*(Paper No. 3591.)***"Note on the Towing-Resistance of a Floating Dock."**

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BEING interested some time ago in the towing of a large floating dock, the Author thought that an attempt might be made to deduce approximately the towing-resistance of the dock from the indicator horse-power of the towing steamer, thus avoiding the expense and complication of a dynamometer.

The dock is 320 feet in length by 86 feet in width over all, and the draught at the time of the experiment was 4 feet 6 inches. The wetted surface at this draught is 31,655 square feet. The dock consists of three rectangular box-like pontoons, the centre-pontoon being 320 feet in length by 65 feet in width, and the two side-pontoons 272 feet in length by 8 feet 6 inches in width. The draught of the side-pontoons is 2 feet, being 2 feet 6 inches less than that of the centre-pontoon. Each of the two side-pontoons is separated from the centre-pontoon by a passage, 2 feet in width, open to the sea. The flow of water through these narrow lanes is considerably baffled by the brackets connecting the three pontoons together, and no doubt this obstruction to the free passage of the water along these two lanes accounts for a large portion of the resistance to towing. The dock was towed by a cargo-steamer of about 9,500 tons displacement and 2,500 I.H.P., having a maximum speed of about $11\frac{1}{2}$ knots per hour. In the following investigation this steamer will be called the tug.

The investigation is based upon two assumptions, which are considered to be fairly correct, viz. (1), that the indicator horse-power of the tug is 2.25 times her "effective" horse-power, adopting Mr. Froude's well-known nomenclature; or, in other words, that the tug's own propulsive coefficient is $\frac{1}{2.25} = 0.44$; and (2), that the augment of the tug's own resistance due to her propeller is 40 per cent. of her total resistance, also in accordance with Mr.

Froude's figures.¹ Of course, neither of these assumptions is strictly accurate, but both are probably fairly correct within the limits of ordinary working.

The power- and speed-curve for a sister-ship to the tug having been previously obtained, the pull on the tow-rope, *i.e.*, the resistance of the pontoon, is arrived at by the following reasoning from the foregoing assumptions. The I.H.P. of the tug is 2.25 times her E.H.P., ("effective" horse-power), but the I.H.P. of the pontoon, having no augment due to a propeller, will be about $2.25 - 0.4 = 1.85$ times the E.H.P. For example, when towing at $5\frac{1}{2}$ knots per hour the observed I.H.P. was 1,094, the I.H.P. of the tug for this speed, previously ascertained, being 240. The I.H.P. due to the tow is the difference between these two powers, or 854. The E.H.P. of the pontoon is $\frac{854}{1.85} = 462$, and the pull on the tow-rope for a speed of $5\frac{1}{2}$ knots per hour is $\frac{462 \times 33,000}{5.5 \times 100 \times 2,240} = 12.37$ tons. The power required to drag the tow-rope through the water is considered negligible. The powers were taken for three speeds, viz., $5\frac{1}{2}$, $6\frac{3}{4}$, and $7\frac{1}{2}$ knots per hour, the speeds being measured by a Massey speed-indicator, which had been ascertained to be correct within about 5 per cent. It is obviously very inconvenient to try such an unwieldy vessel on a measured mile. The weather during the trials was moderate. The results obtained are given in the following Table:—

Speed in Knots per Hour.	Observed I.H.P.	I.H.P. of Tug previously Determined.	I.H.P. of Tow by Difference.	E.H.P. of Tow = $\frac{\text{I.H.P.}}{1.85}$	Resistance of Tow or Pull on Tow-rope.	Resistance of Tow in Lbs. per Square Foot of Wetted Surface.	Calculated Skin-Resistance of Tow.	Wave-making Resistance of Tow.
					Tons.		Lbs.	Lbs.
$5\frac{1}{2}$	1,094	240	854	462	12.37	0.875	5,838	21,870
$6\frac{3}{4}$	1,857	400	1,457	790	17.24	1.219	8,794	29,823
$7\frac{1}{2}$	2,300	570	1,730	935	18.36	1.299	10,857	30,269

It is thought to be of some interest to analyse the total resistance of a body of such unfavourable shape, in order to ascertain in what manner the skin-resistance and wave-making resistance, taken separately, vary with the speed. The skin-resistance is calculated

¹ Transactions of the Institution of Naval Architects, vol. xvii, p. 174.

from the results obtained by Mr. Froude, namely, that it is 1 lb. per square foot of clean wetted surface at a speed of 12·8 knots per hour, and that it varies as the 1·8th power of the speed (here taken as the square for simplicity). The wave-making resistance is then arrived at by subtracting the calculated skin-resistance from the total resistance. These resistances have been plotted in the form of curves in *Fig. 1*. A floating dock is, of course, not built with a view to economical propulsion, and it is not surprising that even at these low speeds the wave-making resistance far exceeds the calculated skin-resistance. It is interesting to observe the very low

Fig. 1.

speed, namely, about $6\frac{1}{4}$ knots per hour, at which the rate of increase of the total resistance begins to fall, as compared with that of properly-formed ships. The average speed over the whole voyage of 6,000 miles was about 5 knots per hour.

In estimating the power required of the tug it will be sufficiently accurate to take the towing-resistance, *i.e.*, the pull on the tow-rope, for similar docks, as 1 lb. per square foot of wetted surface, at a speed of 6 knots per hour, which is quite fast enough for a structure not built for progression. The E.H.P. of the tow is obtained by multiplying the resistance of the tow at 6 knots per

hour by 600 feet per minute, and dividing by 33,000. This multiplied by 1.85 gives the I.H.P. of the tow, and to this product must be added the tug's own I.H.P. for a speed of 6 knots per hour. Needless to say, a good margin must be allowed for head-winds, etc. For the case described,

$$\text{the E.H.P. of the tow} = \frac{31,655 \times 600}{33,000} = 575$$

$$\text{and the I.H.P. ,, ,, ,,} = 575 \times 1.85 = 1,063.$$

It will be seen that the formula is very easily applied, and although no doubt not strictly accurate, it may serve as some guide to the work which a tug will be required to do when towing structures similar to that experimented upon.

The Paper is accompanied by a diagram, from which the Figure in the text has been prepared.