January 24, 1867.

Lieut.-General SABINE, President, in the Chair.

The following communications were read :—

I. "On a New Method of Calculating the Statical Stability of a Ship." By C. W. Merrifield, F.R.S., Principal of the Royal School of Naval Architecture. Received January 15, 1867.

The time required for the calculations of the stability of ships has practically restricted the ordinary draughtsman to the use of the metacentre. This implies that the locus of the centres of buoyancy cuts the transverse midship plane in a curve which may be treated as a circle; and this is only true, in general, for very small limits of inclination. In some particular cases it has been felt desirable to supplement this by computing the moment of stability at some definite angle of inclination, by means of the "ins and outs," or immersed and emersed wedges. But this has only been applied to one selected inclination, generally of 10° or 14°; and owing partly to this, and partly to the very scant time left available to the skilled draughtsman or calculator, this has never been a part of the ordinary work of the computation of a ship's quantities. For this reason it becomes of great consequence to find some method of getting at the stability, with an amount of extra work, which should not exceed that of the ordinary sheet known as the "sheer-draught calculation"*.

A method has occurred to me by which, as I think, this object may be attained. Upon conferring with some of my students†, who have suggested and removed certain difficulties of detail, we think we see our way, by an easy calculation, to place the whole account of a ship's statical stability in the hands of any person who understands simple equilibrium, either in an algebraical or geometrical form, as he may prefer.

It will take some time, with my present occupations, to prepare detailed examples. But as the method is complete in respect of principle, I have thought it best to bring it at once before the Society.

The fundamental assumption is, that the locus of the centres of buoyancy can be sufficiently represented by a conic. The stability is then measured by the perpendicular, from the centre of actual weight, on the normal due to the inclination. The chief step, therefore, is to find the conic, of which, I may remark, we already know the vertex, and the tangent and curvature at the vertex; for these are given by the ordinary calculation of the centre of buoyancy and the metacentre. Now I observe that the conic is completely determined if we can find the length of another radius of curvature corresponding to a known inclination. This is obtained by finding the moment of inertia about one of its principal axes (longitudinal)

* See 'Ship-building, Theoretical and Practical,' by Watts, Rankine, Barnes, and Napier, p. 46, for the sheer-draught calculation commonly used in this country.

† Messrs. Deadman, Edgar, John, and White.

of the plane of floatation at the inclination. This, divided by the unaltered displacement, gives the radius of curvature required.

But the chief practical difficulty lay in finding the means of drawing an inclined water-line across the body plan, so as to give an unaltered displacement. This I have at length succeeded in overcoming, as follows.

The sheer-draft calculation gives us, *inter alia,* the areas of the level sections, belonging to the upright position, as rectangles. Now, if we make one side of each of these equal to the length of the ship, their breadths form a series of ordinates for a curve of mean section; that is to say, the transverse section of a cylindrical body, of which the displacement at any level immersion will be the same as that of the ship. We then make out a scale of displacement for this section at various immersions, for a selected inclination, taking care to measure the immersions on the middle line of the original body plan. By this means the finding of any water-line at the selected inclination is reduced to a problem of plane geometry; and it is obvious that the place of the water-line so found will be a very close approximation to that of the required plane of floatation in the ship.

The calculations are as follows:—

1. Take out the horizontal areas from the sheer-draught calculation, and divide each by the ship's length. Set them off right and left from a vertical line at their present vertical interval, and draw a curve through their ends.

2. Any practised draughtsman will have little difficulty in drawing, at sight, an inclined line of floatation which shall give an unaltered immersed area on this mean section. He can verify it by measuring the immersed and emersed triangles obtained by his first guess, and make the correction due to the difference, if they do not agree.

3. In strictness, the more accurate course would be this,—through each of the vertical stations draw right lines at the selected angle. Thence, by Simpson's rule, form a scale of areas, ending at the highest inclined water-line. Use the vertical interval of the upright displacement, and neglect the cosine of the inclination. Then divide the upright displacement by the ship's length and by the cosine of the inclination, and find to what immersion this displacement corresponds in the scale of inclined areas. But this is needless, unless the calculations have to be made for different draughts of water.

4. Use this immersion to draw the inclined plane of floatation in the body plan.

5. Calculate the area, common moment, and moment of inertia of this plane, about the longitudinal axis formed by its intersection with the original plane of floatation, upright.

6. Transfer this moment of inertia to the longitudinal axis passing through the centre of gravity of the inclined plane of floatation.

7. Divide the moment so found by the displacement. This will give

the radius of curvature of the locus of the centres of buoyancy, corresponding to the selected inclination.

The conic is now implicitly determined. It remains to show what use is to be made of these data.

Let ρ_θ be the radius of curvature, corresponding to the angle θ, made between the normal and axis of a conic; then

$$\rho_\theta=\frac{a(1-e^2)}{(1-e^2\sin^2\theta)^{\frac{3}{2}}},\quad \rho_0=a(1-e^2).$$

From these we obtain

$$e^2=\frac{\rho_\theta^{\frac{2}{3}}-\rho_0^{\frac{2}{3}}}{\rho_\theta^{\frac{2}{3}}\sin^2\theta}, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (a)$$

$$1-e^2=\frac{\rho_0^{\frac{2}{3}}-\rho_\theta^{\frac{2}{3}}\cos^2\theta}{\rho_\theta^{\frac{2}{3}}\sin^2\theta}, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (b)$$

$$a=\frac{\rho_0\rho_\theta^{\frac{2}{3}}\sin^2\theta}{\rho_0^{\frac{2}{3}}-\rho_\theta^{\frac{2}{3}}\cos^2\theta}, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (c)$$

$$ae^2=\frac{\rho_0(\rho_\theta^{\frac{2}{3}}-\rho_0^{\frac{2}{3}})}{\rho_0^{\frac{2}{3}}-\rho_\theta^{\frac{2}{3}}\cos^2\theta}; \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (d)$$

and these afford the means of calculating all the elements of the conic.

Now, let us take any other inclination ϕ: we may calculate ρ_ϕ from the foregoing value of e^2 by means of the formula

$$\rho_\phi=\frac{\rho_0}{(1-e^2\sin^2\phi)^{\frac{3}{2}}}. \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (e)$$

Now, if λ be the distance of the centre of gravity of the ship below the metacentre of the upright position, and p the perpendicular from the centre of gravity on the normal of the conic in the inclined position, we shall have

$$\frac{p}{\sin\phi}=\lambda+\frac{\rho_0^{\frac{2}{3}}(\rho_\phi^{\frac{2}{3}}-\rho_0^{\frac{2}{3}})}{\rho_0^{\frac{1}{3}}+\rho_\phi^{\frac{1}{3}}\cos\phi}; \quad \ldots\ldots\ldots\ldots \quad (f)$$

and $p\times D$ is the moment of stability, D being the displacement.

Strictly, it is only necessary to use the formulæ (a), (e), (f) in actual work. Formula (f) shows clearly how an alteration in the position of the weights affects the stability. If λ be altered, the altered value of p is obtained (geometrically) by a very obvious construction.

In Mr. Scott Russell's treatise on 'Naval Architecture,' p. 604, it is shown how the stability may be obtained by geometrical construction when the conic is known.

It is worth while to remark that the condition that the conic should be

a hyperbola, a parabola, or an ellipse, is

$$\rho_0 <, =, \text{ or } > \rho_\theta \,.\, \cos^3\theta\,;$$

and whether the ellipse is referred to its major axis, becomes a circle, or is referred to its minor axis, depends upon whether

$$\rho_0 <, =, \text{ or } > \rho\ ;$$

θ having any value whatever within the limits of continuity.

It is to be observed that this method only applies on the supposition that there is no abrupt discontinuity. The immersion of the gunwale, for instance, would vitiate it. But in ordinary ships, experience leads to the conclusion that a conic would be a very accurate representation of the locus of centres of buoyancy within all reasonable limits.

I have not waited to try the method throughout upon a specific example. But every step is separately well known; most of the steps familiarly so, within my own experience. My *estimate* of the extra amount of work is, that it would be rather less than would be involved in making an independent calculation of the ordinary sheer-draught work. I shall have an immediate opportunity of verifying this in my school; but I wished to announce the method publicly before beginning to teach it.

II. "Transformation of the Aromatic Monamines into Acids richer in Carbon." By A. W. Hofmann, LL.D., F.R.S. Received January 21, 1867.

In a previous communication* to the Royal Society I have described the formation of *methenyldiphenyldiamine,* a substance which I obtained some years ago, by the action of chloroform on aniline, by means of a new method, namely, by treating a mixture of phenylformamide and aniline with trichloride of phosphorus.

The continuation of these researches necessitated the preparation of phenylformamide, and later also of tolylformamide in greater quantities. I have repeatedly obtained these bodies by the action of formic ether on the corresponding monamine, but in consequence of the difficulties with which the preparation of formic acid in large quantities is still beset, I have of late returned to the old method, viz., distillation of the oxalate of the monamine, since I found that by employing the materials in the appropriate proportions, the formation of very large quantities of the formyl compounds may be readily accomplished.

According to Gerhardt, the principal product of the distillation of the secondary aniline-oxalate is *diphenyloxamide, phenylformamide* being formed only as by-product. In fact, 1 molecule of oxalic acid and 2 molecules of aniline yield almost exclusively diphenyloxamide by the separation of 2 molecules of water from the secondary aniline-oxalate, thus:—

$$\left.\begin{matrix}(C_2O_2)''\\ H_2\end{matrix}\right\} O_2 + 2\left[\left.\begin{matrix}C_6H_5\\ H\\ H\end{matrix}\right\} N\right] = \left.\begin{matrix}(C_2O_2)''\\ (C_6H_5)_2\\ H_2\end{matrix}\right\} N_2 + 2H_2O.$$

* Proceedings of the Royal Society, vol. xv. p. 55.