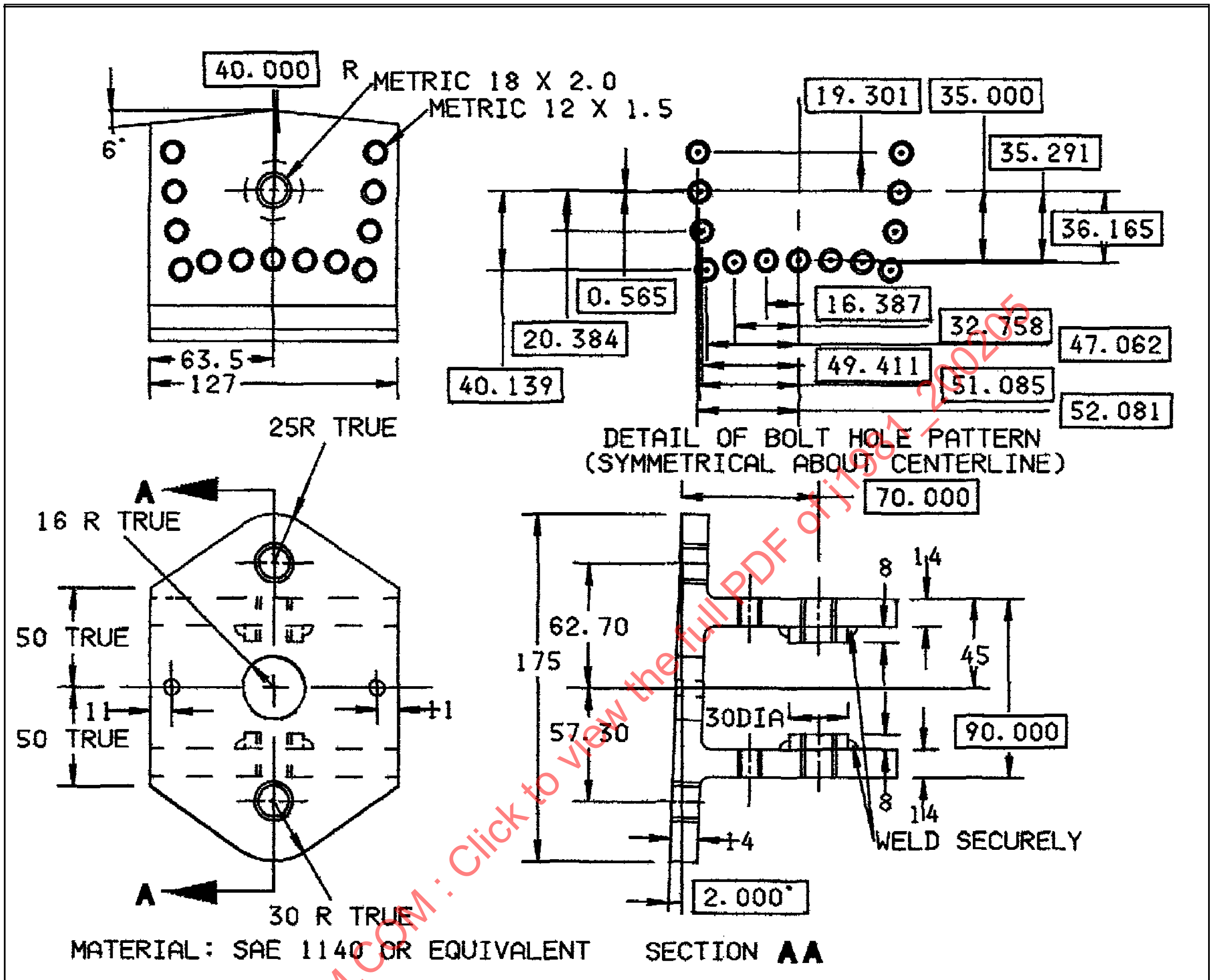

FIGURE 4—SAE J1981 STRIKER BRACKET

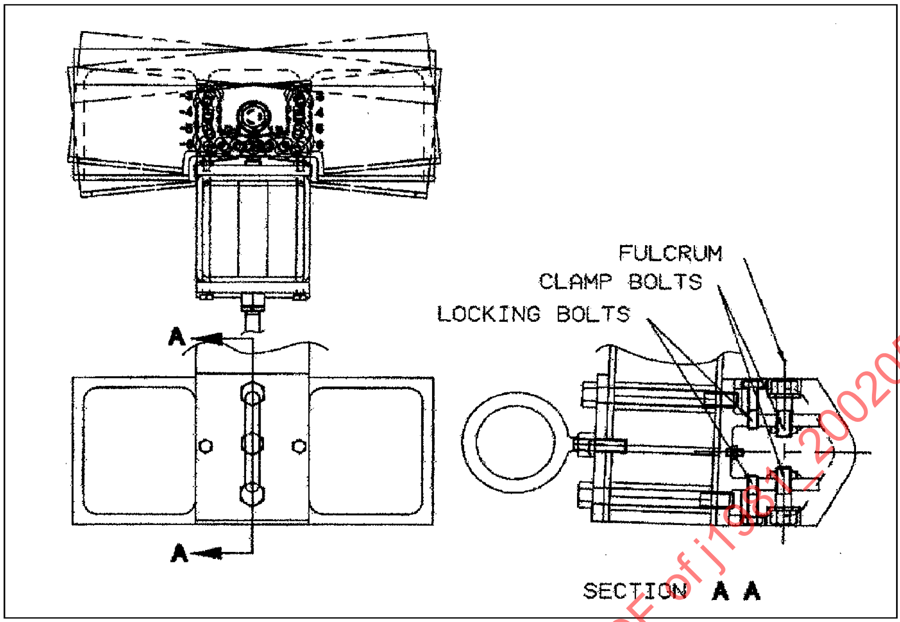

FIGURE 5—SAE J1981 STRIKER ASSEMBLY

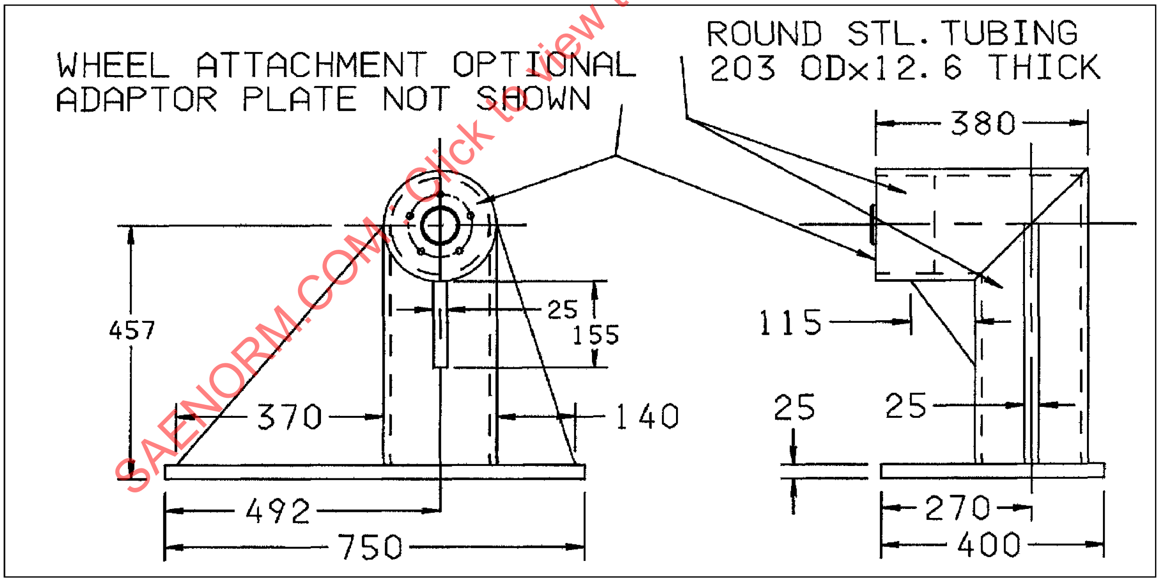

FIGURE 6—SAE J1981 WHEEL HOLDING FIXTURE

4.2.1 EQUIPMENT CALIBRATION—The impact force on the wheel and tire assembly depends upon the length of the pendulum, the inertia of the pendulum, the shape and angle of the striker and the friction at the fulcrum. To be sure the impact force is correct and distributed properly to the inboard and outboard rims make the following checks and calibrations:

a. With the pendulum hanging freely and the striker parallel to the wheel axis, locate and mark the striker mass center used to determine the drop height. The line between the mass center and the fulcrum is required in order to set the pendulum in a “horizontal” position for checks c and d (Figure 7).
b. Confirm the pendulum length (fulcrum to striker mass center) at 1828.8 mm (6 ft).
c. With the pendulum horizontal and the striker set at zero angle, check that the mass at the striker nose is 54 kg (Figure 7).
d. Confirm that the total mass of the pendulum is 164 kg (Figure 7)
e. Confirm that the included angle of the striker nose is 120 degrees.
f. Confirm that the nose radius of the striker is 50 mm.
g. Confirm that there is negligible friction or binding of the fulcrum by measuring the velocity of the striker 5 degrees before bottom dead center when released from the horizontal position. The velocity should be 23.33 km/h. (A slave wheel and tire must be used to stop the pendulum at BDC).
h. Check that the wheel center height is the same as the striker mass center height at impact.

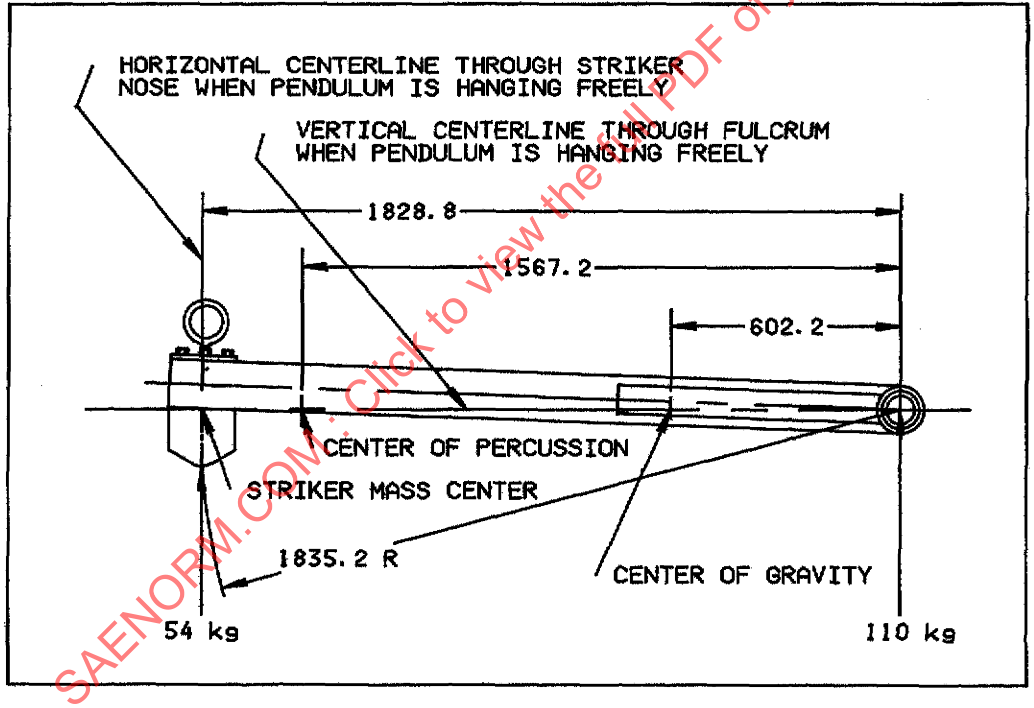

FIGURE 7—PENDULUM GEOMETRY AND MASS DISTRIBUTION

4.3 Procedure—When running the impact test all necessary precautions must be taken to provide a safe operation.

4.3.1 Mount the wheel to the holding fixture and move the holding fixture or pendulum laterally so that the striker is centered with the rim flanges. With the pendulum hanging freely and the striker set parallel to the wheel axis move the holding fixture fore or aft until the striker nose just touches the rim flanges. Bolt the wheel holding fixture securely to the bed plate and lock in place with a suitable stop plate. Remove the wheel from the holding fixture.

4.3.2 Set and lock the striker at the angle required for outboard or inboard flange impact.

4.3.3 Mount the test tire to the test wheel and inflate to the required pressure. Install the tire and wheel assembly to the holding fixture and tighten the wheel fasteners to the specified torque. Orient the wheel spoke to the required test position.

4.3.4 Raise the pendulum to the predetermined drop height or equivalent angle. (Height of the **striker mass center** above the wheel hub center). Set the trigger of the device that prevents the second hit.

4.3.5 Allow the pendulum to fall freely from this predetermined height.

4.3.6 Note and record any visible damage to either rim.

4.3.7 Repeat the procedure if the wheel is to be tested with a different spoke orientation.

NOTE— When observing for visible damage the same test wheel can be reoriented and retested at other impact sites. Impact sites should be separated by at least 100 mm.

5. Performance Criteria—It is not within the scope of this document to determine levels of performance. The angle at which the striker should be set, to simulate a pothole test, must be determined using vehicle test data. Once test criteria have been set, the test will accurately determine the threshold at which damage begins to occur and relate this to the field performance of individual vehicles.

6. Notes

6.1 Marginal Indicia—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE WHEELS STANDARDS COMMITTEE

APPENDIX A

A.1 Pendulum Specifications

A.1.1 Fixed

a. Center of Gravity from Fulcrum (a) = 0.6022 m
b. Center of Percussion from C of G (c) = 0.9650 m
c. Moment of Inertia about Fulcrum (I) = 154.77 kg.m²
d. Radius of Gyration about axis through C of G (k) = 0.7623m
e. Fulcrum to Striker Mass Center Length (L) = 1.8288 m
f. Total Mass of Pendulum (m) = 164.0 kg
g. Periodic Time (n) = 0.39812 oscillations/s
h. Equivalent Mass at Center of Percussion (p) = 63 kg
i. Fulcrum to Striker Nose (r) = 1.8352 m

A.1.2 Variable

a. Fall Height of Pendulum C of G (h)
b. Fall Height of Striker Mass Center (H)

A.2 Calculation for Radius of Gyration about Axis through the C of G

$$n = \frac{\sqrt{\dfrac{9.80665 * a}{k^2 + a^2}}}{2\pi} \qquad \text{(Eq. A1)}$$

$$k^2 = \frac{9.80665 * a}{(n * 2\pi)^2} - a^2 \qquad \text{(Eq. A2)}$$

$$k^2 = \frac{9.80665 * 0.6022}{(0.39812 * 2\pi)^2} - 0.6022^2 = 0.581123 \qquad \text{(Eq. A3)}$$

$$k = \sqrt{0.581123} = 0.7623 \text{ m} \qquad \text{(Eq. A4)}$$

A.3 Calculation for Location (c) of the Center of Percussion from C of G

$$k^2 = a * c \qquad \text{(Eq. A5)}$$

$$c = \frac{k^2}{a} = \frac{0.581123}{0.6022} = 0.9650 \text{ m} \qquad \text{(Eq. A6)}$$

A.4 Calculation of Mass Moment of Inertia about the Fulcrum

$$I = p*(a+c)^2 \quad \text{(Eq. A7)}$$

where:

$$p = m*\frac{a}{a+c}$$

$$I = \frac{164*0.6022}{1.5672} * 1.5672^2 = 154.75 \quad \text{kg-m}^2$$

A.5 Calculation of Final Velocity for a Free Falling Striker of Any Mass

$$v = \sqrt{2*g*h} \quad \text{(Eq. A8)}$$

where:

v = Final Velocity (m/s)
g = Acceleration due to gravity (m/s²)
h = Drop Height (m)

EXAMPLE—For 3.6 Meter Free Fall the final velocity will be:

$$v = \sqrt{2*9.80665*3.6} = 8.4028 \quad \text{m/s} = 30.25 \text{ km/h} \quad \text{(Eq. A9)}$$

A.6 Calculation of Final Velocity for the SAE J1981 Pendulum Striker

A.6.1 Pendulum Potential Energy:

$$m*g*h = \frac{164*9.80665*0.6022*H}{1.8288} = 529.6H \quad \text{Nm} \quad \text{(Eq. A10)}$$

$$\text{Kinetic Energy at Impact} = \frac{I*\omega^2}{2} \quad \text{(Eq. A11)}$$

where

I = Moment of Inertia about the Fulcrum
ω = Final Velocity in radians /second

A.6.2 Since Kinetic Energy will equal the Potential Energy:

$$m*g*h = \frac{I*\omega^2}{2} \quad \text{(Eq. A12)}$$

$$\omega = \sqrt{\frac{2(m*g*h)}{I}} = \sqrt{\frac{2(529.6H)}{154.74}} \quad \text{radians/second} \quad \text{(Eq. A13)}$$

A.6.3 Impact Velocity of the Striker Nose will be:

$$\omega * r = \omega * 1.8352 \text{ meters/second} \quad \text{(Eq. A14)}$$

or

$$\frac{\omega * 1.8352 * 3600}{1000} \text{ km/h} \quad \text{(Eq. A15)}$$

EXAMPLE—For 3.6 meter drop of the striker mass center, the final velocity will be:

$$\omega = \sqrt{\frac{2(529.6 * 3.6)}{154.74}} = 4.964 \text{ radians/second} \quad \text{(Eq. A16)}$$

or

$$\frac{4.964 * 1.8352 * 3600}{1000} = 32.80 \text{ km/h} \quad \text{(Eq. A17)}$$

EXAMPLE—Final Velocity for Calibration of Pendulum use 2.0 m drop, then:

$$\omega = \sqrt{\frac{2(529.6 * 2.0)}{154.74}} = 3.7 \text{ radians/second} \quad \text{(Eq. A18)}$$

or

$$\frac{3.7 * 1.8352 * 3600}{1000} = 24.44 \text{ km/h} \quad \text{(Eq. A19)}$$

APPENDIX B

RATIONALE

B.1 Rationale—The SAE J175 Impact Test was designed as a destructive test to evaluate the structural integrity of a wheel during a side, curb, impact. The SAE Wheel Committee felt that there was a need to evaluate the wheel and tire assembly for road hazard performance with a test that would reproduce damage experienced when a wheel and tire assembly has a frontal hit with a pot hole or curb. Not only was it thought necessary to reproduce the damage but also to have a test that could clearly define the threshold between no damage and slight damage. Impact velocities in the 10 to 30 km/h would be required to simulate vehicle testing. It was required that the test should be accurate and reproducible so that small wheel and tire design variations could be evaluated. In addition, it was envisioned that the equipment could be used for a pass/fail sample approval test. In order to gain wide acceptance in the industry, it was also felt that the test equipment should be robust, low cost, require little maintenance and be easily calibrated.

B.1.1 Design Comparison—Two design concepts were considered for the impact test – a free-fall and a pendulum. After evaluating both designs the pendulum was chosen for the following reasons:

B.1.1.1 HIGHER VELOCITY—For a given drop height, the pendulum can produce a higher impact velocity, providing the mass distribution is not biased too heavily towards the fulcrum.

B.1.1.2 REPEATABLE, CONSTANT VELOCITY AT IMPACT—Figure B1 shows the comparison in final impact velocities between a free-fall striker and the SAE J1981 Pendulum striker. Note that for the same drop height, the pendulum travels considerably farther and has almost constant velocity when it impacts the tire. When a free-fall striker reaches the tire it is still accelerating due to gravity. The longer travel and repeatable velocity at impact are considerable factors in making the pendulum test more consistent and reliable.

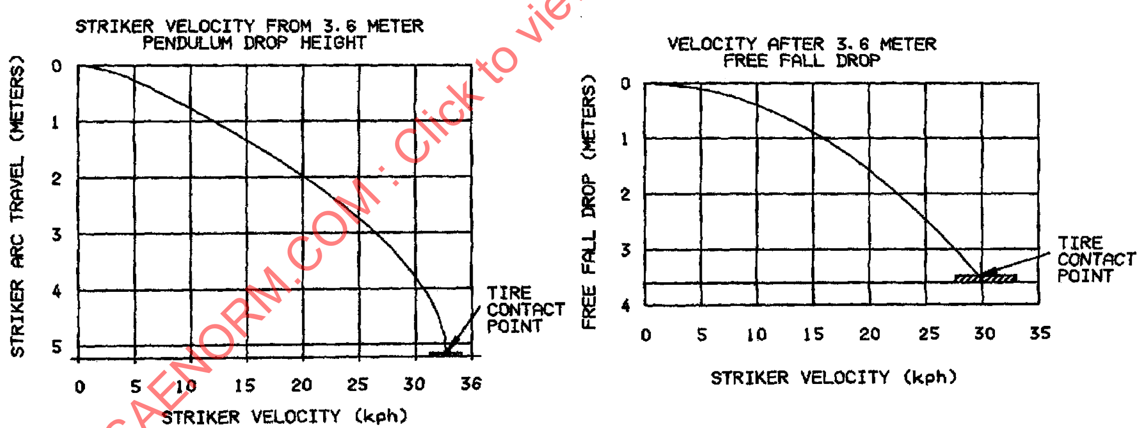

FIGURE B1—FREE-FALL VERSUS SAE J1981 PENDULUM VELOCITY AT MAXIMUM TRAVEL

B.1.1.3 CONSTANT LOW FRICTION—Free-fall carriages have to be guided; as a result, the friction can vary not only due to binding during the free-fall but also due to the more severe binding that occurs after the striker contacts the tire. Providing self-aligning ball bearings are used, the pendulum on the other hand, has negligible friction and there is no binding after contact with the tire.

B.1.1.4 LOWER COST—The pendulum is simple to construct and can be accommodated easily in most commercial buildings.

B.1.1.5 LESS MAINTENANCE—A pendulum with just two self-aligning bearings is easy to maintain whereas free-fall equipment with its guides and linear bearings is difficult to maintain.