WIND EFFECTS IN A HARBOR ENVIRONMENT

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1) WIND FORCES
2) FACTORS
    a. TEMPERATURE EFFECT
    b. HUMIDITY EFFECT
    c. SQUARE EFFECT
    d. DRAG COEFFICIENT EFFECT
    e. TABLES
3) LEE AND BUILDINGS EFFECT ON WIND

1) Wind Forces :

$$F = \frac{1}{2}(\rho \times C_y \times V^2) \times S$$

-F Newton (force)
-ρ kg/m^3 (density)
-Cy (drag coefficient)
-V m/s (wind speed)
-S m^2 (surface)

If air density is ρ =1,28 kg/m3 so, $Ftonnes = \frac{C_y \times S \times V^2}{60}$ where S is lateral surface divided per 1000 and V is wind in knots.

Traditionally on standard cargo vessel, Cy was 0,82 so $Ftonnes = \frac{S \times V^2}{73000}$. V in knots and S total surface.

We will see later that in fact Cy is higher.

2) Details on each variable of wind equation:

- **Influence of temperature on density**

$$\rho = \frac{P}{R \times T}$$

-ρ kg/m^3 (density), P (Pa) Air Pressure, R is the gas constant for air (J.kg^{-1}.K^{-1}) and T is temperature (K)

For dry air R=287,05 J.kg^{-1}.K^{-1}

If P=1013,25 PA $\Rightarrow \rho = 1{,}293 \times \frac{273}{273+t}$

Temp ℃	Temp ºK	Density ρ kg/m^3
0	273,15	1,293
20	293,15	1,204
25	298,15	1,184
30	303,15	1,165

$\Rightarrow \Delta(\rho 0° - \rho 30°) = 10\%$

Conclusion : The Colder The Wind Is, The Stronger Its Effect

- **Influence of humidity on density**

$$\rho(\vartheta,\varphi,p)=\frac{1}{287{,}06\times(\vartheta+273{,}15)}\times\left(p-230{,}617\times\varphi\times\exp\left[\frac{17{,}5043\times\vartheta}{241{,}2°C+\vartheta}\right]\right)$$

-φ is relative humidity
-φ is temperature in Celsius
-P is air pressure

With P=1013,25 PA :

Humidity	100 %	80 %	60 %	40 %	20 %	Δ
0℃	1,289	1,290	1,290	1,291	1,292	0,2 %
10℃	1,241	1,242	1,243	1,244	1,245	0,3 %
20℃	1,194	1,196	1,198	1,200	1,202	0,7 %
30℃	1,146	1,150	1,153	1,157	1,161	1,3 %

Conclusion : The wind force is reduced with humidity.

"happy captain under rain…"

- **Square effect**

V(kts)	5	10	15	20	25	30	35	40	45	50
V^2	25	100	225	400	625	900	1225	1600	2025	2500

From 30 to 35 knots: wind speed is increased of 16 % but the effect is increased of 36 %
From 20 to 30 knots: wind speed is increased of 50 % but the effect is increased of 125 %

- **<u>Ship designs influence drag coefficient Cy</u>**

to determine Cy is very difficult.

Loaded Tanker 0,75
Ferries 0,95
Containers ship 1,00
Loaded Gas carrier 1,10
Modern Cruise ship 1,40
Sail (spinnaker) : 1,7

Remarks :
1) a gas tanker is 45% more influenced by the wind than a loaded tanker
2) If each balcony on cruise ship is considered as a small lateral spinnaker it is easy to understand the Cy of 1,4….

So, we can certainly consider that the classical formula $Ftonnes = \frac{S \times V^2}{73000}$ calculated with Cy=0,82 **can be changed into** $Ftonnes = \frac{S \times V^2}{60000}$ **with Cy=1,00**.

We can use the two next tables to evaluate roughly (error 10 to 20 % of approximation due to Cy variation. In this table, Cy=1, so it is really easy to built equivalent with 0,9 or 1,1)

Table 1 : surface calculation

L / H	10	15	20	25	30	35	40	45	50
100	1000	1500	2000	2500	3000	3500	4000	4500	5000
120	1200	1800	2400	3000	3600	4200	4800	5400	6000
140	1400	2100	2800	3500	4200	4900	5600	6300	7000
160	1600	2400	3200	4000	4800	5600	6400	7200	8000
180	1800	2700	3600	4500	5400	6300	7200	8100	9000
200	2000	3000	4000	5000	6000	7000	8000	9000	10000
220	2200	3300	4400	5500	6600	7700	8800	9900	11000
240	2400	3600	4800	6000	7200	8400	9600	10800	12000
260	2600	3900	5200	6500	7800	9100	10400	11700	13000
280	2800	4200	5600	7000	8400	9800	11200	12600	14000
300	3000	4500	6000	7500	9000	10500	12000	13500	15000
320	3200	4800	6400	8000	9600	11200	12800	14400	16000
340	3400	5100	6800	8500	10200	11900	13600	15300	17000
360	3600	5400	7200	9000	10800	12600	14400	16200	18000

Table 2 : angle correction

Angle between wind and vessel	15°	30°	45°	60°	90°
Multiplicator Coefficient	0,25	0,5	0,7	0,86	1

Table 3 : force due to wind on effective surface

knots	m/s	1000	2000	4000	6000	8000	10000	12000	14000	16000	18000
10	5	2	3	7	10	13	17	20	23	27	30
15	8	4	8	15	23	30	38	45	53	60	68
20	10	7	13	27	40	53	67	80	93	107	120
25	13	10	21	42	63	83	104	125	146	167	188
30	15	15	30	60	90	120	150	180	210	240	270
35	18	20	41	82	123	163	204	245	286	327	368
40	21	27	53	107	160	213	267	320	373	427	480
45	23	34	68	135	203	270	338	405	473	540	608
50	26	42	83	167	250	333	417	500	583	667	750

BOW THRUSTERS POWER		
KW	Hp	Tonnes
500	676	6
750	1014	10
1000	1351	13
2000	2702	27
3000	4053	40

TUG BOLLARD POOL	
VOITH	10 t /1000 Hp
ASD	13 t /1000 Hp

Example : vessel L=320m, H=25m Wind=30 knots, angle 90 °

With table 1 : surface is 8000 m^2 coef 1 (angle 90°)

With table 2 : Force of wind 120t

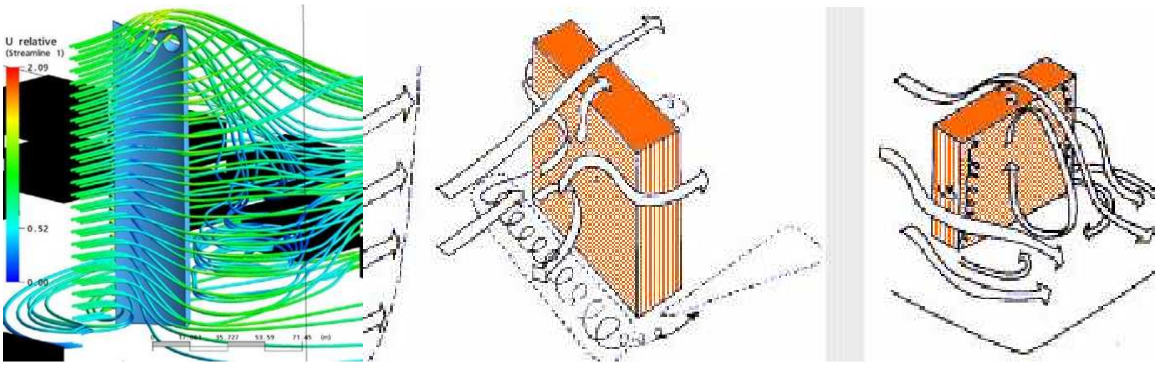
One bow of 2000 kW+ one Voith (tractor) tug 5000 Hp forward : 77 tonnes forward
One tug of 5000 Hp aft : 50 tonnes aft.
More than enough….

Power has to be adjusted as a function of calculated wind force on a hull.

3) lee and buildings effects on wind

Shelter is very variable in harbour environments because it depends directly on the distribution of the fields's pressures around buildings and big ships.

As we can see on these 3 drawings, wind direction is really complex around obstructions. Several effects take place at the same time. We will analyse them one by one.



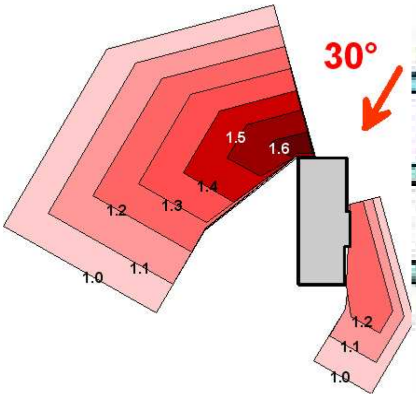
1) **The shelter of a large building is approximately twice its height.**

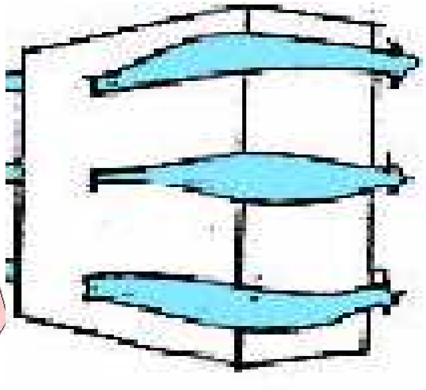
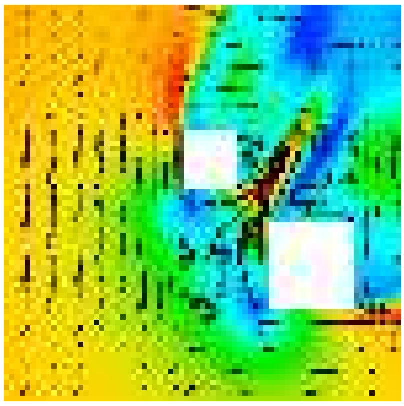
This means that if your vessel passes under the shelter of a larger vessel (h=40m), the lee created is efficient to 80 m… for example; if the building is 20m high, the blue numbers show the percentage of original force after building (in the lee).

58	100	100	100	100	100	99	99	99	99	98	98	98	98	98	98
55	100	100	100	100	100	99	99	98	98	98	98	98	98	98	98
53	100	100	100	100	99	99	98	98	98	97	97	97	97	97	97
50	100	100	100	99	99	98	98	97	97	97	97	97	97	97	97
48	100	100	100	99	98	98	97	96	96	96	96	96	96	96	96
45	100	100	99	99	98	97	96	95	95	95	95	95	95	95	95
43	100	100	99	98	96	95	94	94	93	93	94	94	94	94	95
40	100	100	98	96	95	93	93	92	92	92	92	93	93	94	94
38	100	99	97	95	93	91	90	90	90	90	91	91	92	93	93
35	100	98	95	92	90	88	88	87	87	88	89	90	91	92	92
33	100	97	92	88	86	85	84	84	85	86	87	89	90	91	91
30	99	94	87	83	81	80	81	81	82	84	86	87	88	90	91
28	99	89	81	76	75	75	76	78	79	81	84	86	87	89	90
25	96	81	71	68	68	70	72	74	76	79	82	84	86	88	89
23	90	68	59	58	60	63	67	70	73	77	80	83	85	87	89
20	78	48	43	46	52	57	63	67	71	75	79	82	85	87	88
18	52	21	24	34	43	52	59	65	69	74	79	82	85	87	88
15	4		4	22	36	48	56	63	69	74	79	82	85	87	89
13				13	32	46	56	63	69	75	79	83	86	88	90
10				9	32	47	58	65	71	77	81	85	87	89	91
8				14	38	53	63	70	75	80	84	87	89	91	92
5				31	51	63	72	78	82	85	88	91	92	94	94
3			36	60	72	80	84	88	90	92	94	95	96	97	97
	21	43	64	86	107	129	150	171	193	214	236	257	279	300	321

2) Corner effect

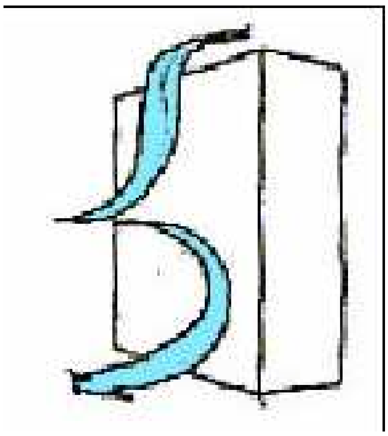
Wind speed is higher after a corner (multiplication per 1.2 to 2). Therefore, the closer you are to the corner the greater the effect.



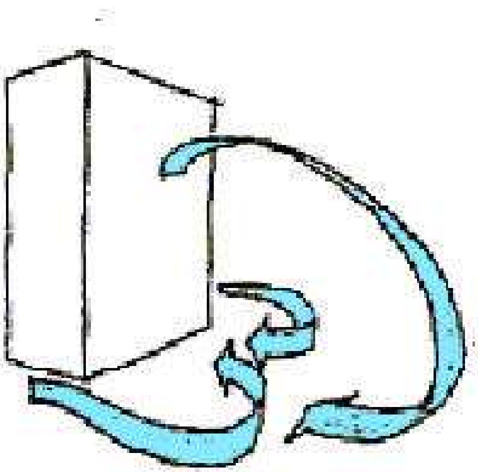
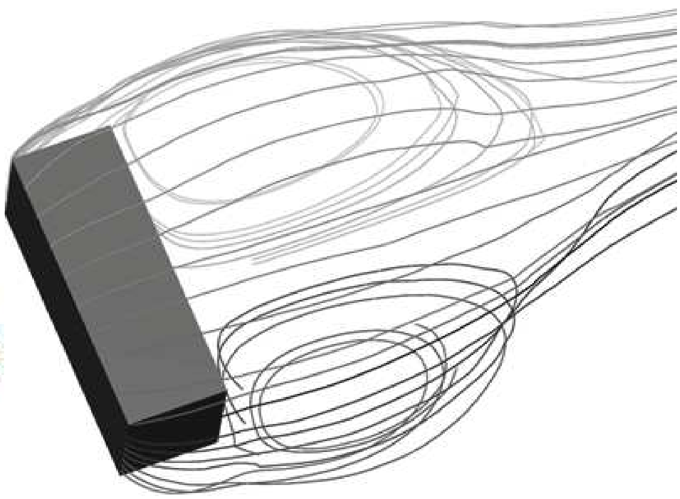
3) Upstream effect

The air flow in contact with a building is divided into 2 parts; one upwards, one downwards. The speed on top of the building is higher due to additional effect. The wind below the building is inferior/ lower, due to back wind effect.



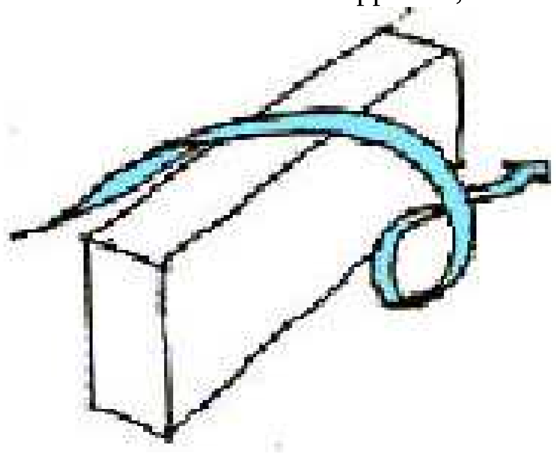
4) Trail effect

There is a low pressure on the lee side. The wind is backs and returns to make contact with the building. The effect is approximately less than twice the height of building.

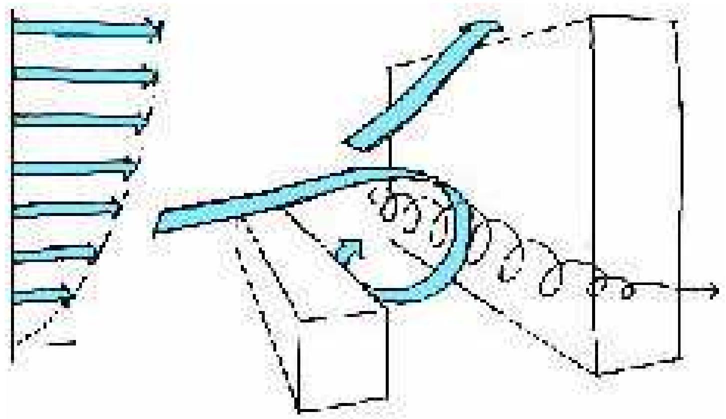
5) **High rise block effect :**

If the wind hits at an angle of 45° with a large parallel sided building, the corner effect on top and rotation effect on the lee side make an acceleration of approx 1,4 to an elevation of 1m …



6) **Wise effect**

The association between two parallel buildings with different heights creates a vertically, rising and rotating wind.



7) **Venturi effect**

The Venturi effect is the reduction in fluid pressure that results when a fluid flows through a constricted section of pipe. The Venturi effect is so-called after Giovanni Battista Venturi, (1746–1822), an Italian physicist who discovered its principles.
This principle can also be applied to air on a building. If buildings create an angle with a corridor between them with the space between being 2 or 3 times the height of the buildings, then the wind effect is 1,6 times greater in the corridor.

It may make the article clearer to read if units of measurement were put after the necessary numbers; i.e 1.6Cy etc.