Correspondence.

Mr. J. C. R. OKES considered the efficiency of the pumps both in the "Waterwitch" and in Messrs. Thornycroft's boats low, as compared with that of some pumps. On the 17th of August, 1883, some tests of a Root's rotary-pump, made by Messrs. Mather and Platt, gave the following results, where in one case the efficiency rose to 0·74 of the power applied:— Mr. Okes.

RESULTS of TESTS of a No. 7 ROOT'S ROTARY PUMP.

Suction- and Delivery-Pipes, 7 inches diameter.

No. of Test.	Revolutions of Engine.	Revolutions of Pump.	Depth of Overflow 2 feet Wide.	Delivery per Hour.	Vacuum in Suction Pipe.	Pressure in Delivery Pipe.	Height Lifted calculated from Pressure and Vacuum.
				Gallons.	lbs. ft.	lbs.	Feet.
1	156	152	5·0	43,185	6 = 14	11	39
2	148	146	4·9	41,715	$9\frac{3}{4} = 22\frac{1}{2}$	$10\frac{1}{2}$	47
3	136	132	4·4	35,610	$4\frac{3}{4} = 11$	22	62
4	160	156	5·1	44,377	$7\frac{1}{4} = 17$	9	37
5	110	106	4·0	30,900	6 = 14	$7\frac{1}{2}$	31
6	176	172	5·6	51,217	$8 = 18\frac{1}{2}$	8	37
7	116	108	3·3	23,175	$12\frac{1}{2} = 28\frac{1}{2}$	20	75
8	160	152	4·9	41,715	$10\frac{1}{2} = 24$	16	61
9	160	156	4·9	41,715	$12 = 27\frac{1}{2}$	19	71
10	156	152	4·8	40,552	$5\frac{1}{2} = 12\frac{1}{2}$	29	79

No. of Test.	Theoretical HP. required for the Water Lifted.	Indicated HP.	Friction of Engine in HP.	Actual HP. required.	Efficiency of Pump.	Gallons of Water the Pump would deliver, assuming there to be no Slip.	Slip of Water.	Slip of Strap.
							Per cent.	Per cent.
1	8·50	17·6	5·7	11·9	0·714	53,017	18·5	3·2
2	9·90	20·2	5·4	14·8	0·668	50,925	18·0	2·0
3	11·15	21·8	5·0	16·8	0·663	46,042	22·6	3·6
4	8·29	18·2	5·9	12·3	0·674	54,413	18·5	3·0
5	4·83	10·5	4·0	6·5	0·743	36,973	16·4	4·3
6	9·57	22·4	6·5	15·9	0·600	59,994	14·6	3·0
7	8·77	19·0	4·3	14·7	0·597	37,670	38·5	7·5
8	12·85	24·3	5·9	18·4	0·698	53,017	21·3	5·6
9	14·95	27·8	5·9	21·9	0·683	54,413	23·3	3·0
10	16·18	34·2	5·7	28·5	0·568	53,017	23·5	3·2

Mr. J. F. SPENCER remarked that Mr. H. Somerset Mackenzie of Falmouth had made a series of experiments on hydraulic propulsion in a boat 42 feet long by 6 feet 6 inches, fitted with a dual Mr. Spencer.

Mr. Spencer. engine, the pump or turbine being two screws, one left one right, working close to each other on a solid and a hollow shaft respectively. The water entered through an aperture 2 feet 6 inches square in the bottom of the hull, and was discharged through two $9\frac{1}{2}$-inch nozzles just clear of the water-surface. With the same engine-power, the speed was increased from about 8 to 10 miles per hour by enlarging the diameter of the nozzles from $7\frac{1}{2}$ to $9\frac{1}{2}$ inches; and Mr. Mackenzie's experiments led him to conclude that volume of discharge was more important for efficiency and speed than velocity of discharge.

Mr. Wilson. Mr. G. WILSON observed that the Author of the Paper, in analysing the results obtained from the trials with the "Thornycroft" boat, used as a basis for calculation the pressures of the jets of water from the outlet-nozzles on a thin plate $1\frac{5}{16}$ inch square. The plate was placed in the jet just where it left the nozzle. Referring to the calculations of reaction when the boat was moored, the Author stated that at two hundred and ninety-five revolutions of the turbine per minute the pressure of the jet of water on this plate was $9 \cdot 35$ lbs., or $8 \cdot 4$ lbs. mean pressure, the latter being equivalent to $\frac{8 \cdot 4}{1 \cdot 3125^2} = 4 \cdot 87$ lbs. per square inch. From that pressure it was calculated that the weight of water forced through the outlet-nozzles was 1,426 lbs., and that the velocity of the water was 24 feet per second. The reaction of the water issuing through the nozzles was given at 1,062 lbs. $= 9\frac{1}{2}$ cwt. The pull recorded on the dynamometer attached to the stern of the boat was $9\frac{7}{8}$ cwt. The Author considered that the reaction of the water discharged through the nozzles, and the pull on the dynamometer being about equal in intensity, was a satisfactory test of the accuracy of his method of research.

For the purpose of ascertaining the pressures of the water issuing through the outlet-nozzles of pumps, Mr. Wilson had tried various methods, one of which was similar in principle to the Author's; but he never obtained reliable results except in actually measuring the quantity of water ejected through the outlet-nozzle in a given time. The method adopted was simply to set a tank or other receptacle in a suitable position close to the nozzle of the pump. An open trough or gutter was placed underneath the nozzle in line with the issuing stream of water in such a manner that the water flowed along the trough. At a given signal the end of the trough was instantly shunted so as to cause the water to flow into the tank. At another signal the end of the trough was moved away from the tank. Between those two signals the time was noted by a chronograph registering the time to one-tenth of a second, and the number of revolutions of the turbine was counted. The water inside the tank was the quantity which flowed through the pump during the time registered. If the tank was a small one he found, by repeating the operation say four times, and averaging them, that reliable results were obtained in ten or twelve seconds as the time of each operation. When operating with large pumps the trough was arranged with a flexible end. Mr. Wilson.

Since the outlet-nozzles of the "Thornycroft" boat were above the water, this method of measuring the quantity of water flowing through them in a given time might readily be carried out in that boat. The small plate adopted by the Author would in his opinion register less pressures than actually existed by causing reactive pressures on the boat, inasmuch as the water after flowing round the curved outlet-pipes would not be in compact streams; this was proved by the fact that the pressures on the plate varied in intensity in different sections of the stream. Water, when it issued from a short curved pipe, spread laterally in a greater degree than when it flowed out of a straight pipe.

The question now arose, How was it possible that the reactive pressures tending to propel the boat, as calculated by the Author from the pressures of the water on the plate, could be doubtful, inasmuch as those reactive pressures were practically equal in intensity to the pull registered by the dynamometer at the stern of the boat? When the boat was moored and consequently at rest, the water flowing through the inlet-pipe caused back-pressure to the boat. The inlet-water flowed in an oblique direction mainly from forward to aft of the boat, therefore the inlet-water was partially deviated against the curved inlet-pipe into the pump, and such force of deviation caused back-pressure to the boat. The reactive pressures of the water issuing out of the discharge-pipes must evidently be equal in intensity to the pull registered by the dynamometer, plus the back-pressure to the boat caused by the force in deviating the water flowing through the curved inlet-pipe. If the precise direction in which all the atoms of the water entered the inlet-pipe and the angle at which the same were deviated were known, and if also the quantity of water flowing in a given time was ascertained, the intensity of the back-pressure to the boat could be calculated; but the shape, and the oblique position which the pump and inlet-pipe occupied in the boat were such that these facts could not be ascertained; nevertheless, the intensity of the back-pressure on the boat was considerable.

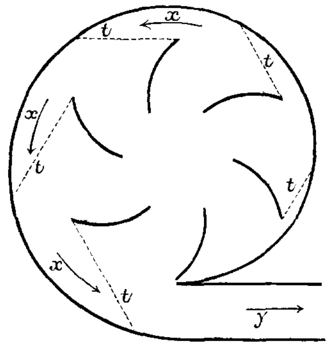
Mr. Wilson. Respecting the centrifugal pump, the Author calculated that at two hundred and ninety-five revolutions of the pump-wheel or turbine per minute the velocity of the water discharged through the nozzles was 24 feet per second. The diameter of the turbine wheel was stated to be 2 feet 6 inches, equivalent to $7 \cdot 85$ feet circumference. The velocity of the periphery of the wheel would therefore be $\frac{7 \cdot 85 \times 295}{60} = 38 \cdot 6$ feet per second, as against the velocity of the discharged water, namely, 24 feet per second. This showed an unusual slip for a centrifugal pump, which must cause an unusual loss of power. Again, according to the Author's calculations, the velocity of the water discharged from H.M.S. "Waterwitch" was 29 feet per second; and as the pump-wheel was 14 feet in diameter, and the revolutions forty per minute, therefore $\frac{14 \times 3 \cdot 1416 \times 40}{60} = 29 \cdot 3$ feet per second, the velocity of the periphery of the wheel; and, therefore, in this case there was practically no slip. These figures would seem to show that the "Thornycroft" centrifugal pump was inferior to the pump fitted to H.M.S "Waterwitch." He was of opinion, however, that such was not the case. The "Thornycroft" pump was, he believed, well designed for its purpose; but the pump had not yet been credited with its actual duty from two causes. One was that the weight of water passing through the pump and discharge-pipes at two hundred and ninety-five revolutions was greater than 1,426 lbs.; and the other that the water flowing through the suction-pipe was not sufficient to maintain a full volume through the pump and discharge-pipes when the pump was run at high speeds. The relative area of the suction- to the discharge-pipes in the "Thornycroft" pump was $1 \cdot 52$ to $0 \cdot 951$ square foot or $1 \cdot 6$ to 1. In the "Waterwitch" pump the sectional area of the inlet was $28 \cdot 25$ square feet against $6 \cdot 28$ square feet sectional area of discharge, equivalent to $4 \cdot 5$ to 1. In his experiments, as to the volume of water passing through pumps, he obtained augmented percentages of useful effect in shaping and arranging the size of the suction-pipe to the required speed of the pump-wheel.

The nozzles of the "Thornycroft" pump were not properly shaped to obtain the full effect of the reactive pressures of the water issuing from them in propelling the boat. To secure the full reactive pressure for the boat, straight pieces as tangents to the curve in lengths from one and a half to twice the diameter, should be joined to the end of the curved discharge-pipes. Such straight pieces might not be so convenient for reversing the nozzles, but their absence prevented the full reactive pressures from being utilized. Mr. Wilson.

Messrs. Thornycroft and Co. had succeeded in propelling their boat at 12·6 knots per hour, the highest speed hitherto attained by hydraulic propulsion. But the "Thornycroft" screw-boat, by the expenditure of an equivalent indicated HP., had attained a speed of 17·3 knots per hour. It was important to determine precisely the reactive pressures of the water issuing through the discharge-nozzles, inasmuch as those pressures constituted the basis for calculating what became of the indicated HP. of the engines, and where the loss of useful effect took place. He thought those reactive pressures could only be ascertained with certainty by measuring the volume of water discharged through the nozzles during a known interval of time. When the loss in useful effect had been more precisely ascertained, the same would be found to depend on the shape of the discharge- and inlet-nozzles, and particularly the position and direction in which the water was admitted, notwithstanding that some authorities thought that these points were immaterial. The main loss in useful effect, as the Author remarked, would be shown to exist in the centrifugal pumps. Those pumps gave out a fair percentage of useful effect when used for raising water to moderate lifts; but, when used for propelling purposes, wherever they had been tried the percentage of useful effect had been low. The difference in the percentage of useful work in a centrifugal pump for lifting water and propelling a boat was mainly owing to the difference of velocity, in the two cases in which the water was forced through the pump and discharge-pipes. In lifting water the speed of the pump-wheel was regulated to overcome the lift, and to discharge the water at a uniform velocity of from 7 to 9 feet per second, in order to obtain an economical result. On the other hand, for propelling purposes, the water was forced through the pump and discharge-pipe at a high velocity. In the "Thornycroft" boat, the Author calculated that, at a speed of 12·6 knots, the velocity of the water through the discharge-pipes was $37\frac{1}{4}$ feet per second, which was about five times higher than the velocity of the discharged water generally adopted when pumps were used for lifting water. The action of a centrifugal pump consisted in the water passing through the pump being thrown from the tips of the disk vanes in tangents to the periphery of the disk across the water flowing round the channel between the periphery of the disk and pump-casing. That action caused concussions of the atoms of the water, resulting in an important percentage of the power being converted into the

Mr. Wilson. mechanical equivalent of heat. This would be seen in Fig. 15, which was a skeleton section through a centrifugal pump:—

Fig. 15.



$t \ldots t$ represented the directions in which the water was thrown from the tips of the disk vanes across the channel around which water was flowing in the line of the arrows x, x, and through the discharge-pipe y. The higher the velocity at which the water left the tips of the vanes, and also flowed round the channel, the greater would be the magnitude of the concussions of the atoms of the water.

For the purpose of obtaining a more economical apparatus in forcing water at high velocities, after carrying out numerous experiments he had designed a hydraulic wheel, the principle of which was shown in Figs. 16 and 17 (p. 77), which were sections through the apparatus.

The wheel (shown by the thick black lines), similar in shape to a grooved pulley or sheave of a block, rotated around the casing $m \ldots m$, on the shaft g, which passed through the stuffing-boxes. A block K extending from Y to Y′, shaped in a suitable manner, fitted within and close to, but did not touch, the cavity of the wheel. The passage or channel for the water, extending from F to G round the casing, was of a uniform section o. Supposing the wheel to be rotated in the direction of the arrow s, the action of the cavity of the wheel forced the water around the casing in that direction, and although the wheel revolved freely over the block K, no water could pass; consequently, the water entering the suction-pipe F, was forced by the action of the cavity of the wheel round the casing, and discharged through the pipe G in a constant, uniform, and compact stream, the same in section as the cavity at o.

Mr. Wilson.

If the wheel was caused to rotate in a contrary direction to that of the arrow *s*, then the water entered the suction-pipe G and was discharged through the pipe F in a constant and uniform volume. The cavity of the wheel was turned and made as smooth

FIG. 16.

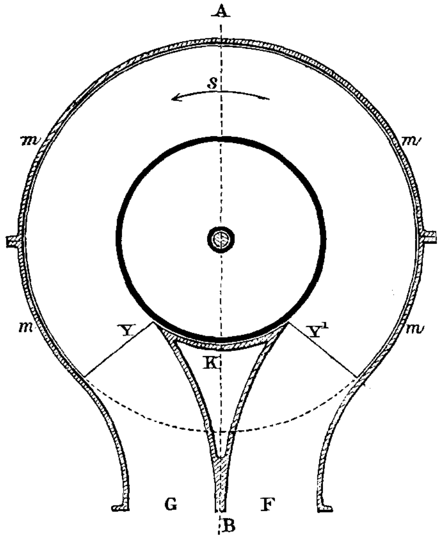
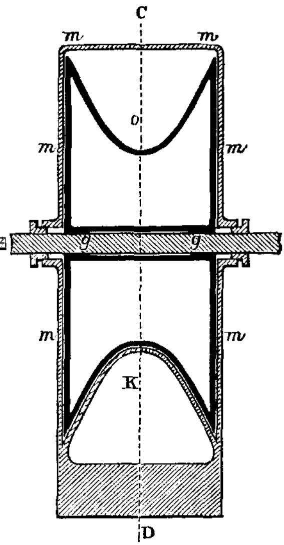


FIG. 17.



as possible. The main principle of the action of the cavity of the wheel in forcing the water (which was not surface friction) was difficult to explain except by means of a model.

In order to obtain the volume of water necessary for propelling large vessels, without having to resort to a wheel with one large cavity and enlarging the diameter of the wheel, he had adopted a wheel with several cavities fixed on a single shaft.

Mr. Barnaby.

Mr. S. W. BARNABY, in reply to the correspondence, questioned the accuracy of Mr. Wilson's statement that, when the boat was moored and pulling against a dynamometer, the reaction of the discharge nozzles was balanced by the pull registered by the dynamometer plus a backward reaction caused by the deviation of the inflowing water in the curved inlet pipe. The sternward pressure upon the boat, caused by the change of direction of the inflowing water, was exactly balanced by the forward pressure of the outside water upon the hull of the vessel, caused by the relief of pressure at the inlet. Suppose the inlet to be stopped up, the statical pressures upon the hull would be balanced. If then

Mr. Barnaby. the inlet was unstopped, and water allowed to flow in, there would be a momentary unbalanced pressure driving the boat forward, which was immediately balanced by the sternward pressure exerted by the inflowing water as it was deflected upwards by the pipe, and there would be no resultant effect.

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4 March, 1884.

Sir J. W. BAZALGETTE, C.B., President, in the Chair.

The following Associate Members have been transferred to the class of

Members.

Edward Golding Barton.
Mark William Carr, Jun.
George Edward Moore.
Richard James Harris Saunders.
James Stuart Swallow.
William Thomson.

The following Candidates have been admitted as

Students.

Léon Harry Barker.
Hugh Walter Belcher.
Arthur Coleman.
Alfred Howe Collinson.
John Rowland Crook.
Frederick William Cross.
John Richard Davison.
Frederic James Edge.
Andrew Forbes.
George Leopold Greg'son.
Arthur Harnett.
George Hilder Libbis.
Thomas Lodwick Miller.
Fred Platt.
Hans Wessel Poppe.
Peter Augustus Ransom, B.A.
Frank Walter Scott, Jun.
George Thomas Sibbering.
John Bunting Simpson.
Charles Gordon Stuart.

The following Candidates were balloted for and duly elected as

Honorary Members.

The Right Hon. Lord Bramwell.
Sir William Robert Grove, M.A., D.C.L., LL.D.

Members.

Ralph Peacock.
William Willcox.
John Edward Wolfe.
Thomas William Worsdell.
James Walker Wright.
William Wright.