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NAVAL ARCHITECTURE.

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By CHAS. H. HASWELL, C. E., M. E.
Member American Society of Civil Engineers.

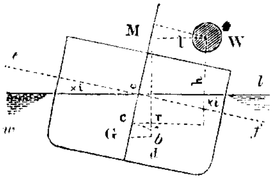
STABILITY.

Statical Stability is the moment of force which a body in flotation exerts to attain its normal position or that of equilibrium, it having been deflected from it, and it is equal to product of weight of fluid displaced and horizontal distances between the two centres of gravity of body and of displacement, or it is product of weight of displacement, height of *meta-centre* and sine of angle of inclination.

Dynamical Stability is amount of mechanical work necessary to deflect a body in flotation from its normal position or that of equilibrium, and it is is equal to product of sum of vertical distances through which centre of gravity of body descends and centre of buoyancy descends, in moving from vertical to inclined position by weight of body.

TO DETERMINE MEASURE OF STABILITY OF HULL OF A VESSEL OR OF A FLOATING BODY.

The measure of stability of a floating body depends essentially upon



horizontal distance, G *b*, of *meta-centre* of body from centre of gravity of the body; and it is product of the force of the water, or resistance to displacement of it, acting upward, and the distance of G *b*, or P×G *b*. If distance, *c* M, ir represented by *r*, and the angle of rolling, *c* M *r*, by M°, the measure of stability or S is determined by P *r*, sin. M° = S; and this is therefore greater, the greater the weight of the body, the greater the distance of *meta-centre* from centre of gravity of the body, and the greater the angle of inclination of this or of *c* M *r*.

Assume figure to represent transverse section of hull of a vessel, G centre of gravity of hull, *w l* water-line, and *c* centre of buoyancy or of displacement of immersed hull in position of equilibrium. Conceive the vessel to be heeled or inclined over, so that *e f* becomes the water-line, and *b* centre of buoyancy of the immersed section; produce *b* M, and the point M is *meta-centre** of the hull of the vessel.

Comparative Stability of different hulls or vessels is proportionate to the distance of G M for same angles of heeling, or of distance G *b*. Oscillations of hull of a vessel may be resolved into a rolling about its longitudinal axis, pitching about its transverse axis and vertical pitching, consisting in rising and sinking below and above position of equilibrium.

If transverse section of hull of a vessel is such that, when vessel heels, the level of centre of gravity is not altered, then its rolling will be about a permanent longitudinal axis traversing its centre of gravity, and it will not be accompanied by any vertical oscillations or pitchings, and the moment of its *inertia* will be constant while it rolls. But if, when hull heels, the level of its centre of gravity is altered, then axis about which it rolls becomes an instantaneous one, and the moment of

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* The transverse *meta-centre* depends upon position of centre of buoyancy, for it is that point, where a vertical line drawn from the centre, intersects a line passing through the centre of gravity of the hull of the vessel perpendicular to plane of the keel.

The point of *meta-centre* may be the same, or it may differ slightly for different angles of heeling. The angle of direction adopted to ascertain the position of the *meta-centre* should be the greatest which, under ordinary circumstances, is of probable occurrence; in different vessels this angle ranges from 20° to 60°.

If *meta-centre* is above the centre of gravity, the equilibrium is Stable; if it coincides with it, the equilibrium is Indifferent; and if it is below it, the equilibrium is Unstable.

its *inertia* will vary as it rolls; and rolling, must then necessarily be accompanied by vertical oscillations.

Such oscillations tend to strain a vessel and her spars, and it is desirable, therefore, that transverse section of hull should be such that centre of its gravity should not alter as it rolls, a condition which is always secured if all water-lines, as $w\ l$ and $e\ f$, are tangents to a common sphere described about G; or, in other words, if the point of their intersections, o, with the vertical plane of keel, is always equidistant from the centre of gravity of the hull.

TO COMPUTE STATICAL STABILITY.

$D \times c\ M$ sin. $M = S$, *D representing displacement, M angle of inclination, and S stability.*

ILLUSTRATION 1. Assume a ship weighing 6000 tons is heeled to an angle of 9°, distance $c\ M = 3$ feet,

$$\text{Sin. } 9° = \cdot 1564,$$

Then $6000 \times 3 \times \cdot 1564 = 2815 \cdot 2$ *foot-tons.*

ILLUSTRATION 2. Weight of a floating body is 5515 pounds, distance between its centre of gravity and *meta-centre* is 11·32 feet, and angle $M = 20°$.

$$\text{Sin. } M = \cdot 34202.$$

Hence $5515 \times 11 \cdot 32 \times \cdot 34202 = 21352 \cdot 24$ *foot-pounds.*

TO COMPUTE ELEMENTS OF STABILITY OF A FLOATING BODY.

$$\frac{A'}{A}\, a = s,\ \frac{c}{\text{sin. } M} = r,\ \frac{s}{\text{sin. } M} = g \text{ and sin. } M\, r = c\,.$$

A representing area of immersed section; A′ section immersed by careening of body, as f o l; s horizontal distance c r, between centres of buoyancy; a horizontal distance between centres of gravity i i, of areas immersed and emerged by careening; g distance c M, between centre of buoyancy or of water displaced and meta-centre; r distanee G M, between centre of gravity and meta-centre; c horizontal distance G b, between the centre of gravity and of line of displacement of it when careened, e vertical distance between centre of gravity and buoyancy, all in feet; and M angle of careening.

NOTE.—When centre of gravity G, is below that of displacement, c, then e is $+$; when it is above c it is $-$; and when it coincides with c it is 0; or e is $-$ when $\frac{S}{P} < s$; and a body will roll over when e sin. $M =$ or $> s$.

The assumed elements of figure illustrated are $A = 86$, $A' = 21·5$, $b = 21·5$ and $e = ·5$.

The deduced are $s = 3·7$, $c = 3·87$, $g = 10·82$, $a = 14·9$ and $r = 11·32$, *b representing breadth at water-line or beam in feet and P weight or displacement in pounds or tons.*

The $s = \frac{21·5}{86} \times 14·8 = 3·7$ feet, $r = \frac{3·87}{·34202} = 11·32$ feet, $e = r - g$, $g = \frac{3·7}{·34202} = 10·82$ feet, $c = ·34202 \times 11·32 = 3·87$ feet.

Of Hull of a Vessel.—$\left(\frac{b^3}{10·7 \text{ to } 13^* \, A} \pm e\right) P, \sin. M = S;\ d \cos. ·5\, M = d'$, $\frac{b^3}{10·7 \text{ to } 13\,(11·93)\, A} = g$, $\frac{1}{\sin. M}\left(\frac{S}{P} - s\right) = \pm e;\ P \left(\frac{ba}{A} + \overline{e \sin. M}\right) = S;$ and $P\,(s \pm \overline{e \sin. M}) = S$.

d representing depth of centre of gravity of displacement under water in equilibrium, and d′ the depth when out of equilibrium, all in feet.

ILLUSTRATION.—Displacement of a vessel is 10,000,000 pounds; breadth of beam, 50 feet; area of immersed section, 800 square feet; vertical distance from centre of gravity of hull up to centre of buoyancy or displacement, 1·9 feet, and horizontal distance a between centres of gravity of areas immersed and emerged, when careened to an angle of $9° \, 10'' = 33·4$ feet, the immersed area being 50 square feet.

$$\sin. 9° \, 10'' = ·1593$$

Then $s = \frac{50}{800} \times 33·4 = 2·0875$ feet, $800 \times 2·0875 = 50 \times 33·4$, $r = \frac{2·39}{·1593} = 15$ feet.

$g = \frac{50^3}{11·93 \times 800} = 13·1$ feet, $S = \left(\frac{50^3}{11·93 \times 800}\right) + 1·9 \times 10{,}000{,}000 \times ·1593 = 23{,}905{,}396$ pounds, and $e = \frac{1}{·1593}\left(\frac{23905396}{10000000} - 2·0875\right) = 1·9$ feet.

ILLUSTRATION 2.—Assume a ship having a displacement of 5000

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* Unit for the section of a parallelogram is 10·7; of a semicircle, 12, and of a triangle, 12·8.

tons and a height of *meta-centre* of 325 feet, to be careened to 6° 12′—what is her statical stability?

$$\text{Sin. } 6^\circ\ 12' = \cdot 1079$$

Then $5000 \times 3{\cdot}25 \times {\cdot}1079 = 1753{\cdot}37$ foot tons.

ILLULTRATION 3.—Assume a weight, *W*, of 50 tons to be placed upon her spar deck, having a common centre of gravity of 15 feet above her load-line.

Then $5000 \times 3{\cdot}25 - \overline{50+15} \times {\cdot}1079 = 1745{\cdot}29$ foot tons.

ILLUSTRATION 4.—Assume 100 tons of water ballast to be admitted to her tanks at a common centre of gravity of 15 feet below her load-line.

Then $5000 \times 3.25 + \overline{100 \times 15} \times {\cdot}1079 = 1915{\cdot}22$ foot tons.

ILLUSTRATION 5.—Assumeme her masts, weighing 6 tons, to be cut down 20 feet.

Then $\frac{10 \times 20}{5000} = \frac{2}{50}$ foot = fall of centre of gravity and $5000 \times \left(3{\cdot}25 = \frac{2}{50}\right) \times {\cdot}1079 = 1774{\cdot}95$ tons.

TO COMPUTE ELEMENTS OF POWER, ETC., REQUIRED TO CAREEN A BODY OR VESSEL.

$$\text{Sin. } M\,(h - \overline{n \text{ sin. } M}) + \overline{n \text{ sec. } M} - s = l$$

$$\frac{b^3}{10{\cdot}7 \text{ to } 13\,A}\ \sqrt[3]{\frac{P}{64{\cdot}125\,L\,A}} = m$$

$$W\,l\,r = P\,c \text{ and } W\,l = S.$$

W representing weight or power exerted and l distance at which weight or power acts to careen body taken from centre of gravity of displacement perpendicular to careening force, h vertical height from centre of gravity of displacement to centre of weight or power to careen body when it is in equilibrium, n horizontal distance from centre of vessel to centre of weight or power, L length of vessel and m meta-centre and S as in preceding case, all in feet.

ILLUSTRATION.—A weight is placed upon deck of a vessel at a mean distance of 3·87 feet from centre line of hull; height at which it is placed is 11·32, and other elements as in first case given.

$$\text{Sec. } 20^\circ = \cdot 342$$

Then $h = 11{\cdot}32$, $n = 3{\cdot}87$ and $l = {\cdot}342\,(1{\cdot}3 - \overline{3{\cdot}87 \times {\cdot}342}) + \overline{3{\cdot}87 \times 1{\cdot}0642} - 3{\cdot}7 = {\cdot}342 \times 10 + 4{\cdot}12 - 3{\cdot}7 = 3{\cdot}84$ feet.

Assume $W = 5515$.

Then $5515 \times 3{\cdot}84 = 21187{\cdot}6$ foot pounds.

Or $P\,(w \cos. M + h \sin. M) = S$, *w representing distance of weight from centre of vessel and h height of w above water-line, both in feet.*

Illustration.—If a weight of 30 tons placed at 20 feet from centre of hull or deck, 10 feet above water-line, careens it to an angle of 2° 9′, what is its stability?

$$\cos.\ 2^\circ\ 9' = {\cdot}9993 \quad \sin.\ 2^\circ\ 9' = {\cdot}0375$$

$$30\,(20 \times {\cdot}9993 + 10 \times {\cdot}0375) = 30 \times 20{\cdot}361 = 610{\cdot}83 \text{ foot tons.}$$

Statical Surface Stability.

Moment of statical surface stability at any angle is $c\,z \times D$. Assuming centre of gravity of vessel coincided with c, coefficient of a vessel's stability at any angle of heel is expressed when the displacement is multiplied by vertical height of the *meta-centre* for the given angle of heel above centre of gravity or $D \times c\,M$.

Approximately. Rule.—Divide moment of inertia of plane of flotation for the upright position, relatively to the middle line by volume of displacement; and quotient multiplied by sine of angle of heel will give result.

Per Foot of Length of Vessel, $\frac{2}{3}\,(B^3 \times \sin.\ M)$, *B representing half breadth.*

Dynamical Surface Stability.

Moment of dynamical surface stability is expressed by product of weight of vessel or displacement and depression of centre of buoyancy during the inclination, that is for angle M.

TO COMPUTE DYNAMICAL STABILITY OF A VESSEL.

Approximately. Rule.—Multiply displacement by height of *meta-centre* above centre of gravity and product by versed sine of angle of heel.

Or multiply statical stability for given angle by tangent of one-half angle of heel.