REVIEW OF NAVAL CONSTRUCTOR WILSON'S EXPERIMENT FOR ASCERTAINING THE CENTRE OF GRAVITY OF THE U. S. STEAMER
"SHAWMUT."

By Chief Engineer B. F. ISHERWOOD, U. S. Navy.

Having occasion to consult the 58th volume of this JOURNAL, my eye was arrested on page 97 of the number for August, 1874, by an article headed *Experimental Determination of the Centre of Gravity of the United States Steamer "Shawmut"* by T. D. Wilson, Naval Constructor, U. S. N. As this steamer was one of a class of large screw gun-boats for which I designed the machinery in 1863, and whose elements and performance I obtained with the greatest exactness, I read the article with interest in the expectation of finding the subject properly handled, and my knowledge of the qualities of those fine vessels increased. Great, therefore, was my disappointment, when in place of a carefully executed experiment under proper conditions, and an accurately calculated result from correct data, I found mainly errors of fact, procedure and deduction. Now, inasmuch as sagacious experiments of this kind are of the highest value in furnishing science with its indispensable data, so fallacious ones, being correspondingly injurious, should have their faults promptly exposed to prevent the serious mistakes that would follow their acceptance; and, as I am known to possess the true data in this case, I am not willing to sanction, by my silence, the propagation of errors I am able to correct.

The experimental method of determining the position of the centre of gravity of a ship, was completely set forth by Bouguer, more than one hundred and twenty years ago, as is well known to all persons educated in this and kindred subjects. To the dead Bouguer, therefore, is due the credit of the investigation and not, as the reader is left to infer from the remarks of Mr. Wilson, to the living Mr. Barnaby, whose demonstration has been textually copied word for word. The method, in fact, is neither new nor unknown, nor is there any difficulty in its application.

For the proper understanding of an experiment of any kind, the scale on which it was tried must be known, or the size of the object experimented on, which in this case would be defined by the dimen-

sions of the "Shawmut." As Mr. Wilson—apparently unaware of this necessity—has not stated these dimensions, I now give them in supply of his omission.

Length on mean load-line from forward side of rabbet	
of stem to after side of sternpost,	179·5 feet.
Extreme breadth,	30·0 feet.
Mean load-line above the lower edge of the rabbet of	
the keel,	9·33 feet.
Lowest port-sill above the mean load line,	5·5 feet.
Displacement to the mean load-line,	29216 0 cu. ft.
Area of mean load-line,	4196 0 sq. ft.
Area of the greatest immersed transverse section, .	240·4 sq. ft.
Centre of displacement before the middle of the length,	0·2 foot.
Centre of displacement below the mean load-line,	3·87 feet.
Latitudinal meta centre above the centre of dis-	
placement,	8·53 feet.
Ratio of displacement to circumscribing parallelopipedon,	0·5813.
Ratio of load-line to circumscribing parallelogram,	0·779
Ratio of greatest immersed transverse section to cir-	
cumscribing parallelogram,	0·858
Area of the ten principal sails. (Courses, topsails,	
topgallant sails, jib and spanker.)	9199 sq. ft.
Centre of effort of the sails before the middle of the	
length of the mean load-line,	6·56 feet.
Centre of effort of the sails above the mean load-line,	45·92 feet.
Ratio of forward moment to after moment,	1·00 to 0·75.

In December, 1866, the "Shawmut" having on board all she could stow, including one hundred and sixty tons of coal, one hundred and eighteen men, bread for forty days, other provisions for sixty days, and water in tanks for eight days, was officially reported as having a mean draught of water of 10 feet above the lower edge of the rabbet of the keel, at which draught her displacement of sea-water is 917·8 tons. Now Mr. Wilson states that during his experiment her draught of water was 11 feet forward and 13 feet 6 inches aft above the bottom of the keel, corresponding to a mean draught of 10 feet 7 inches above the lower edge of its rabbet. As his experiment was made at Washington, this draught was in fresh water, but even after correction for sea-water it is still about 4 and 6-10ths inches more than

the reported deep load draught of the vessel in 1866. The exact displacement of the vessel at 10 feet 7 inches mean draught above the lower edge of the rabbet of the keel, is 965·4 tons in fresh water instead of the 1010 84 tons stated by Mr. Wilson. Further, I find the centre of displacement or buoyancy at that draught of water is 4·42 feet below the mean load line. Also, the meta centre is 7·56 feet above the centre of displacement. These errors vitiate Mr. Wilson's calculations, but he seems to have made a still more serious one (supposing his data to be correct) in giving 199·32 as the product of the weights into the distances through which they were moved, whereas, if we take the only weights and distances he gives, a very different result follows, namely:—

The transfer of the 9 inch gun = 10437 pounds = 4·66 tons	
× 20·66 feet =	96·27
The transfer of the 11 inch gun = 24159 pounds = 10·78 tons	
× 7·00 feet =	75·49
The transfer of the 20 pounder gun = 3793 pounds = 1·69 tons	
× 3·665 feet =	6·20
	<hr/>
	177·96

The moments are thus 177·96, and not 199·32 as given by Mr. Wilson. He does not show how he obtained this 199 32, but merely says the moments amount to that figure. Experiments to be satisfactory and reliable, must have every process clearly described, and all the data exhibited in such manner that each step can be followed and every quantity recalculated. Nothing should be offered on faith. Restating his calculations with corrections, we have

$$\frac{1\frac{1}{2}}{20} = \frac{1}{15} = 3^{\circ} 48' 51'' = \cdot 0666$$

$$GM = \frac{pc}{W \tan \theta} = \frac{177\cdot96}{965\cdot4 \times \cdot 0666} = \frac{177\cdot96}{64\cdot386} = 2\cdot765 \text{ for the dis-}$$

tance in feet that the centre of gravity is below the meta centre, and the centre of gravity is consequently 4·80 feet above the centre of displacement which is the real result sought by the experiment, but which he neglects to give. In strictness, the calculations on the vessel should be made to the exact difference of her draughts of water forward and aft, and not from the mean draught.

Mr. Wilson refers to a trial made with the British sailing sloop-of-war "Scylla" for the purpose of determining the position of her centre of gravity. He does not state the result, but the trial and the necessary calculations were made in a very different manner from those of the "Shawmut," and gave, for the position of that centre, 0·42 foot below the load water-line; while, in the case of the steamer "Shawmut," it seems to be 0·38 foot above, provided the experiment had been made with more accuracy than the calculations based on it.

Apart from the errors of calculation, the conduct of the experiment was such as to allow of nothing more than a very rough approximation to the truth. Such a trial to be of any value must be made in a dock or basin where there is no current and during a perfect calm, the vessel being free from moorings and merely held by lines. She should also be inclined both ways and to varying inclinations, and the mean of the determinations taken. In the case of the "Shawmut," however, the vessel was anchored in a stream, and the wind is stated to have blown a little fresh, which must have caused some rolling, but no effort appears to have been made to measure it. The fact that the vessel was riding with an anchor down, must have seriously affected the result; while nothing is said of the current which in the narrow and crooked channel of the river must have had influence and may have combined with the wind to increase or diminish the inclination. And then, only one inclination was tried which is altogether insufficient. As the pivot-gun formed a large portion of the inclining weight, the distance of the centre of gravity of its slide and of its carriage should have been given separately, as well as that of the gun, for they are at very different distances from the pivot or axis of motion. This seems to have been neglected, as only the distance the gun was moved is mentioned.

The principle on which the centre of gravity of a vessel is experimentally ascertained, is so simple that an extended explanation is not necessary, as easily appears from the following:—

If D represents the displacement of a vessel, p the meta centric height, and a the height of the centre of gravity above the centre of displacement or centre of buoyancy; then, if the vessel be inclined through the small angle θ , the expression $D(p - a) \sin \theta$ is the measure of stability at that inclination, provided it be so small that p may be taken as the initial metacentric height without sensible error. If

this inclination produced by placing a weight, w , at a distance, d , from the vertical longitudinal plane, then we have the equality

$$D(p - a) \sin \theta = wd \cos \theta.$$

$$p - a = \frac{wd \cos \theta}{D \sin \theta} = \frac{wd \cos \theta}{D} \text{ or } \frac{wd}{D \tan \theta}$$

$$\text{whence, } a = p - \frac{wd}{D \tan \theta}$$

This is the usual and proper expression for the height of the centre of gravity above the centre of displacement.

In calculating the displacement of vessels, the United States' ton of 2240 pounds is used both in this country and in England. The 35 cubic feet used to represent a ton in the English books from which Mr. Wilson so extensively copies, shows this, and is adapted merely for simplicity of calculation, though not correct, as it makes the specific gravity of sea-water 1024, and thus gives a small error of immersion on the safe side. The French naval architects always assume the specific gravity of sea-water at 1026, which is nearer the truth. The French ton is 1000 kilograms, or 2204.737 pounds, which closely approximates the English ton.

Other errors could be noted, but enough have been pointed out to show the utter worthlessness of the experiment, which both in its method and in the calculations based on it exhibit a want of knowledge of the true principles governing such an investigation. The science of the Navy-Department must have been rated very low for such a report to have been submitted to it.

The U. S. Commission on tests of Iron and Steel.—Committee F, "On the effects of temperature," requests information as to the behavior of rails and machinery exposed to the extremes of temperature in northern latitudes, when subject to wear or breakage. Information of any kind on the subject, such as specimens, photographs, results of analysis, statistics of railroads, statements of manufacturers, essays, etc., may be sent to the chairman, R. H. Thurston, Stevens' Institute, Hoboken, N. J.