blade is above the keel, but at sea the screw is dropped. The results obtained with this arrangement are said to be excellent.

The author now proceeds to the consideration of the second portion of his subject, namely, the shafts and fittings of screw propellers; about these he ventures to think there is still a good deal to be learned. The best form, as well as the best mode of fitting a shaft, which has to transmit on occasion the strain of engines exerting, it may be, 8000-horse power, deserves attentive consideration, more especially when it is remembered that the safety of much valuable property depends frequently on the trustworthiness of a screw shaft. The whole arrangement of these shafts involves some of the nicest questions of mechanical science. It is at all times a nice matter to centre truly a considerable length of shafting, even to a series of rigid supports, but the difficulty is greatly increased when, as on board a ship, the supports are not rigid, but yield with each strain and "working" of the vessel's hull. The author will refer to one out of numerous examples of the failure—first of a screw, and then of a shaft—illustrating the importance of this question. This was the case of the Atrato, which sailed from Plymouth for Australia, with some hundreds of emigrants on board, on the 17th September, 1872. On the 19th she returned with her screw broken. The damage was made good and she put to sea again, only to return again, however, about the 26th October with her shaft broken. Diagram No. 17 shows the general nature of the fracture. This second mishap gave rise to a lengthy correspondence between Messrs. James Watts & Co., who made her machinery, and the Board of Trade. By order of the House of Commons this correspondence was printed. Subsequently the Board of Trade sent a circular to all its marine machinery surveyors—thirty-two in number—requesting them to forward, in a tabulated form, the rules they adopted for calculating the diameters of screw shafts. This table, which can be seen in the printed report of the Board of trade, gives respectively the names of ships, the makers of engines, diameters of the cylinders, length of stroke, steam pressure, diameter of shafting abaft of the crank, and diameter of same as obtained by the rule the surveyor uses. Two columns of the table are bracketed together under the common head of differences between diameters of existing shafting in the vessels named and the sizes obtained by the surveyor's formulæ—the one column containing the amount less than existing shafting and the other giving the amount greater than the existing shafting in the respective vessels named. A list of thirty-eight ships was given. Some of the surveyors used respectively rules of their own, and of the remainder some used Rankine's, some Molesworth's and some Anderson's rules. The Table No. 11, gives a few of the more striking examples selected from these figures.

Atrato's Shaft.

Actual diameter of broken shaft	12 inches	
Proper diameter as computed by surveyors:—		
By Rankine's rule	13·7	"
" Anderson's rule	13·4	"
" Molesworth's rule	13·9	"
" Caird & Company's rule	13·4	"
" Mr. J. Rose, Hull Surveyor	14·0	"
" Mr. W. Wheatley, Cork	14·4	"
" Spencer's, used by Mr. Biped, Liverpool, Surv.	13·2	"
" Mr. G. Carlisle, Leith Surveyor	13·4	"
" Mr. R. Taplin, Liverpool Surveyor	13·2	"
" Mr. Snowden, London Surveyor	13·9	"

Particulars of the engines (compound): — Diameter of high pressure cylinder, 57 in.; diameter of low-pressure cylinder, 90 in.; stroke, 4 ft.; pressure of steam in boilers, 60 lb.; cut-off at about two-thirds stroke in small cylinder.

The sizes of shaft suitable for the Atrato's engines, deduced by the various surveyors, were from ½ in. to about 3 in. greater in diameter than the shaft which broke, and which was 12 in. in diameter; hardly any two surveyors however, found the same dimension. In the author's opinion, the probable causes of the fracture of total absence of any adequate torsional elasticity between the propeller and the engines. Hence, when the screw makes some revolutions out of the water, or it draws down air, then the engines race, and afterwards the screw may become suddenly and deeply submerged, throwing an abrupt strain on the cranks, causing the ship to tremble fore and aft, and some weak point in the shaft probably gives way, leaving the ship a helpless log upon the waves. In the author's opinion, two remedies present themselves for this evil; the one offering the prospect of greatly reducing the chances of fractures taking place and the other of repairing such fractures when they do come. The indicates that something more than this is requisite, the mere casual stripping of the screw being, in his opinion, not sufficient to account for the screw losing its hold of the water; citing as a proof of this the tendency that a screw displays to race in the smoothest water, if working against a great resistance, as when towing another vessel or even when starting its own. He states that his attention was attracted to this subject by the connection between the breakage or disturbance of the water surface, and the consequent admission of the air to the blades. He remarked that the screw never raced without getting air, and the admission of air was always followed by racing. With the view of satisfying himself on this subject he tried numerous experiments one of which was made with a model fitted first with a screw of a small diameter, and which had about 1 in. of water covering, and the other was with a larger one that had but ¼ in. of covering. When the boat was held still the small screw did not race whereas the large one did. In the opinion of the author, the tendency evinced by the thinly covered screw to race is due, not alone to the suction of the air, but also to the fact that any screw will race if it has not sufficient water to re-act upon, and as the resistance of the water must depend upon its solidity, so to speak, it follows that when a screw is near the surface of the water the column acting against the thrust of the screw becomes broken and the screw, losing resistance, races.

In the end of March, 1874, Professor Reynolds read a paper before the Institute of Naval Architects, on the effect of immersion on screw propellers, and he commented upon the results of two series of experiments — see Table No. 10 — made by him with a model screw 2 in. in diameter and caused to rotate by a spring.

Professor Reynolds' First Series of Experiments where same strength of Spring was used.

Number of experiment.	Depth of immersion.	Time taken to run down.	Remarks.
		Seconds.	
1	1	19	Did not race.
2	2	19	Do.
3	3	20	Do.
4	1	20	Do.
5	2	20	Do.
6	$\frac{5}{8}$	20	Do.
7	$\frac{1}{2}$	20	Race a little at starting.
8	$\frac{1}{4}$	12	Raced.
9	$\frac{3}{16}$	12	Do.
10	$\frac{1}{8}$	12	Do.
11	0	12	Do.
12	0	12	Do.
13	$-\frac{3}{8}$	10	Do.
14	$-\frac{1}{8}$	7	Do.

Professor Reynolds' Experiments. — Second set, where a stronger spring than in last series was used.

Number of experiment.	Depth of immersion.	Time taken to run down.	Remarks.
		Seconds.	
1	3	10	Did not race.
2	1	10	Do.
3	$\frac{5}{8}$	11	Raced at starting.
4	$\frac{5}{8}$	11	Do.
5	$\frac{7}{16}$	9	Raced intermittently.
6	$\frac{7}{16}$	9	Do.
7	$\frac{3}{8}$	6	Raced.
8	$\frac{1}{8}$	4	Do.
9	0	4	Do.

From the results of these experiments Professor Reynolds deduces that so long as the screw is not frothing but working in solid water, the resistance is independent of the depth of immersion, and he calls attention to the point that when a boat is stationary, there is a much greater chance of the screw drawing down air than when it is under way, illustrating his remarks by referring to observations made by him during a voyage on board the Palmyra, whose screw, although eight clear feet under water, frothed the water before there was "way" got on the ship, but did not do so once the vessel was in motion.

In reference to the question of the immersion of screws raised here, the author would call the attention of members to diagram No. 16, which shows Messrs. Harland and Wolfs' arrangement fitted to the Britannic, intended to furnish a deep immersion former method is to provide some elastic or flexible arrangement