Wind Load Analysis

Silent Sentinel - Arrow Board

Silent Messenger – Message Board

Silent Messenger II – Message Board

Silent Messenger II Lift & Rotate – Message Board

WIND STABILITY ANALYSIS

SOLAR TECHNOLOGY

MODEL: SILENT SENTINEL

Chad Owens
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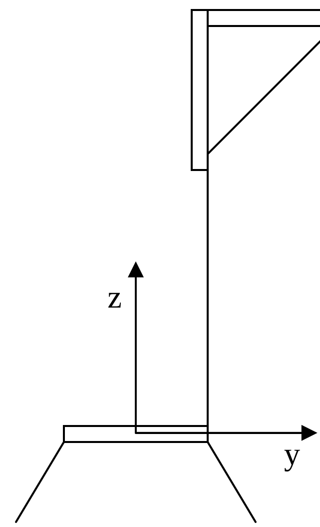
Arrow Board:



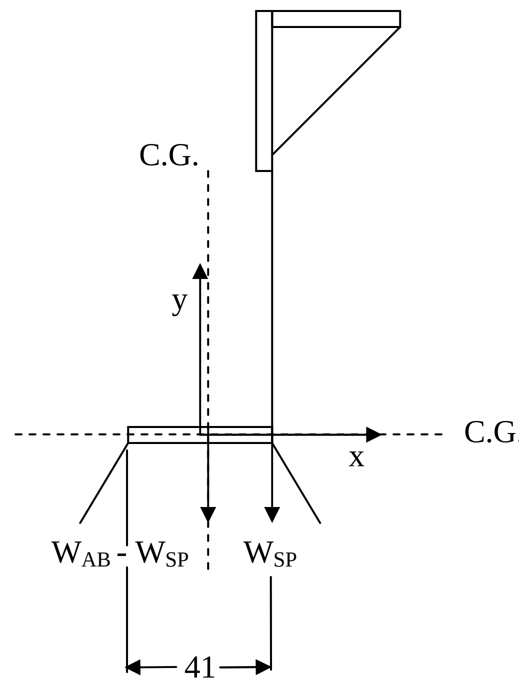
Assumptions:

- 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:

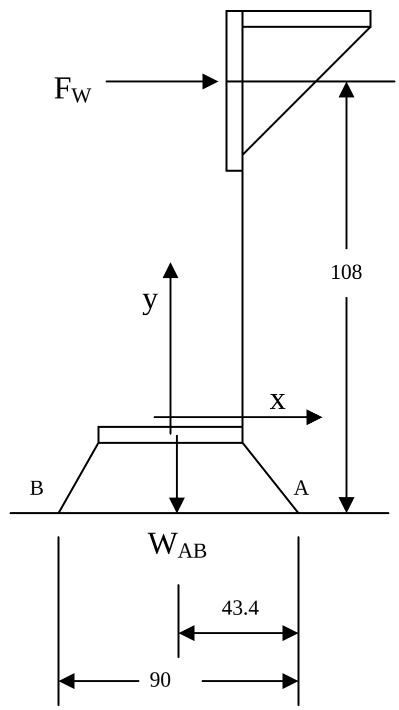
W_{AB} = 1300 lb
$W_{SOLAR\ PANEL}$ = 100 lb
W_{AB} - $W_{SOLAR\ PANEL}$ = 1200lb

	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.

<u>Wind Stability Analysis</u>

Solar Technology Inc.

Model: Silent Messenger

Chad Owens
Project Engineer
Solar Technology, Inc.
August 10, 2006

This report examines the effects of various wind loading conditions on the message board and determines that wind speed which will cause the unit to become physically unstable and possibly tip over. This report assumes the unit is set up properly in accordance with all operating procedures and that the unit is set up level on a non-compressible surface. Finally, the wind direction is perpendicular to the sign face and therefore the surface area normal to the flow direction is at a maximum and the force generated will also be at a maximum.

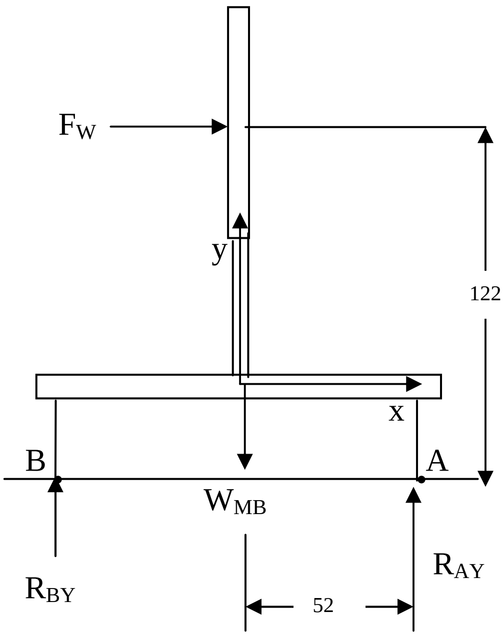


Figure 1

The free body diagram of the message board shown in figure 1 indicates that the center of gravity is located 52” 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 3400 lbs and we assumed that R_{by}=0 so equation 2 reduces to

$$Ray = 3400 \qquad (2a.)$$

Finally summing the moment about point A produces equation 3

$$\sum M_A = 0 = F_w * 122 - W * 52 \qquad (3)$$

Since R_{by}=0 and W=3100 equation 3 can be solved for F_w and the result is

$F_w = 1449$ lbs. and from equation 1a. $R_{ax} = 1449$ lbs.

The result is that a wind force of 1449 pounds will cause the unit to begin to tilt over.

The next step is to determine at what wind speed a force of 1449 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:

$$F_w = (P_2 - P_1) * A = 1449 \text{ lbs} \qquad (5)$$

A=surface area of sign case= 66.5 ft^2

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

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

Substituting in the values for wind force, surface area, and air density into equation 6 and solving results in a velocity of 135 ft/s or 92 mi/hr.

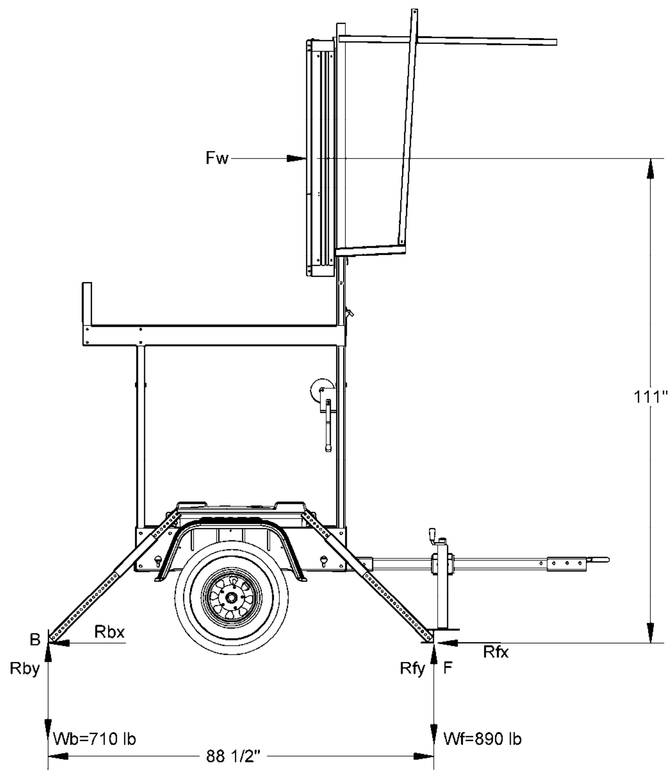
The final result is that wind speeds **in excess of 80 mph** would have to occur for the unit to become physically unstable and begin to tip over. In actuality, the unit will require a greater wind force to eventually completely blow over. The wind force is assumed to be stable and uniform. Therefore, 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.

<u>Wind Stability Analysis</u>

Silent Messenger II

Chad Owens
Project Engineer
Solar Technology, Inc.
January 19, 2007

This report examines the effects of various wind loading conditions on the message board and determines that wind speed which will cause the unit to become physically unstable and possibly tip over. This report assumes the unit is set up properly in accordance with all operating procedures and that the unit is set up level on a non-compressible surface. Finally, the wind direction is perpendicular to the sign face and therefore the surface area normal to the flow direction is at a maximum and the force generated will also be at a maximum. 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 (F_w).



This report will assume that instability of the unit occurs when the unit is in equilibrium with the vertical reaction force at the jack stands is equal to zero indicating that the jack stands carry no load. Since the weight at the rear jack stands W_b is less than the weight at the front jack stands W_f the unit will tip over towards the front first. Therefore the instability condition will occur when the reaction force at point B (R_{by}) is equal to zero..

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_{fx} and R_{bx} are the reaction forces at points F and B in the X direction and F_w is the wind force exerted on the sign case

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

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

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

Summing Forces in the Y direction produces equation 2, where R_{fy} and R_{by} are the reaction forces at points F and B acting in the Y direction and W_b and W_f are the weight of the unit at the front and rear jack stands

$$\sum F_y = 0 = R_{fy} + R_{by} - W_f - W_b \qquad (2)$$

W_f=890 and W_b=710 and we assumed that R_{by}=0 so equation 2 reduces to

$$R_{fy} = 1600 \qquad (2a.)$$

Finally summing the moment about point F produces equation 3

$$\sum M_f = 0 = F_w * 111 - W_b * 88.5 \qquad (3)$$

Equation 3 can be solved for F_w and the result is

$F_w = 566.1$ lbs. and from equation 1a. $R_{bx} = 566.1$ lbs.

The result is that a wind force of 566.1 pounds will cause the unit to begin to tilt over.

The next step is to determine at what wind speed a force of 566.1 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:

$$F_w = (P_2 - P_1) * A = 566.1 \text{lbs} \qquad (5)$$

A=surface area of sign case= 34.5 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 117.5 ft/s or 80.1 mi/hr.

The final result is that wind speeds **in excess of 80 mph** would have to occur for the unit to become physically unstable and begin to tip over.

<u>**Wind Stability Analysis**</u>

Solar Technology Inc.

Model: Silent Messenger II
SM2-LR-3048

Michael Shea
Staff Engineer
Solar Technology, Inc.
January 28, 2008

This report examines the effects of various wind loading conditions on the message board and determines that wind speed which will cause the unit to become physically unstable and possibly tip over. This report assumes the unit is set up properly in accordance with all operating procedures and that the unit is set up level on a non-compressible surface. Finally, the wind direction is perpendicular to the sign face and therefore the surface area normal to the flow direction is at a maximum and the force generated will also be at a maximum. 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 (F_w).

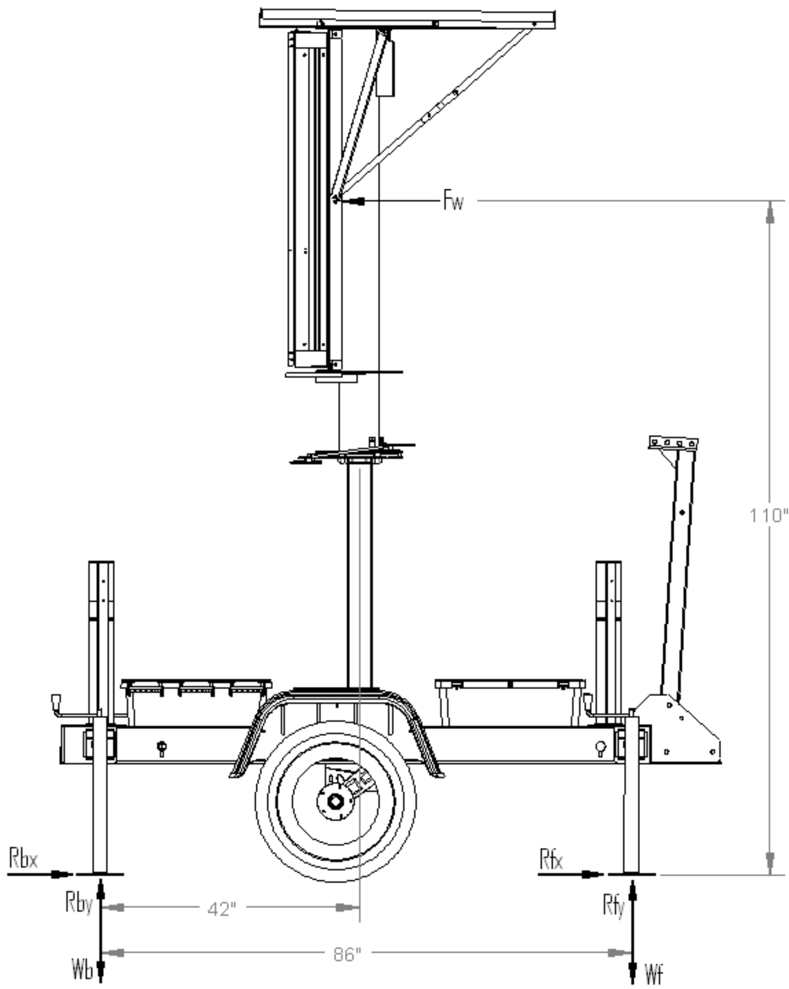


Figure 1: Free body diagram of MBII L&R

This report will assume that instability of the unit occurs when the unit is in equilibrium and the vertical reaction force at the jack stands is equal to zero indicating that the jack stands carry no load. Since the weight at the front jack stands W_f is less than the weight at the rear jack stands W_b the unit will tip over towards the back first. Therefore the instability condition will occur when the reaction force (R_{fy}) is equal to zero.

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_{fx} and R_{bx} are the reaction forces at points F and B in the X direction and F_w is the wind force exerted on the sign case

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

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

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

Summing Forces in the Y direction produces equation 2, where R_{fy} and R_{by} are the reaction forces at points F and B acting in the Y direction and W_b and W_f are the weight of the unit at the front and rear jack stands

$$\sum F_y = 0 = R_{fy} + R_{by} - W_f - W_b \qquad (2)$$

W_f and W_b total 2050 lbs and we assumed that at equilibrium R_{fy}=0, so equation 2 reduces to

$$R_{by} = 2050 \qquad (2a.)$$

Finally summing the moments about the center of gravity produces equation 3

$$\sum M_{CG} = 0 = F_w * 110 - R_{by} * 42 \qquad (3)$$

Equation 3 can be solved for F_w and the result is

$F_w = 782.7$ lbs. and from equation 1a. $R_{bx} = 782.7$ lbs.

The result is that a wind force of 782.7 pounds will cause the unit to begin to tip over.

The next step is to determine at what wind speed a force of 782.7 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

$$P_1 + \frac{1}{2}\rho V_1^2 = P_2 \quad \text{or} \quad P_2 - P_1 = \frac{1}{2}\rho V_1^2 \quad \text{(4a.)}$$

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:

$$F_w = (P_2 - P_1) * A = 782.7\,\text{lbs} \quad (5)$$

A = surface area of sign case = 34.5 ft^2

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

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

Substituting in the values for wind force, surface area, and air density into equation 6 and solving results in a velocity of 138.16 $^{ft}/_{s}$ or 94.2 $^{mi}/_{hr}$.

The final result is that wind speeds **in excess of 90 mph** would have to occur for the unit to become physically unstable and begin to tip over.