WIND STABILITY ANALYSIS

SOLAR TECHNOLOGY

MODEL: SILENT SENTINEL

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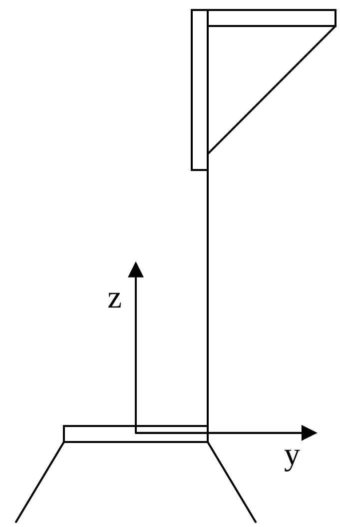
Arrow Board:



Assumptions:

- Jack stands are fully extended - unit set up by I.A.W. operating procedures
- Model rests on a non-compressible surface
- Center of gravity lies within battery box at calculated location

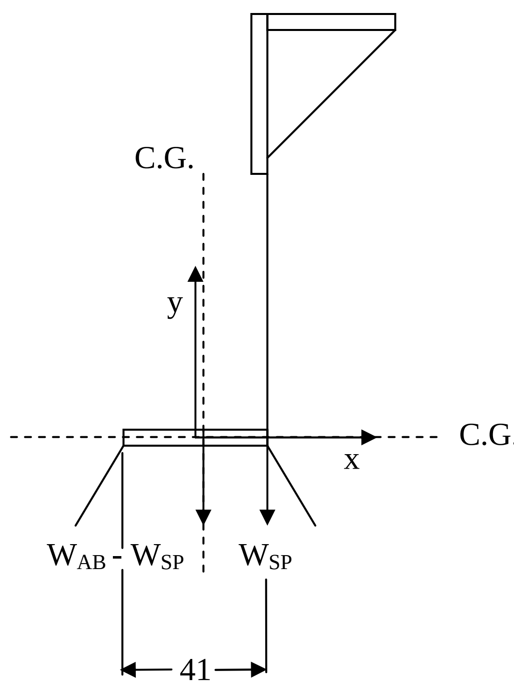
Center of Gravity:

$W_{AB} = 1300$ lb

$W_{SOLAR\ PANEL} = 100$ lb

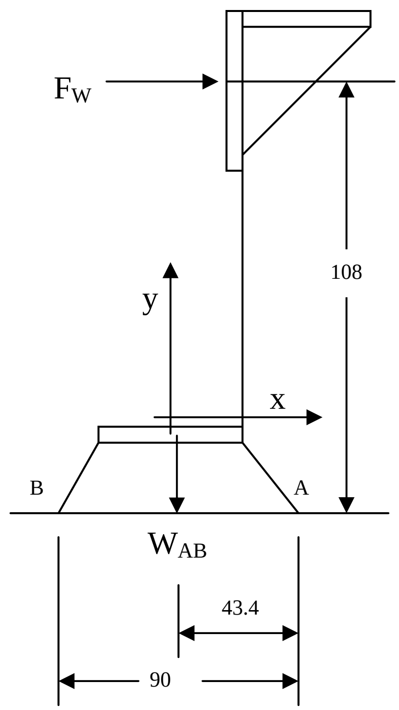
$W_{AB} - W_{SOLAR\ PANEL} = 1200$lb

	Weight	X-position (in)
$W_{AB} - W_{SP}$	1200	0
$W_{SOLAR\ PANEL}$	100	20.5
Total	1300	



X location of C.G.

$$X = \frac{\sum X * W}{Wtotal} = \frac{0*1200 + 20.5*100}{1300} = 1.58''$$



The free body diagram shown above indicates that the center of gravity is located 43.4” from point A. This report will assume that instability of the unit occurs when the unit is in equilibrium with the vertical reaction force R_{by} equal to zero indicating that the jack stands at point B carry no load. The report will also assume that the wind force acts uniformly on the sign case and therefore can be represented as a single force located at the center of the sign panel.

The first step is to evaluate the three equations of equilibrium and solve for the wind force F_w that will cause instability.

Summing forces in the X direction produces equation 1, where R_{ax} and R_{bx} are the reaction forces at points A and B in the X direction and F_w is the wind force exerted on the sign case

$$\sum F_x = 0 = R_{ax} + R_{bx} - F_w \qquad (1)$$

Since we assumed that R_{by}=0, the jack stand can not exert any frictional force so R_{bx}=0 and equation 1 reduces to

$$R_{ax} = F_w \qquad (1a.)$$

Summing Forces in the Y direction produces equation 2, where R_{ay} and R_{by} are the reaction forces at points A and B acting in the Y direction and W is the weight of the unit

$$\sum F_y = 0 = R_{ay} + R_{by} - W \qquad (2)$$

The weight of the unit is 1300 lbs and we assumed that R_{by}=0 so equation 2 reduces to

$$Ray = 1300 \qquad (2a.)$$

Finally summing the moment about point A produces equation 3

$$\sum M_A = 0 = F_w * 108 - W * 43.4 + R_{by} * 90 \qquad (3)$$

Since R_{by}=0 and W=1300 equation 3 can be solved for F_w and the result is

$F_w = 522.4$ lbs. and from equation 1a. $R_{ax} = 522.4$ lbs.

The result is that a wind force of 522.4 pounds will cause the unit to begin to tilt over.

The next step is to determine at what wind speed a force of 522.4 pounds will be generated on the sign panel. This report will assume the flow is isentropic, so there are no frictional effects and no energy added to the flow. The air will also be assumed to be incompressible. These two assumptions can be made because we are dealing with a low speed flow. The assumption will also be made that the pressure distribution is constant over the entire face of the sign. This assumption will result in the calculated force being higher then the actual wind force because the pressure distribution actually decreases closer to the edges of the sign as the air flows around the sign instead of stopping. Any turbulent effects will be ignored because the wind speeds are not that high and the turbulence in the flow will have little effect on the force generated. Because the flow is incompressible and isentropic Bernoulli's equation, equation 4 can be used.

$$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2 \qquad (4)$$

Assuming that we are at standard sea level conditions and the flow comes to a complete stop at the sign case

P_1= Free stream pressure = atmospheric pressure=2116 lbs/ft^2

ρ = Density of air = 0.002377 slugs/ft^3

V_1= Free stream Velocity or wind speed

P_2= Pressure on the Sign face

V_2= Velocity at the sign face = 0 ft/s

Equation 4 simplifies to the following

$$P_1 + \frac{1}{2}\rho V_1^{\,2} = P_2 \qquad (4a.)$$

The force exerted on the sign is a result of the difference in the pressure between the sign face and the atmospheric pressure and is equal to this pressure difference multiplied by the surface area of the sign. The result is as follows:

$$F_w = (P_2 - P_1) * A = 522.4 \text{ lbs} \qquad (5)$$

A=surface area of sign case= 32 ft^2

Combining equations 4a and 5 results in the following equation:

$$\frac{F_w}{A} = \frac{1}{2}\rho V_1^{\,2} \qquad (6)$$

Substituting in the values for wind force, surface area, and air density into equation 6 and solving results in a velocity of 117 ft/s or 80 mi/hr.

The final result is that a wind speed of approximately **80 miles per hour or greater** would have to occur for the unit to become physically unstable and begin to tip over under this worst-case scenario.

•The calculated wind speed is that at which the unit exhibits zero force on the rear jack stands. This is when the unit becomes unstable. In actuality, the unit will require a greater wind force to eventually blow it over.
• The wind force is assumed to be stable and uniform. Therefore, the calculations do not account for turbulence within the air.
• Calculations are worst case. There is no allowance for inefficiencies, slippage, etc., during actual operating conditions because the wind will probably only generate 90% of calculated force.