

# EXPERIMENTAL WIND TUNNEL TESTS ON LARGE PASSENGER SHIPS

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## SUMMARY

The papers was developed as part of the research "Analisi critica del Criterio di Stabilità Meteorologico e formulazione di proposte di modifica pre le grandi navi passeggeri" financed by CETENA SpA in the frame of CETENA Research Plan 2002, with the aim of the possible revision of IMO Weather Criterion for ships having the characteristics of the Large Passengers Ships. Tests on two large model of Passenger Vessel was held in the wind tunnel of the Vienna Model Basin. The aim of the tests were to obtain the experimental results of the wind forces and moment acting on two Ship, built from Fincantieri, at various angle of heel, with beam wind, for comparison with those assumed from the Weather Criterion. Suggestion for a new procedure of the calculation of the Weather Criterion based on wind tunnel model test is given.

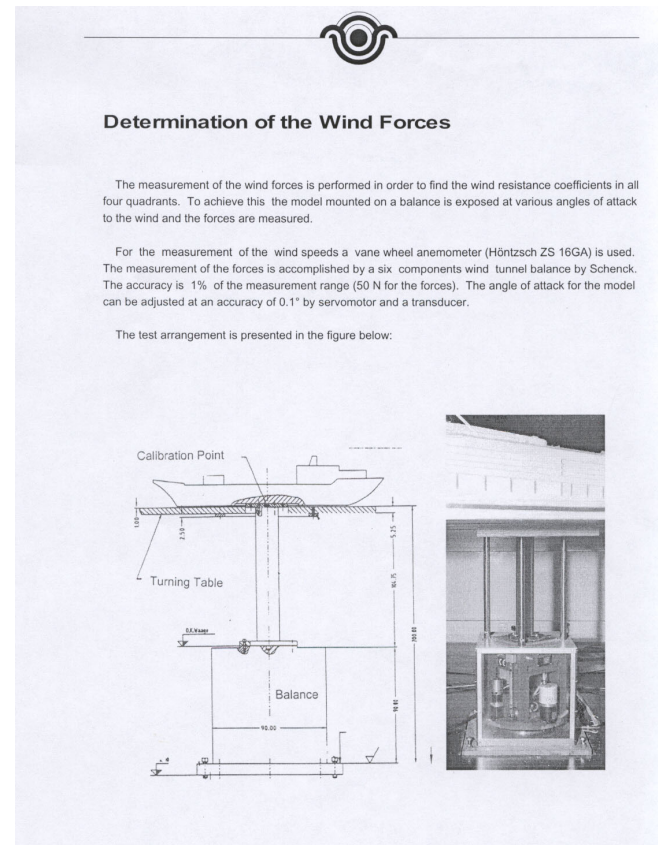
## NOMENCLATURE

Re Reynolds number  
IMO is the International Maritime Organisation  
Weather Criterion IMO Resolution A.749

### 1. Aim of the tests

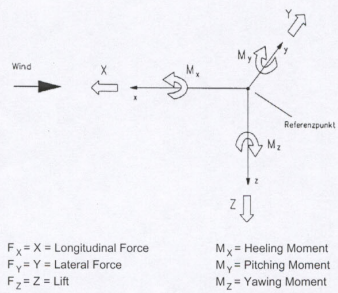
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### 2. The Vienna Model Basin wind tunnel



## Evaluation

The co-ordinate system is defined in the figure below:



The results are presented as non-dimensional coefficients:

Longitudinal force component  $C_X = F_X / (\rho_{AA} / 2 \times V_{WR}^2 \times A_F)$

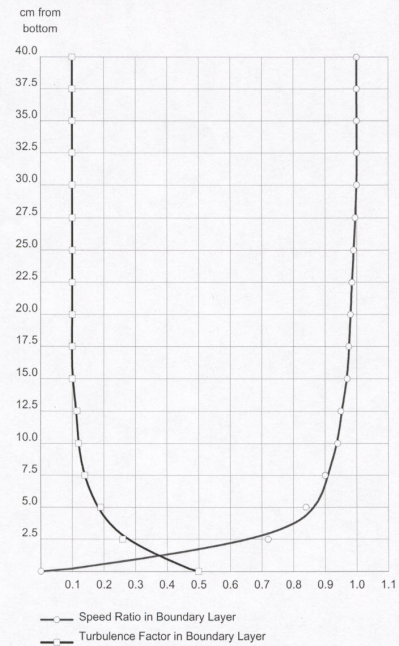
Lateral force component  $C_Y = F_Y / (\rho_{AA} / 2 \times V_{WR}^2 \times A_S)$

Heeling moment coefficient  $C_{MX} = M_X / (\rho_{AA} / 2 \times V_{WR}^2 \times A_S \times H_S)$

Yawing moment coefficient  $C_{MZ} = M_Z / (\rho_{AA} / 2 \times V_{WR}^2 \times A_S \times L_{OA})$

From the yawing moment divided by the lateral force the longitudinal centre of wind pressure is calculated for each angle of attack. The distance is given from the reference point, positive forward. The height of lateral centre of wind pressure is calculated the same way with the water level as reference height.

## Boundary Layer and Turbulence in the Wind Tunnel



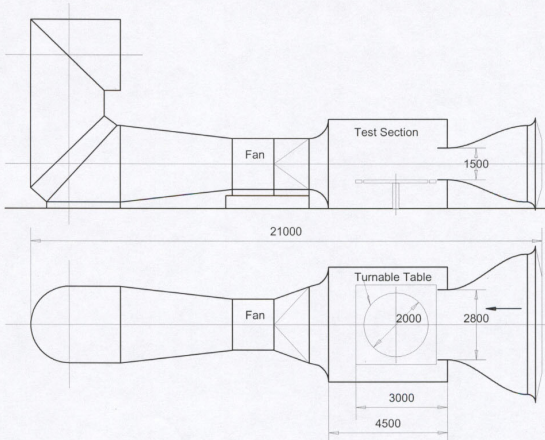
## Description of the Wind Tunnel

The wind tunnel of Vienna Model Basin is an open measuring section type tunnel which has no closed circulation. The principal construction and the main dimensions are shown in the sketch below.

Dimension of the measuring section: 2800 mm x 1500 mm  
Possible Velocities: 0.5 m/s - 28 m/s

Different boundary layer profiles can be adjusted by the application of grids of different wire meshes in front of the measuring section. The boundary layer which was present during the tests is given in the Figure next page.

For the measurement of the wind speeds a TWI multi-channel hot wire anemometer is used. To control the speed of the wind tunnel a vane wheel anemometer by Höntzsch is used.





### 3. Description of the models

The models were built in wood, scale 1/125, having represented the particulars with accuracy. To put the model in the heeled position, in similitude with the real ship, wedges have been applied to the model.



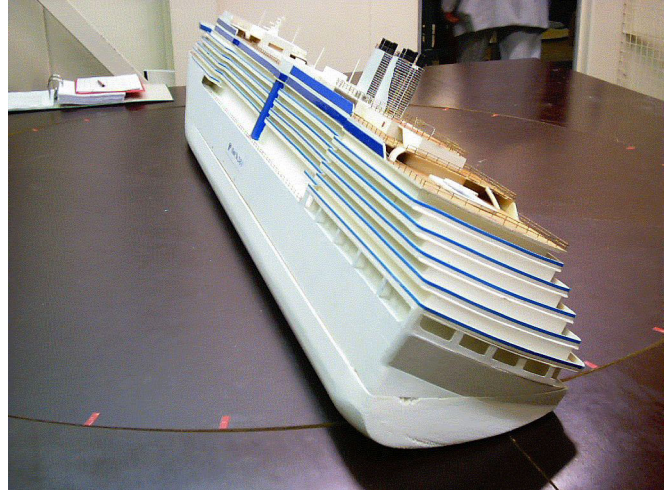
**Model n. 2036**



**Model n. 1852**



**Wedges applied to the models in order to obtain the position in similitude with the real ship in respect to the waterline.**



**Model n. 2036 in heeled position**

#### 4. Measurements

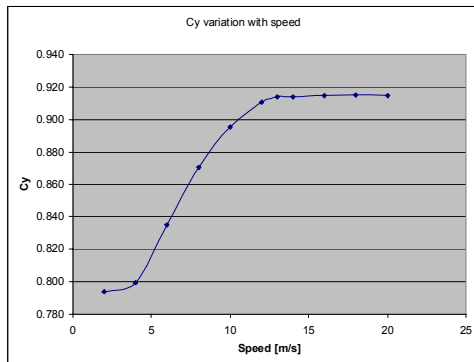
The measurements have been performed with a wind speed of 13 m/s, the Reynolds number (with the reference of the length of the model) is:

$$Re = \frac{v \cdot l}{\nu} = \frac{13 \cdot 2,32}{14,607 \cdot 10^{-6}} \cong 2 \cdot 10^6$$

if one takes the breadth of the smaller model as references, it is:

$$Re = \frac{v \cdot l}{\nu} = \frac{13 \cdot 0,258}{14,607 \cdot 10^{-6}} \cong 2,3 \cdot 10^5$$

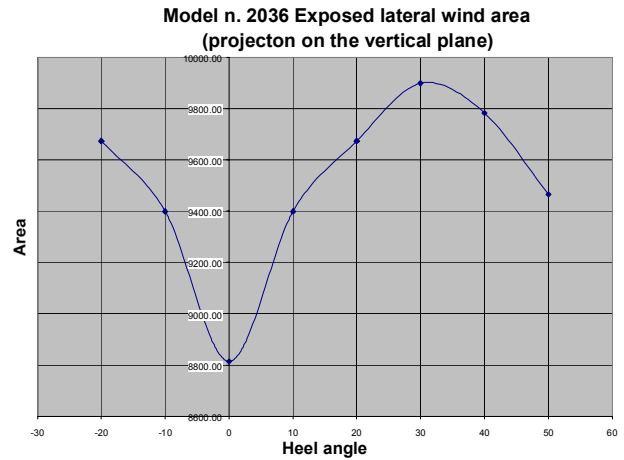
a condition not completely turbulent, but as already found by Blendermann [Wind loading of Ships], the local phenomenon of separations don't have a big effect on the total force on the model; then it is possible apply the same wind coefficient for the ship in real scale. A wind speed variation test on the model n.2036 was



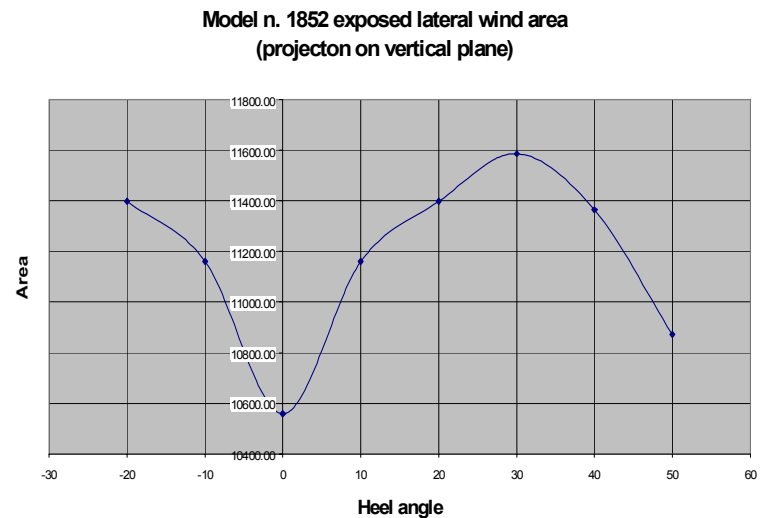
conducted to demonstrate the constancy of the wind coefficient.

#### 5. Wind area

The calculated area values against the heel is plotted below for the two models:



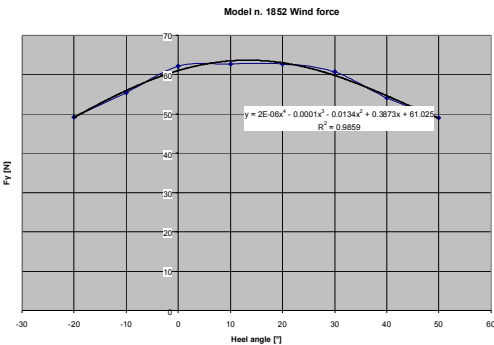
The value of the calculated area reach a maximum at 30 degrees of heeling and then reduces.



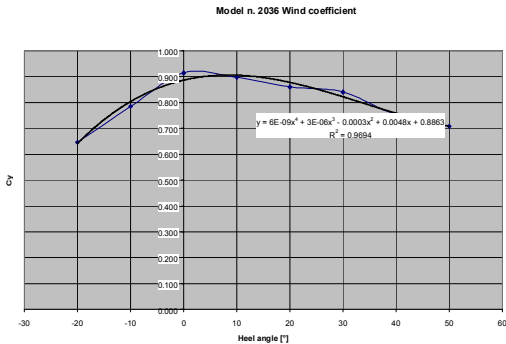
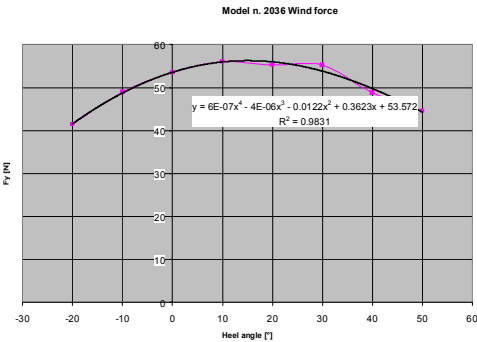
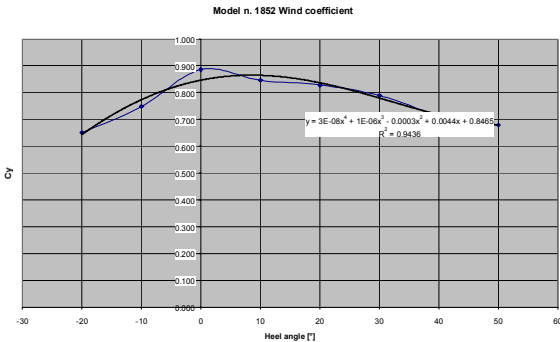
**6. Forces, moments, centres of pressures coordinates related to the respective geometrical centre.**

Here following are presented the trend of forces, moments and the values of the centres of pressures coordinates related to respective geometrical centres.

**Wind forces**

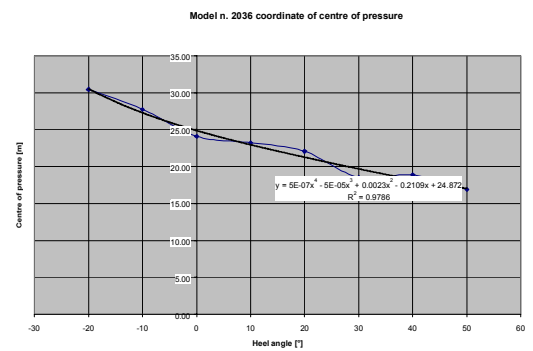
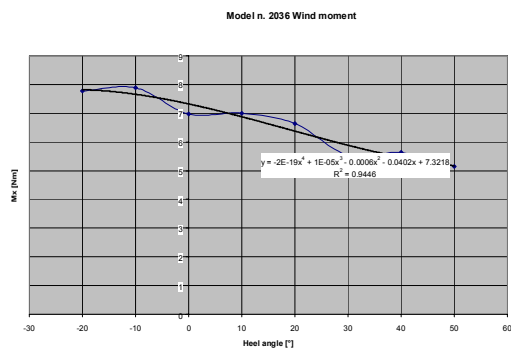
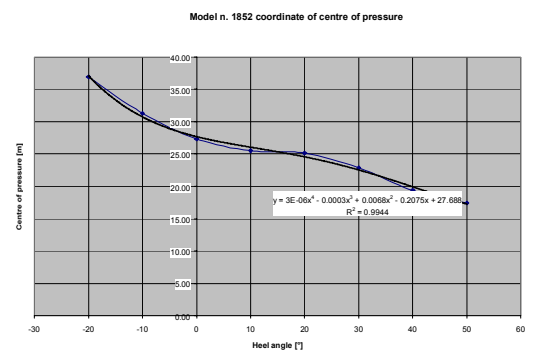
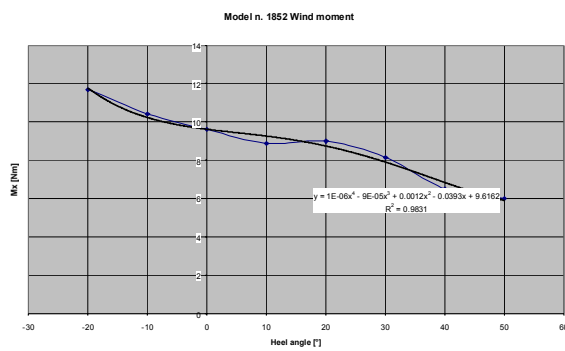


**Wind coefficients**

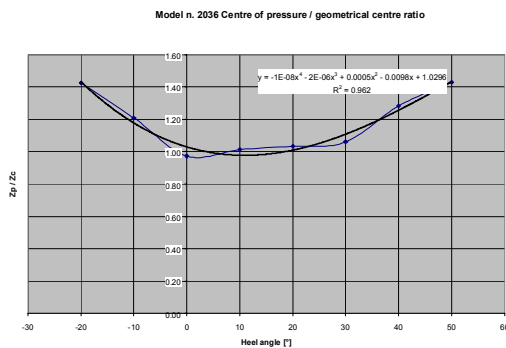
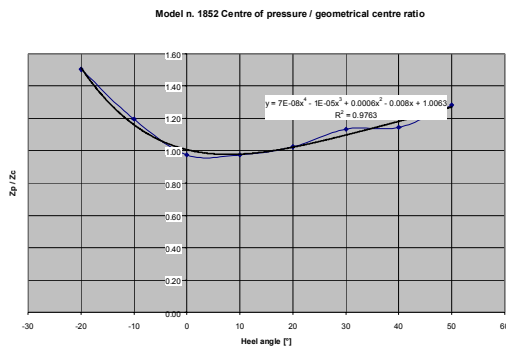


## Wind moments

## Coordinate of centre of pressure



## Centre of pressure / geometrical centre ratio



## 7. Wind coefficient

The wind coefficient assumed from I.M.O., as evidenced in "Francescutto, A., Serra, A. "Weather Criterion for intact Stability of Large Passenger Vessels", Proce. 5<sup>th</sup> Int. Workshop on Ship Stability and Operational Safety, Trieste, 2001", is: 1,13, while those resulting from the tested model, with the ship upright, are between 0,89 and 0,91.

## 8. Centre of pressures coordinate, geometrical centre ratio.

The value of the ratio between the centre of pressure and the geometrical centre assumed from I.M.O. is 1,08, while those resulting from the tested models is 0,97.

## 9. Heeling moments

The values of the heeling moment don't remain constant varying the heel, for an inclination of 50° opposite to the wind, the heeling moment assumed a value of 60-70% of the value at 0°.

## 10. Calculation of the forces and moments for the ship in real scale

Once obtained the forces and moments on the model, following the hypothesis used in the IMO weather criterion that assumed a medium speed (abt 26 m/s) derived from a certain vertical wind speed distribution, one could obtain the medium speed from the vertical distribution of the wind speed applied in the wind tunnel and bring to the real scale the results applying the Newton law.

(Standards and methodologies for the tests for: vertical distribution of the speed, procedures, etc. will be treated in following papers )

## 11. Practical application

The values obtained from the experimental results could be used in order to obtain the stability figures of GM satisfying at this criterion, taking in to account with more reliability the real behaviour of the ship.

## REFERENCES

Francescutto, A and Serra, A (2001). "Weather Criterion for Intact Stability of Large Passenger Vessels," Proc. 5th Int. Workshop on Ship Stability and Operational Safety, A Francescutto Ed., Trieste, pp. 4.6.1-4.6.4.

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