figure to 40 or even 50 per cent. When the Author submitted his Paper to the Institution he had not the advantage of being in possession either of the speed table of the "Umbria" or of Mr. Cowper's calculations; and he estimated the efficiency of the repairs at 6 to 7 per cent., as compared with the resistance of a perfect shaft; and notwithstanding the conclusions he had arrived at, showing that the repairs were equal to at least 34 per cent. and probably to a stress of 40 to 50 per cent. of that which was exerted when the vessel was propelled at 20 knots, the Author adhered to his estimate, for it was presumable that the strength of a perfect shaft would probably be several times greater than that which would be required to withstand the stress due to a speed of 20 knots; for some such margin was indispensable to meet the strain caused by the sudden bringing up of a racing screw in stormy weather. He should be glad if at any time it became worth the while of some one more competent than himself to work out this question of the efficiency of repairs. Under circumstances such as he has described, he entirely agreed with what Lord Brassey had said as to twin screws, for that he might say was the only moral he was able to deduce from his Paper. Unfortunately, whether with twin screws or single screws, adventuring at sea was attended with danger and difficulty. The great accident which befell the "City of Paris" was still within memory and now they had the fate, which he feared was a sad one, of the steamship "Naronic," both of which vessels had twin screws. It would be an advantage to put the engines of twin screws one ahead of the other, instead of abeam, in order to distribute the weight and to avoid the possibility of the accident which befell the "City of Paris." Mr. Sopwith.

Correspondence.

Dr. W. ANDERSON thought the frequent breakages of screw-propeller shafts, usually after long terms of service, appeared to point to the gradual encroachment of molecular changes in the metal due to the frequent alternation of strain. He suggested the application of a remedy which had been found efficacious in crane-chains and in the working parts of locomotives and other machines, namely, that of periodical annealing by heating the shafts to about the temperature *b* of Chernoff's scale, and per- Dr. Anderson.

Dr. Anderson. mitting them to cool slowly, buried in ashes or sand to secure gradual and equable action. Propeller-shafts were subjected to varying torsional stresses due to the unequal impulses given by the cranks and to the inertia of the screw. They had also to resist bending-stresses, both positive and negative, caused by the unequal wear of the bearings and the working of the ship. Thus they appeared to be under very favourable conditions for setting up deleterious molecular changes.

Mr. Hallett. Mr. J. H. HALLETT supplied details of the accident to the thrust-shaft of the s.s. "Sir Walter Raleigh" (*ante*, p. 99) which he was called in to report upon after her arrival in England. The vessel was of 1,262 tons net register, and owned by Messrs. R. B. Triplett and Company of Plymouth. The triple expansion-engines had cylinders 20, 33, and 54 inches in diameter with a stroke of 36 inches. The nominal HP. was 160; boiler-pressure 160 lbs.; diameter of shaft $9\frac{5}{8}$ inches; diameter of collar 18 inches, and its thickness $2\frac{1}{2}$ inches. This shaft broke on the 26th of January, 1892, in longitude 42·20° west; latitude 35° north; twelve days out from Philadelphia to Dunkirk. The engineers attempted to make temporary repairs by fitting around the shaft iron bands procured from the masts. On the 2nd of February these repairs were completed, and at 11 A.M. the engines were started, but when they had only made five revolutions, the bands parted. The chief engineer then began more efficient repairs by boring holes through the collars and body of shaft, as shown in *Figs. 2* (p. 100); these repairs took seven days, namely, from the 3rd to the 9th of February. In this case the collars were tapped and long screwed bolts fitted, having nuts on each side of the collar, except the after-part, which was flush, so as to enable it to take the thrust. After these repairs were completed, the engines were again started and the ship reached Bantry Bay on the 14th of February. The engines made 30 revolutions, the steam-pressure being reduced to 120 lbs.; the vessel's speed was about 5 knots. While the repairs were being effected, the vessel drifted 460 miles E.S.E., encountering during the whole of the time strong westerly gales. In Mr. Hallett's opinion it was all the more creditable that the engineers should have successfully accomplished these repairs, as they were severely handicapped by the want of tools. The drills for drilling through the collars, and the body of the shaft, were made out of a steel triangle, which had been used as the engine-room gong. The bolts and distance-pieces were made out of various pieces of scrap-iron, such as firing-tools, pricker-bars, and bridgerails. The propeller had to be secured under great difficulty, as this class of vessel is not fitted with a break in the tunnel; but eventually this was effected by means of chains and wire ropes. After the bolts and distance-pieces were fitted, the joint was filled in with white metal, and then wire ropes bound tightly round it. The engineer, Mr. David Smail, thus described the casualty:— Mr. Hallett.

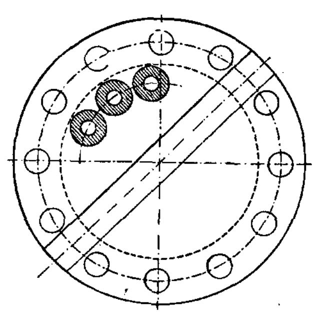
"We were on a voyage from Philadelphia to Dunkirk with a full cargo of maize. When twelve days out and through rough weather having covered only 2,000 miles of our journey, I discovered about midnight, as I was taking my final look round the engines prior to my turning in for the night, that the collars of the thrust, which had been all right a short time before, were heating up very rapidly, and that the shaft was apparently running out of truth. I at once eased down the engines by the throttle, but before I got back to the after end of the engine-room, there was a loud report and crash at the thrust. The engines were at once stopped, when we discovered that the shaft had broken completely through, half of the centre collar being thrown right out, the metal collars and the thrust-block being a complete wreck, and that the shaft had gone out as far as it could get for the sole plate of the thrust."

Mr. R. GORDON NICOL agreed with the Author in thinking that the employment of twin screws would help to eliminate the risks of total disablement in cases of break-down, but at the same time recognized that the employment of duplicate machinery and of outboard shafts with supporting brackets introduced elements of danger not found in the single-screw arrangement. Experience of ocean traffic went to show that a combination of circumstances consequent on the break-down of one set of twin machinery might render the twin-screw vessel as helpless to proceed immediately under steam as the single-screw vessel; of this the accident which befell the s.s. "City of Paris," in 1890 was an instance. From the many failures which occurred in screw-shafts, at the propeller, in the tunnel or in the thrust-bearing, it appeared that the defects of the present arrangements were not fully recognized; otherwise more rapid progress would have been effected in their removal. In all screw-shafts there existed five serious defects:— 1. The thrust of the propeller was applied to the ship amidships, at the weakest part of her hull, and, owing to the height of the shaft-centre above the bottom of the ship, gave rise to rocking motions in the thrust-block and bearers, with fatigue in the adjacent frames and plating. 2. The thrust of the propeller was transmitted throughout almost the whole length of the shaft between the propeller and the engines, and introduced a condition of instability in its form similar to that experienced by a long and slender column under a heavy load. The thrust thus Mr. Gordon Nicol.

Mr. Nicol. deformed the shaft between its bearings and reduced considerably its moment of resistance to torsion. 3. The shaft was exposed to severe bending stresses and fatigue when the vessel pitched or rolled in a seaway; for the working of the hull, when alternately hogging and sagging amongst waves, was transmitted by the shaft-bearings to the shaft itself, and being rigidly secured at all its junctions by massive flange couplings and bolts, could only yield by bending. These bending strains were much intensified at the thrust-collars. 4. The thrust-collars formed part of the shaft itself, being in all cases turned out of the solid enlarged portion, forged on one length of the shaft for that purpose; while to increase the amount of their bearing-surface and keep the velocity of that surface low, the collars were formed without rounded fillets at their junctions with the shaft body. From the manner in which forging-operations were conducted at present, it was impossible to obtain a dense and homogeneous shaft; most of the hammering effect being confined to the outer layers of the mass and large diameters proving more difficult to treat effectively than small diameters. When, however, the enlarged part was cut in the lathe to form the thrust-collars, the continuity of the shaft was broken, the best portion of the material removed and the shaft very much reduced in strength. 5. The thrust-bearing surfaces were insufficiently lubricated; centrifugal force rapidly whirling out the lubricant to the periphery of the collars. The lubricant could not be applied to the rubbing surfaces at the root of the collars, and from the point at which it was introduced it was rapidly dissipated outwards; and although the shaft generally dipped into the lubricant in the thrust-block while running, it was scraped off the collars by the horns of the horseshoe thrust-plates and rarely got between the bearing-surfaces. Racing of the engine and propeller enormously increased the dangers which accompanied these defects. To overcome them he had advocated for a considerable time the adoption of the following expedients: 1. To place the thrust-bearing at the stern of the ship on the tail-end shaft forward of the stern-tube. The thrust would thus be taken directly by the skin of the vessel at the strongest part of her hull and distributed uniformly throughout her entire length; all thrust from the propeller would be confined to the tail-end shaft, which with its ample liner-bearings was well suited to resist deformation; the thrust-block would have no tendency to rock on its seat, being attached by plate-brackets at its centre-line to the hull of the vessel, and the thrust-plates would always offer a proper bearing to the thrust-collars. 2. To introduce flexible couplings in the main shaft. This was only practicable after elimination of end-thrust from the shaft and would prevent bending-stress occurring in the shaft from the straining of the vessel. 3. To separate the thrust-collars entirely from the shaft and apply them in the form of a phosphor-bronze sleeve-casting slipped over the tail-end shaft. They would thus embrace the shaft in a similar way to the shaft liners and be attached by an end-flange to the shaft coupling-flange and coupling-bolts. This would allow the shaft to be constructed of a uniform diameter throughout its length and preserve the dense outside metal of the shaft intact. 4. To apply *lignum vitæ* to the faces of the thrust-plates instead of white metal, and submerge the whole of the thrust-bearing in water. The employment of phosphor-bronze collars running on *lignum vitæ* in a copious supply of water would reduce friction to a minimum, promote by centrifugal action a rapid circulation of water between the bearing surfaces, and effectually prevent any tendency of the bearing to heat. It would require no more attention than the stern bush; but could be examined when required by running off the water. By the adoption of these expedients screw-shafts could be reduced in diameter and thus rendered safer, lighter and less costly. Mr. Gordon Nicol.

Mr. EDWARD REYNOLDS furnished particulars and copies of drawings of the tests made at the works of Messrs. Naylor, Vickers Sons and Company, Limited, under the direction of Mr. Bain, the Cunard Company's engineer, from pieces trepanned out of the Mr. Reynolds.

Fig. 5.

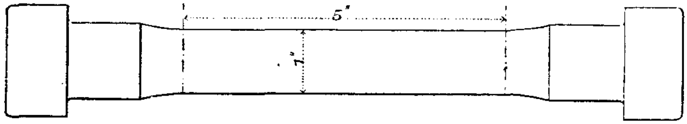


¼ inch = 1 foot.

forward end of the broken shaft, and wedged backwards and forwards until they were broken out, *Fig. 5.* One piece, after being turned to the dimensions shown in *Fig. 6*, was tested for tensile strength; the other two were bent transversely as shown in *Figs. 7.*

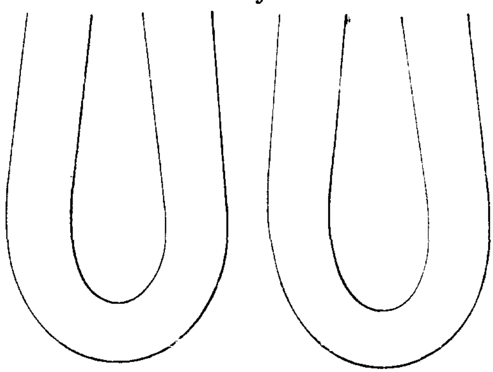
Mr. Reynolds. Results from pieces broken out in this way were possibly from 4 to 5 per cent. inferior to those which would have been obtained

Fig. 6.



if pieces had been cut out without being bent several times in the act of extraction. The end view showed the holes drilled in the

Figs. 7.



S.S. "UMBRIA" THRUST-SHAFT.

25·75 tons per square foot.
26·4 per cent. elongation.
47·1 ,, contraction of area.

shaft at New York, and the key-way which was cut across the shaft to assist the bolts in driving.

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21 March, 1893.

HARRISON HAYTER, President,
in the Chair.

The Discussion upon the Paper on "The Break-down of the R.M.S. 'Umbria'" occupied the evening.
