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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

SAE ARP1328 REV. A

Issued 1974-03
Revised 1997-12

Superseding ARP1328

Aircraft Ground Support Equipment Vehicle Wind Stability Analysis

1. SCOPE:

1. To recommend uniform criteria for determination of wind loads that aircraft ground support equipment can encounter and yet allow personnel to work safely.

2. To recommend uniform systems for maintaining stability (i.e., stabilizers, outriggers, spring lockout devices).

3. To standardize on specific types of interlock systems and actuation systems.

4. To recommend a standard formula with its associated design criteria for calculating the steady-state wind stability (i.e., tip point) for aircraft ground support equipment.

5. To recommend a standard method for testing these systems.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 ANSI Publications:

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 11995 Aircraft-Stability Requirements for Loading & Servicing Equipment
ANSI A92.7 Airline Ground Support Vehicle-Mounted Vertical Lift Devices

QUESTIONS REGARDING THIS DOCUMENT: (412) 772-8510 FAX: (412) 776-0243
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3. DEFINITIONS OF CRITERIA:

JET BLAST: The equivalent of a wind gust produced by the jet engines of an aircraft.

OUTRIGGERS: Stabilizer devices used to improve the stability of vehicles, extending outside the normal envelope of the vehicle.

STABILIZERS: Structural devices used to improve the stability of vehicles, applied within the envelope of the vehicle.

STEADY-STATE WIND: A wind which produces a constant force.

VEHICLE INSTABILITY: Deflection of vehicle due to a wind force, causing unsafe working conditions.

VEHICLE TIP POINT: Maximum vehicle instability where the vehicle center of gravity has been rotated by a wind force to a point directly above the vehicle pivot point.

VEHICLE PIVOT POINT: That point of the vehicle in contact with the ground on the opposite side of the vehicle from the side to which the wind force is applied and furthest from the wind's application point.

WIND: Movement of air which causes a force to be imposed on surfaces of aircraft ground support equipment.

WIND GUST: A temporary increased wind force that exceeds the steady-state wind force.

4. SYSTEMS WHICH PROVIDE INCREASED STABILITY:

a. Integral Vehicle Chassis Methods:

1. Heavy-duty springs and auxiliary overload springs - These produce a harder ride, but provide increased side movement stability and assist in leveling off-center loads when the vehicle is moving or stationary.

2. Heavy-duty shock absorbers - These produce a harder ride but provide increased side movement stability while the vehicle is moving.

3. Tire pressure - High tire pressure on a vehicle increases the overall stability of either a slow moving or stationary vehicle but produces a harder ride.

4. Torsional stabilizer bar systems - These increase stability by reducing chassis movement through a rigid bar or spring and can be applied in several areas of the chassis. These systems do not adversely affect the ride of the vehicle as much as 1, 2, 3, and 5.

4. (Continued):

5. Spring lockout systems - These block out the chassis springs against the axle and improve the stationary stability of a vehicle. Spring lockouts should not be engaged while a vehicle is moving as this produces an extra hard ride and transmits all road shocks directly into the vehicle structure.

b. Stabilizer Jacks and Stabilizer Systems: These systems generally utilize hydraulic cylinders or manually operated structural devices with self-leveling or fixed foot pads that press against the ground within the envelope of the vehicle. These systems stabilize the vehicle chassis when it is stationary by blocking out chassis movement on the springs and tires. Usually stabilizer jacks are used in tandem (one on each side of the vehicle) and placed at various key positions along the length of the vehicle. Two or more can be used as required.

c. Outrigger Systems: These systems generally utilize hydraulic cylinders or manually operated structural devices that extend self-leveling or fixed foot pads to the ground beyond the normal envelope of the vehicle with heavy structural members that are connected to the chassis. The farther out from the chassis that these foot pads are extended, the greater the resistance to tipping.

Generally, a combination of some of the above mentioned systems will be utilized to gain the desired stability and firmness of ride. The choice of these systems is left up to the designer because every vehicle is different in design and function.

5. INTERLOCK SYSTEMS AND ACTUATION SYSTEMS:

The use of interlock and actuation systems partially depends upon the quality and capabilities of the personnel that will be operating the vehicle. It is also advisable to have interlock devices on the outrigger and stabilizer systems that are depended upon for providing the safe working conditions for personnel. Normally, hydraulic power will be used to actuate stabilizers and outriggers, although use of electrical or manual means is possible in some cases. These outriggers and stabilizer interlocks should consist of lock valves at the base of each cylinder to keep the cylinders from retracting if a hydraulic line failure should occur.

When actuating the outriggers or stabilizers, the operator should be located in a position where he/she can see the foot pads being extended. This strategic positioning of the actuation system will help avoid accidents and will assure the operator that the outriggers or stabilizers are fully extended or retracted as required.

Depending on customer requirements, interlocks may be provided for any of the following functions:

a. Prevent operation of lift systems until stabilizing devices are fully extended.

b. Prevent retraction of stabilizing devices until the lift system is full down or below predetermined safe height without stabilizing devices in operation.

5. (Continued):

c. Mechanically or electrically prevent the unit from being driven with the stabilizing devices extended.

d. Provide visual indication, such as a flashing light, visible from the driver's position to show that the stabilizing devices are extended and/or retracted.

6. STANDARDIZED FORMULA FOR CALCULATING THE STEADY-STATE WIND STABILITY (TIP POINT) FOR ALL AIRCRAFT GROUND SUPPORT EQUIPMENT:

Assumptions:

a. The formula is applicable to the vehicle's projected areas in its worst operating condition where stability is involved. This generally occurs when vehicle is at full extension and is unloaded.

b. The air density is assumed to be .07528 lb/ft^3, standard temperature of 68 °F and pressure of 14.696 psi. If extreme temperatures and pressures must be allowed for, the wind force should be corrected in proportion to the density.

c. Wind velocity in miles per hour (mph) is considered as a steady-state wind condition. Aircraft jet blasts will also be considered as a steady-state wind condition, however, they are likely to produce higher effective forces on the vehicle due to their dynamic nature.

Standard formula for calculating tip point of vehicle:

$$M_O = M_R \qquad \text{(Eq. 1)}$$

where:

M_O = Total overturning moment (lb-ft)
M_R = Total restoring moment (lb-ft)

Overturning moment formula:

$$M_O = .00252\, V^2 \left[\sum_{n=1}^{n} S_i H_i C_i \right] \qquad \text{(Eq. 2)}$$

6. (Continued):

where:

M_o = Total overturning moment (lb-ft)
V = Wind velocity (mph) (see Figure 1)
S_i = Area of i^{th} element (ft^2) (see Figure 1)
H_i = Height from ground level of center of area of i^{th} element (ft) (see Figure 1)
C_i = Shape factor of i^{th} element based on aspect ratio $\left(\frac{b}{a}\right)$ in Figure 2
n = Number of elements of sail area with wind loading (i.e., vehicle chassis, vehicle scissor lift system, vehicle body, vehicle boom, etc.)

Restoring moment formula:

$$M_R = Wd \qquad \text{(Eq. 3)}$$

where:

M_R = Total restoring moment (lb-ft)
W = Total weight of the vehicle (lb)
d = Distance from the center of gravity of the vehicle to the pivot point of the vehicle (ft) as in Figure 3. As a wind force is applied to the side of a vehicle, the vehicle center of gravity is caused to move in the direction of the wind force. For this reason, d' should be used as shown in Figure 4. (The center of gravity will move due to spring deflection, tire deflection, and structural deflection.)

Since:

$$M_O = M_R \qquad \text{(Eq. 4)}$$

Then:

$$.00252\, V^2 \left[\sum_{i=1}^{n} (S_i)(H_i)(C_i) \right] = Wd \qquad \text{(Eq. 5)}$$

The shape factors so obtained apply to full scale for structures with sharp edges whose principal resistance is due to the pressure forces. For bodies that do not have any sharp edges perpendicular to the flow, such as spheres or stream-lined bodies, the shape factor C_N is not constant. For such bodies, the law for variation of the shape factor C_N must be determined experimentally before safe predictions of full-scale forces can be made from model measurements. The force N normal to a flat plate depends upon the aspect ratio A = height/(width) of the plate. Writing $N = C_N\, q\, S$, the shape factor C_N varies from about 1.18 to 2 as shown in Figure 2. About 70% of normal force on the plate is due to the large underpressures existing over the rear surface.

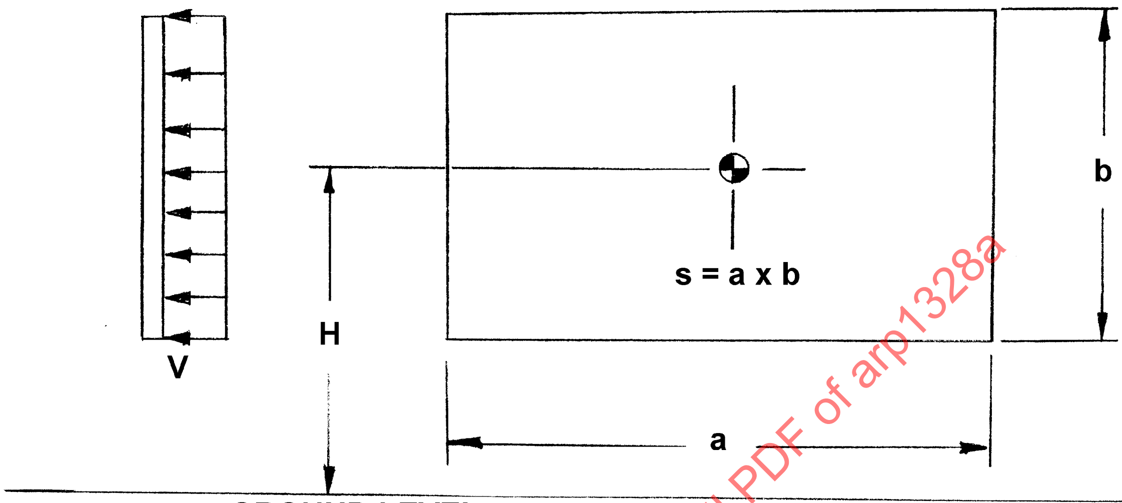

FIGURE 1

Variation of "shape factor" with aspect ratio for rectangular plates perpendicular to the flow.

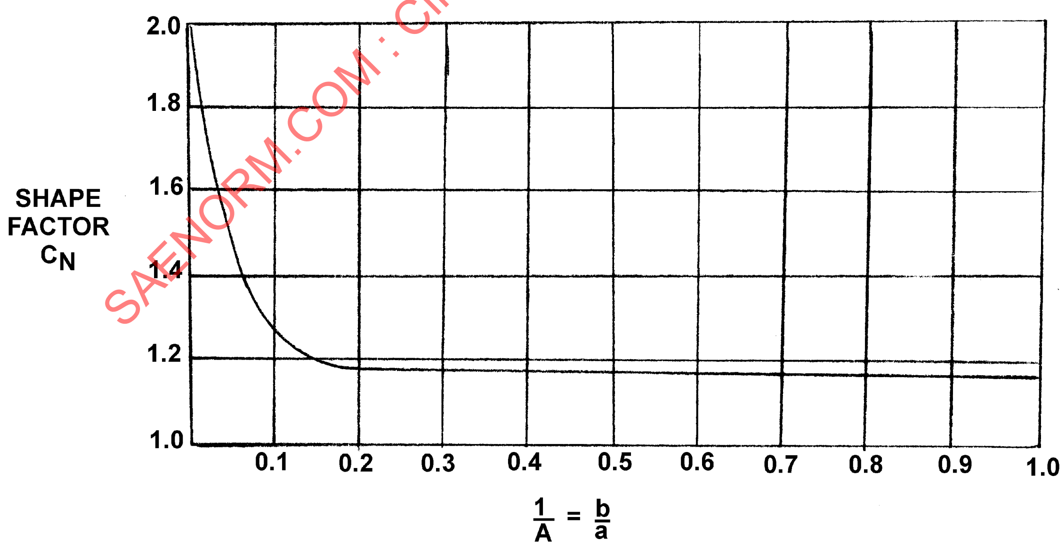

FIGURE 2