Wind Forces

The effects of wind are very important in selecting the right load cell capacity and determining the correct mount to use in outdoor applications. In analysis, it must be assumed that the wind can (and does) blow from any horizontal direction.

The Figure shows the effects of wind force on a vertical tank. Note that not only is there force distribution against the tank on the windward side, but also a "suction" distribution on the leeward side.

These forces tend to be additive and can tip the vessel over in the direction of the wind.

On the sides of the tank the forces are equal in magnitude but opposite in direction, resulting in no effect on the overall stability of the vessel.

Air Velocities of Wind

The maximum air velocity of wind is depending on the geographical place and height and the local situations (buildings, open field, sea, etc.). A National Meteorological Institute can provide more statistical data to determine how air velocity should be taken into account.

Calculation of Windforce

The installation is mostly affected by horizontal forces, acting in the direction of the wind. These forces can be calculated by:

$$F = 0.63 * c_d * A * v^2$$

where,

c_d = Drag coefficient, for an upright circle cylinder this coefficient equals 0.8

A = Exposed cross section, equals height of the vessel* bore of the vessel (m^2)

h = Height of the vessel (m)

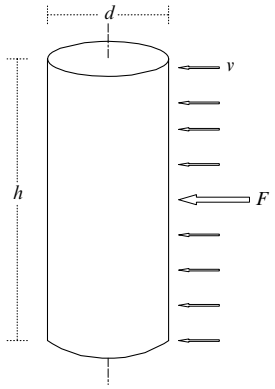
d = Bore of the vessel (m)

v = Air velocity of wind (m/s)

F = Force generated by the wind (N)

Hence, for upright cylindrical vessels, the following formula can be used:

$$F = 0.5 * A * v^2 = 0.5 * h * d * v^2$$



Specifications:

v = 30 m/s

h = 10 m

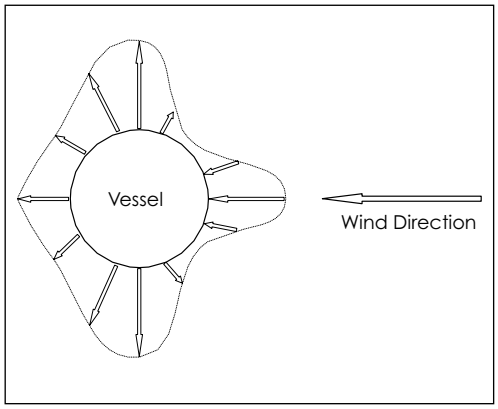
d = 3 m

Calculation of force:

$F = 0.5 * h * d * v^2$

$F = 0.5 * 10 * 3 * 30^2$

$F = 13500$ N



Description	Beaufort	km/h	mis/h	m/s
Normal wind	4	19.8 - 28.8	12.4 - 18.0	5.5 - 8.0
Strong normal wind	5	30.6 - 37.8	19.1 - 23.6	8.5 - 10.5
Strong wind	6	39.6 - 48.6	24.8 - 30.4	11.0 - 13.5
Very Strong	7	50.4 - 59.4	31.5 - 37.1	14.0 - 16.5
Stormy	8	61.2 - 72.0	38.3 - 45.0	17.0 - 20.0
Storm	9	73.8 - 84.6	46.1 - 52.9	20.5 - 23.5
Heavy storm	10	86.4 - 99.0	54.0 - 61.9	24.0 - 27.5
Very heavy storm	11	100.8 - 113.4	63.0 - 70.9	28.0 - 31.5
Hurricane	12	115.2 - 180.0	72.0 -	32.0 - 50.0

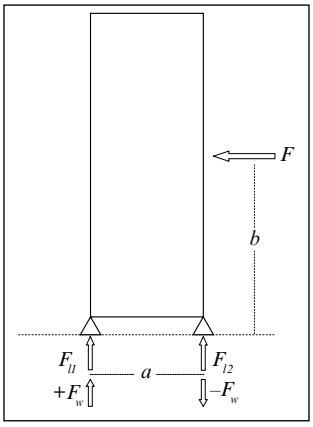
Wind Forces

Conclusion

- The installation should be protected against capsizing.
- Wind force should be taken into account during load cell capacity selection.
- As the wind does not always blow exactly horizontally, a vertical component could cause a measuring error, by an arbitrary zero shift. Errors bigger than 1% of the net weight can only be expected with very strong wind >7 Beaufort.

The Effect on Load Cell Capacity and Mounts

The effect of the wind force to the load cells is different from that to the vessel. The wind force causes a capsizing moment, which will be counteracted by the reactive moment of the load cells.



F_1 = Force on load cell

F_w = Force caused by wind force

a = Distance between load cells

$$F * b = F_w * a$$
$$F_w = (F * b)/a$$

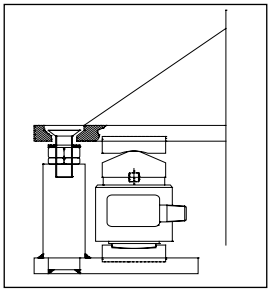
Which will cause an increase F_w of F_{l1} and a decrease F_w of F_{l2}.

Using a calculated wind force of 13500 N and a value for b which is approximately half the height of the vessel, F_w can be calculated by:

$$F_w = (F * b)/a = (13500 * 5)/3 = 22500 \text{ N}$$

Conclusion

- In case of an empty vessel, uplift protection should be considered if the tare weight of the vessel on each load cell is smaller or equal to 2250 kg.
- In case of a fully loaded vessel, 2250 kg should be added to the calculated load cell capacity to provide the load cells from being overloaded.
- It is common practice to multiply the calculated windforce on a load cell with a safety factor of two (2) or three (3).



If the mount does not offer uplift protection, one may be established externally as per the drawing opposite. The uplift protection should be adjusted with a clearance of at least 1 mm and requires regular inspection of this clearance.

Load Cell Capacity Selection

The selection of which capacity to use in a weighing application should be based on the following factors:

- Determine the maximum weight of the applied load, or "Live Load".
- Calculate the weight, "tare", of the construction, or "Dead Load".
- Determine the number of load cells to be used in the structure (N).
- Check the possible presence of unequal loading conditions (factor f_a). This factor is an allowance for low tare estimates and unequal load distribution. Standard: f_a = 1.3.
- Check on extra factors as vibration, shock, etc. (factor f_b). This factor is a dynamic load factor; for static weighing f_b = 1.
- Calculate F_w (in Newton!, not in kg). The individual minimum load cell capacity can be calculated by:

$$F_w + (f_a * f_b * (\text{LiveLoad} + \text{DeadLoad}) / N)$$

Accuracy

The specifications illustrated on the load cell datasheet should be the basis for calculating the accuracy of a non-approved weighing system.

The accuracy of a weighing system which must be approved by the "Weights and Measures" has to meet a relevant OIML recommendation. For example, non-automatic weighing systems have to meet OIML R 76-1 edition 1992 (E).

Customer Support

VPG Transducers combines fifty years of load cell manufacturing with fifty years of application know-how. For any further question, please contact our manufacturing operation or any one of our regional sales offices.