Annex 6

METHODS RELATING TO THE INTACT STABILITY INVESTIGATION OF HYDROFOIL CRAFT

The stability of these crafts should be considered in the hull-borne, transient and foil-borne modes. The stability investigation should also take into account the effects of external forces. The following procedures are outlined for guidance in dealing with stability.

1 Surface piercing hydrofoils

1.1 Hull-borne mode

1.1.1 The stability should be sufficient to satisfy the provisions of 2.3 and 2.4 of this Code.

1.1.2 Heeling moment due to turning

The heeling moment developed during manoeuvring of the craft in the displacement mode may be derived from the following formula:

$$M_R = 0.196 \frac{V_0^2}{L} . \Delta . KG \text{ (kN m)}$$

Where M_R = moment of heeling;
V_O = speed of the craft in the turn (m/s)
Δ = displacement (t);
L = length of the craft on the waterline (m)
KG = height of the centre of gravity above keel (m).

This formula is applicable when the ratio of the radius of the turning circle to the length of the craft is 2 to 4.

1.1.3 Relationship between the capsizing moment and heeling moment to satisfy the weather criterion.

The stability of hydrofoil boat in the displacement mode can be checked for compliance with the weather criterion K as follows:

$$K = \frac{M_C}{M_V} \geq 1$$

Where M_C = minimum capsizing moment as determined when account is taken of rolling;
M_V = dynamically applied heeling moment due to the wind pressure.

1.1.4 Heeling moment due to wind pressure

The heeling moment M_V is a product of wind pressure P_V the windage area A_V and the lever of windage area Z.

$$M_V = 0.001\ P_V A_V Z\ \text{(kN m)}$$

The value of the heeling moment is taken as constant during the whole period of heeling.

The windage area A_V is considered to include the projections of the lateral surfaces of the hull, superstructure and various structures above the waterline. The windage area lever Z is the vertical distance to the centre of windage from the waterline and the position of the centre of windage may be taken as the centre of the area.

The values of the wind pressure in Pascal associated with Force 7 Beaufort Scale depending on the position of the centre of windage area are given in Table 1.

Table 1

The values of the wind pressures, 100 nautical miles from land, for Beaufort Scale 7

Z above waterline (m)	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
P_V (Pa)	46	46	50	53	56	58	60	62	64

Note: These values may not be applicable in all areas.

1.1.5 Evaluation of the Minimum Capsizing Moment M_C in the displacement mode

The minimum capsizing moment is determined from the static and dynamic stability curves taking rolling into account.

.1 When the static stability curve is used, M_C is determined by equating the areas under the curves of the capsizing and righting moments (or levers) taking rolling into account - as indicated by Figure 1, where θ_Z is the amplitude of roll and MK is a line drawn parallel to the abscissa axis such that the shaded areas S_1 and S_2 are equal.

M_C = OM if the scale of ordinates represents moments

M_C = OM x Displacement if the scale of ordinates represents levers

.2 When the dynamic stability curve is used, first an auxiliary point A must be determined. For this purpose the amplitude of

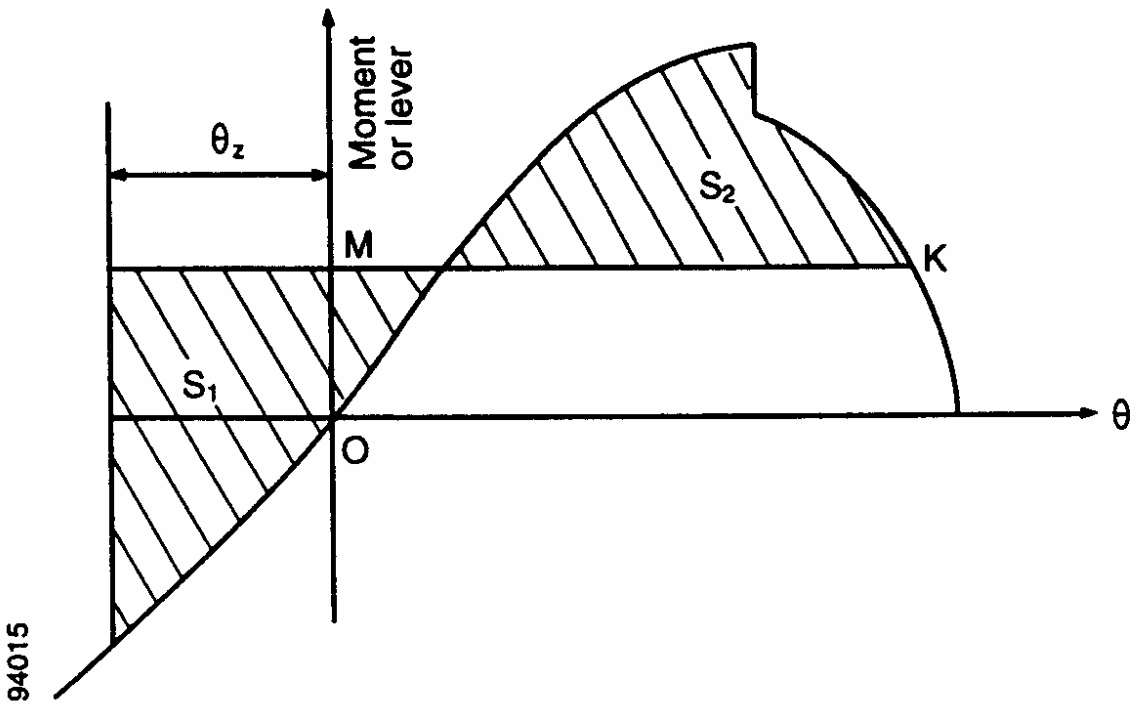

Fig 1 - Static stability curve

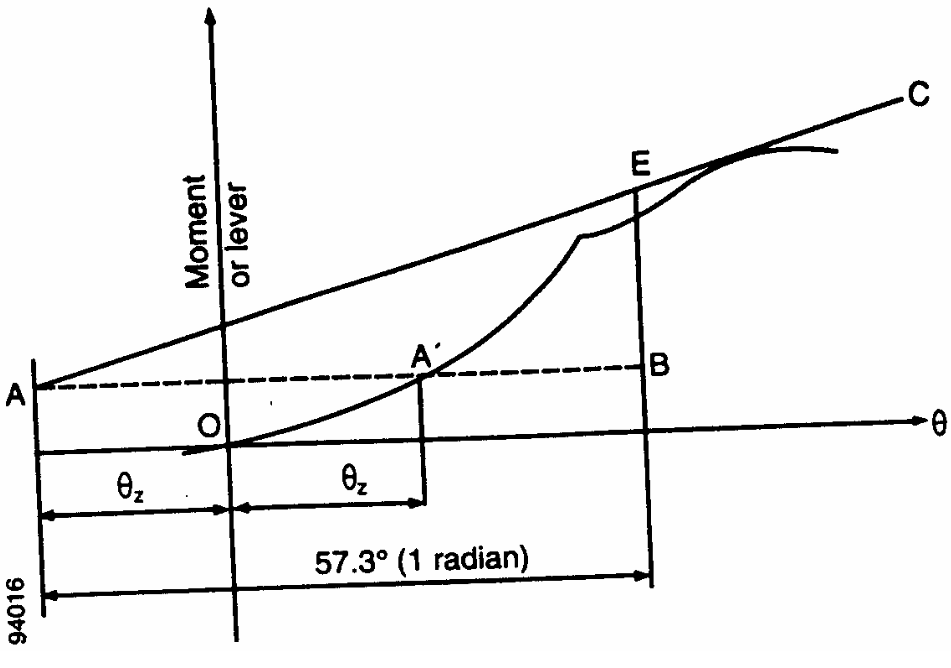

Fig. 2 - Dynamic Stability Curve

heeling is plotted to the right along the abscissa axis and a point 'A'' is found (see Figure 2). A line AA' is drawn parallel to the abscissa axis equal to the double amplitude of heeling (AA' = $2\theta_z$) and the required auxiliary point A is found. A tangent AC to the dynamic stability curve is drawn. From the point A the line AB is drawn parallel to the abscissa axis and equal to 1 radian (57.3°). From the point B a perpendicular is drawn to intersect with the tangent in point E. The distance $\overline{BE}$ is equal to the capsizing moment if measured along the ordinate axis of the dynamic stability curve. If, however, the dynamic stability levers are plotted along the axis $\overline{BE}$ is then the capsizing lever, and in this case the capsizing moment M_C is determined by multiplication of ordinate $\overline{BE}$ in m by the corresponding displacement in tonnes.

$$M_C = 9.81\,\Delta\,\overline{BE} \text{ (kN m)}$$

.3 The amplitude of rolling θ_z is determined by means of model and full-scale tests in irregular seas as a maximum amplitude of rolling of 50 oscillations of the a craft travelling at 90° to the wave direction in sea state for the worst design condition. If such data are lacking the amplitude is assumed to be equal to 15°.

.4 The effectiveness of the stability curves should be limited to the angle of flooding.

1.2 Stability in the transient and foil-borne modes

1.2.1 The stability should satisfy the provisions of 2.4 and 2.5 of this Code.

1.2.2.1 The stability in the transient and foil-borne modes should be checked for all cases of loading for the intended service of the craft.

1.2.2.2 The stability in the transient and foil-borne modes may be determined either by calculation or on the basis of data obtained from model experiments and should be verified by full-scale tests by the imposition of a series of known heeling moments by off-centre ballast weights, and recording the heeling angles produced by these moments. When taken in the hull-borne, take-off, steady foil-borne, and settling to hull-borne modes, these results will provide an indication of the values of the stability in the various situations of the craft during the transient condition.

1.2.2.3 The angle of heel in the foil-borne mode caused by the concentration of passengers at one side should not exceed 8°. During the transient mode the angle of heel due to the concentration of passengers on one side should not exceed 12°. The concentration of passengers should be determined by the Administration, having regard to the guidance given at annex 7 to this Code.

1.2.3 One of the possible methods of assessing foil-borne metacentric height (GM) in the design stage for a particular foil configuration is given in Figure 3.

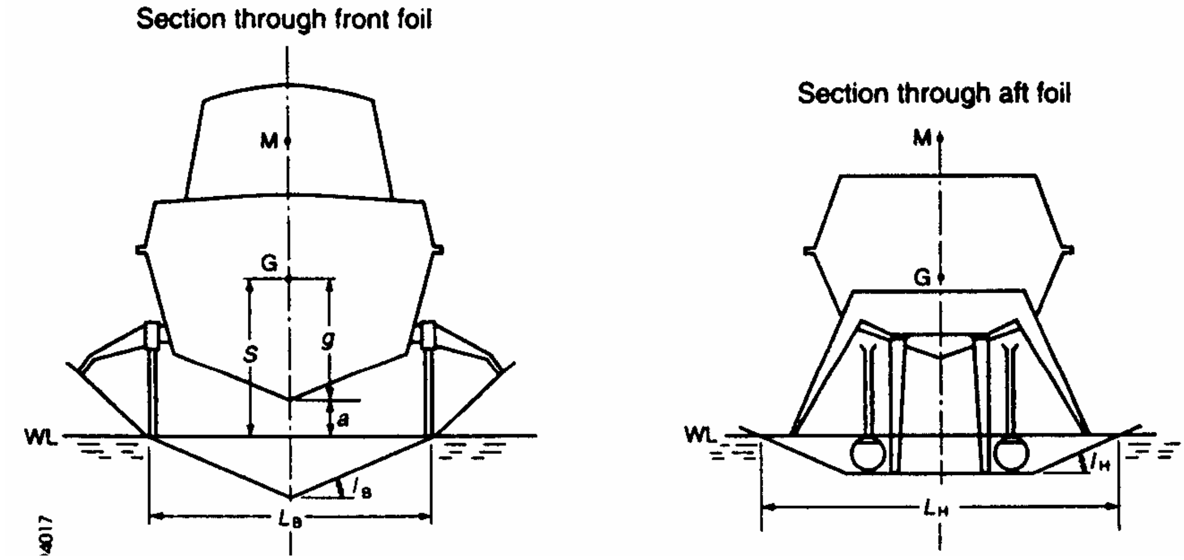

Fig. 3

$$GM = n_B\left(\frac{L_B}{2\tan l_B} - S\right) + n_H\left(\frac{L_H}{2\tan l_H} - S\right)$$

Where:

n_B = percentage of hydrofoil load borne by front foil
n_H = percentage of hydrofoil load borne by aft foil
L_B = clearance width of front foil
L_H = clearance width of aft foil
a = clearance between bottom of keel and water
g = height of centre of gravity above bottom of keel
l_B = angle at which front foil is inclined to horizontal
l_H = angle at which aft foil inclined to horizontal
S = height of centre of gravity above water

2 Fully submerged hydrofoils

2.1 Hull-borne mode

.1 The stability in the hull-borne mode should be sufficient to satisfy the provisions of 2.3 and 2.6 of the Code.

.2 Paragraphs 1.1.2 to 1.1.5 of this annex are appropriate to this type of craft in the hull-borne mode.

2.2 Transient mode

2.2.1 The stability should be examined by the use of certified computer simulations to evaluate the craft's motions, behaviour and responses under the normal conditions and limits of operations, and under the influence of any malfunction.

2.2.2 The stability conditions resulting from any potential failures in the systems or operational procedures during the transient stage which could prove hazardous to the craft's watertight integrity and stability should be examined.

2.3 Foil-borne mode

The stability of the craft in the foil-borne mode should be in compliance with the provisions of 2.4 of this Code. The provisions of paragraph 2.2 of this annex should also apply.

2.4 Paragraph 1.2.2 of this annex should be applied to this type of craft as appropriate and any computer simulations or design calculations should be verified by full-scale tests.