

excess of velocity of the effluent water, and the elevation of the nozzle, 70 per cent. of the total indicated power of the engine, might be utilised by Ruthven's propeller.

The draught of the vessel, during the trial, was stated to be 3 feet 2 inches, and the immersed midship section 40·5 square feet. The united area of the nozzles being 1·09 square feet, the ratio of the area of propulsion to the immersed section was 1 to 37. To the load water line, the immersed midship section was 55 square feet, and the ratio 1 to 50.

Many advantages of Ruthven's propeller, for large vessels, were pointed out and contended for. Several nozzles could be applied to one vessel, one acting for another in case of accident; whereas paddles and screws could not be so multiplied, and a number of engines and nozzle-propellers, of moderate size, worked at high speeds, would, it was contended, be less weighty, more compact, and more manageable, for a large vessel, than the huge engines and appurtenances required by the present system.

In the discussion, it was contended, that there was no novelty in the system of propulsion proposed by Messrs. Ruthven. Benjamin Franklin was among the first to notice it; he related, that as a boy, whilst bathing in a pool, into which a wooden pump had been thrown, to swell the timber, he got astride upon it, and commenced pumping; to his astonishment he found that he was propelling himself across the water; subsequently he investigated the circumstances, and admitted the inefficient application of power. Sir Isambard Brunel attempted propulsion by means of a tube, in which there was a diaphragm, pushing the water before it, and acting upon a very light valve on the return stroke; this was only an elongated paddle-wheel with an intermittent and inefficient action.

Mr. Bidder also tried the system, on board a canal-boat, and although quite aware of the loss of power incidental to it, he expected a compensation from the advantageous application of steam, as opposed to animal power.

As to this particular case of Ruthven's and other similar propellers, it was argued, that the reasoning in the Paper was as totally at variance with the actual results of the experiments, as with the received laws of hydraulics.

To show this, it sufficed to state, that according to the Paper, the useful effect realized, was 64 per cent. of the power of the engine, or 40 H. P. (indicated), which would give $25\frac{1}{2}$ H. P. useful effect; but it was stated, in the experiments, that the two nozzles were 10 inches diameter each = together $1\frac{1}{2}$ square foot area. The head of water was $8\frac{6}{10}$ feet = to a pressure of nearly 540 lbs. per foot, or to a total pressure of about 580 lbs., which represented, also, the resistance of the vessel at $9\frac{1}{2}$ miles per hour, giving, therefore, a useful effect of $14\frac{3}{4}$ H. P., instead of $25\frac{1}{2}$ H. P., as stated in the Paper.

It was an error to state, that the maximum of useful effect was when the velocity of the issuing water was equal to that of the vessel, or when the water dropped vertically from the nozzles; it could be shown, that in that particular condition there was not any development of useful effect. The actual operation of this system of propulsion, was then shown to be analogous to the assumed case of a closed vessel of any shape, filled with a fluid of given density, and under a given pressure; it was evident, that so long as the vessel remained in that normal state, no propulsive force would be exerted in any direction, the whole being 'in equilibrio;' but on an aperture being made, in either of the sides of the vessel, it was obvious, that the area of the opening, being relieved from pressure, the 'equilibrium' would be disturbed, exactly by the extent of that aperture, into the head, and there would be a corresponding force exerted in the opposite direction.

To apply this to the case under consideration, a vessel must be imagined, containing water under a pressure = to 3 feet, which was the head due to the velocity of the vessel, in the experiment. By making an aperture of about $3\frac{1}{8}$ feet area, there would be an unbalanced pressure of about 580 lbs., equivalent to that of the former statement; but the velocity of issue would be 14 feet per second, and the power used would be about 15 H. P. But if the aperture was assumed to be reduced to $1\frac{1}{2}$ square foot = the area of the two nozzles; then it would require $8\frac{6}{10}$ ths feet head to produce the same pressure. The velocity of issue would be 23 feet per second, and the power would be about 25 H. P.; thus the power required was exactly in the ratio of the velocity of issue, or inversely as the square

root of the head. The loss was therefore 60 per cent. instead of 12 per cent., as stated in the Paper.

But the fundamental error, in the Paper, was the omission of the loss of power, arising from picking up the water, in a state of rest, and communicating to it the velocity of the vessel. Supposing the water to be composed of an infinite number of globules, possessing weight, and being in a state of rest, they must all be raised to the head due to the velocity of the vessel, and then to the additional head, requisite for propulsion.

In the present case, the quantity of water issuing from the nozzles was 25 feet per second; this required to be raised 3 feet, to be equivalent to the velocity of the vessel—demanding therefore the exertion of 9 H. P. The results of the experiments would be more correctly stated thus:—

Useful effect	<u>14$\frac{3}{4}$ H. P.</u>
Power consumed in raising the water to the velocity of the vessel =	9 H. P.
Power used in propelling the water through the nozzles =	<u>25 H. P.</u>
Total power expended, exclusive of the friction in the water-ways, and of the engine itself =	<u>34 H. P.</u>

The absence of indicator diagrams was regretted, as tending to throw a doubt on the results; but it was admitted, that the boiler surface, and the actual consumption of fuel, bore out the statements of the Paper.

It was contended, in reply, that, though engine power was consumed, in getting the water up to the speed of the vessel, it did not necessarily follow, that an equal amount of power was further required, to expel the water. This single employment of power could be arrived at, by properly forming the water passages, so as to avoid all concussions of the water, by rectangular bends, or by sudden enlargements, or alterations of form; and the desired object, was stated to be, so to proportion the dimensions of the engine and the propeller, that the effluent speed of the water in one direction, would be equal to that of the vessel in the other. In this case, it was stated, 100 per

cent. of the engine-power, minus fractional resistance, would be usefully available.

That, practically, there were situations in which such a propeller might be found very serviceable. For instance, in crowded rivers, where paddle-wheels were objectionable, amidst ice, and in shallow water, where the screw was not available, and in many other situations, where any great projections from the sides of the hull, were undesirable.

As an example, it was stated, that it would be very desirable, for the purposes of the Fire Brigade, in the Metropolis, to have the means of bringing up the large floating-engine, at all times of the tide, and under all the circumstances of ice, of an encumbered stream, or of shallow water, at a speed of ten miles an hour, propelled by its own engines. Experiments had already been made upon one of the floating-engines, which although very imperfect, were sufficient to prove the adaptability of the system to the wants of the Fire Brigade.

In fine, it was contended, that although there still remained much to be done, to demonstrate the practical efficiency of so great an innovation, the experiments were sufficiently successful to induce further investigations, which the Author was requested to continue and to report to the Institution.

It was observed, that the statements in the Paper had been misunderstood; as it had been assumed, that it was said that the useful effect realised, was 64 per cent. of the whole power of the engine at the pistons; whereas it was really stated to be 50 per cent., and that the useful effect was 64 per cent. of the power delivered to the wheel-shaft; which would materially affect the deductions then made.

One most important element in the calculation was lost sight of, namely, the duplicate pressure of reaction due to the efflux of water through the side of a vessel at rest; the whole unbalanced hydraulic pressure being twice the hydrostatic pressure due to the height of the column of water. It was contended, that this duplicate pressure must exist to some extent, so long as the effluent velocity of the water exceeded the receding velocity of the vessel; and that it diminished in some ratio with the receding speed of the vessel, and vanished only, when the vessel had acquired the effluent velocity of the water,—when the simple pressure, due to the head of water, remained. There-

fore, some allowance must be made for this duplicate pressure ; and, assuming it to decrease uniformly with the difference of speeds, the power might be thus estimated, when the speed of the vessel was 62 per cent. of that of the effluent water, leaving 38 per cent. of excess :—

$1 \times 100 = 100$ per cent., when the speed of the vessel was equal to that of the effluent water ;

$1.38 \times 62 = 85.56$ per cent., when the speed of the vessel was 62 per cent. of that of the effluent water ;

Leaving 14.44 per cent. of loss, by excess of speed, as originally deduced in the Paper.

It was added, that the proportion of the useful effect would be more simply estimated in the ratio of the squares of the speeds, as was done in the Paper, thus :—

$$100^2 : 38^2 :: 100 : 14.4 \text{ per cent.}$$

The proposition of the power employed was reduced nearly to common algebra, by separating the various causes and effects : the useful effect, in proportion to the power employed, was shown to be a maximum, when the speed of the boat was equal to the velocity of the effluent water, the “vena contracta” being taken into consideration. The ratio of useful effect to power employed, was shown to be $\frac{2N}{N^2 + 1}$; the velocity of the effluent water being to the velocity of the boat as N to 1.

It also appeared, that taking the sum of the useful effect, that is, in driving the boat, added to the effect not so employed, or wasted, was in all cases equal to the power employed, it was of no importance, theoretically speaking, whether the water was pumped up from the bow, the sides, or the bottom.

The subject was investigated in three different ways, each giving the same result.

It was stated, that in 1848 Mr. Purkis, being engaged in the construction of a fan-blower, thought the same principle might be adapted to the propulsion of a boat, and tried it in a model, about 4 feet long and 8 inches wide, with a small steam-engine and two fans, each 2 inches in diameter ; with this he attained a speed of 3 to 4 miles per hour. He then built another boat 25 feet long, and 4 feet wide, fitted with an engine, with two cylinders 4 inches diameter and $4\frac{1}{2}$ inches stroke, driving two

fans 12 inches diameter of the same form as the fans of Appold's pump; the water issuing from two orifices, each of 25 square inches. With this apparatus, the boat could only hold her way against a tide of about 3 miles an hour. On the substitution of two fans of 7 inches diameter and the reduction of the propelling orifices to 7.75 square each, the boat attained an estimated speed of nearly 8 miles an hour. It was admitted, that these experiments were imperfect, but they tended to corroborate the statements of the performances of Ruthven's propeller.

The arrangement of Purkis' boat differed from Ruthven's, chiefly in there being three holes on each side of the vessel;—one to propel her ahead,—one astern,—and one midship to supply the pump,—each being supplied with a valve to close the orifices not in action, and to act instead of the curved nozzles of the "Enterprise," which were supposed to be objectionable in absorbing power.

In allusion to the former experiments, it was shown, that the power required for the propulsion of the "Enterprise," at $9\frac{1}{2}$ miles per hour, was 35 indicated H. P., as estimated by Bourne's formula for resistance, founded on the results obtained by the "Rattler;" this power was nearly what was stated in the paper, (40 H. P.,) with which, also, the stated consumption of fuel was in accordance.

It was argued, with respect to the supposed loss of power, in communicating to the water the velocity of the vessel, that, inasmuch as the action of the propeller was, in principle, the same as if the intercepted water was raised to the height due to the velocity imparted to it, the velocity was only lent to the water, and ready, in virtue of that head, to be refunded, when required; and that the necessary engine-power was equal to that which could raise the quantity of water, required for propulsion, from the level of the sea to the height due to the velocity of efflux. On these principles, it was calculated, from the data contained in the Paper, that in the management of the water, exclusive of all frictional resistance, the ratio of power to effect was,

The power used	=	12.28	H. P.
Ditto wasted	=	3.94	do.
Total . . .		<u>16.22</u>	do.

and it was concluded, that there was much to be said in favour of Ruthven's mode of propulsion. The statements as to the former experiments were reiterated, viz., that the power required to communicate velocity to the water passed through the propeller, was not afterwards utilized. For, that assuming a ball to be suspended over the vessel, at a height due to the velocity of the vessel, and moving at the same rate; it was urged, that to raise the ball to that height, and to communicate to it the velocity, would obviously require just double the power necessary to raise it. Assuming the ball to be detached, it would descend vertically, as regarded the vessel, and would act upon it precisely as it would, if both the ball and the vessel were at rest; as a consequence, therefore, it would only act with the effect due to the height from which it fell.

As another illustration:—it was assumed, that the deck of a vessel was level with the surface of the surrounding medium, and that a given portion of fluid was transferred from the medium to the level of the deck; then a certain amount of power would be expended, in changing the condition of the water and imparting to it the velocity of the vessel; but as this water would only be at the level of the surrounding medium, it would not flow out again, and the power that had been absorbed would not be again utilized.

It was contended, that the inference from the experiments quoted, viz., that the pressure was double the hydraulic height due to the velocity, was incorrect; for the pressure was measured upon the reduced section of the 'vena contracta,' which was only $\frac{5}{8}$ ths of the area of the real aperture, upon which area, as had been shown, the unbalanced pressure should be estimated, and it was contended, that the contrary inference led to inconsistent and anomalous results. But in no respect did these experiments apply to the case of water passing through a tube, or pipe, beyond the 'vena contracta,' as the area of unbalanced pressure would then be immediately reduced.

Referring to the experiment quoted in the paper, and assuming the possibility of the reaction pressure being equal to double the height due to the velocity, viz., 23 feet per second, *i. e.*, = $8\frac{9}{10}$ ths feet; then double that would = $17\frac{2}{10}$ ths feet + $1\frac{9}{10}$ ths foot (the height of the issue above the sea) would give a total height of $18\frac{1}{10}$ th feet; this \times 25 feet (the quantity of

water per second) and \times into 60 (seconds per minute) and \div 528 feet (the quantity of water raised one foot high per minute, per horse power) gave 51 H. P. ; then adding to that, the loss from the friction of the water in the passages, as stated in the Paper, together with the friction of the engine itself, it would appear that the power applied must have been = 80 H. P. instead of 40 H. P. as stated, thus showing that the experiment and the inference could not be reconciled.

Again, it was argued, that the useful effect was expressible, simply by the difference of the power consumed, in giving to the water the speed of the vessel, and the power in expelling it ; that, in the admission and in the expulsion of the water, reacting pressures, measured by twice the head due to the velocities of admission and expulsion, were exerted longitudinally upon the vessel, the difference of these reacting pressures expressing the useful effect. Taking V for the speed of the boat, and V' for the effluent velocity of the water, with respect to the nozzles from which it issued ; then, the power expended being taken as unity, the useful effect was found to be represented by

$$2V \frac{V' - V}{V'^2}$$

which showed, that when the forward speed of the vessel and the effluent speed of the water were equal, there was no useful effect ; and that the maximum useful effect was obtained, when the effluent speed of the water was twice the speed of the vessel, and when the useful effect was just one-half of the power expended, exclusive of the frictional resistance. Whereas, with the paddle, or the screw, there did not appear, theoretically, any limit to the ratio of the efficiency,—it might be equal to the power,—and in practice, it was limited only by the extent of surface which it was convenient to give to the paddle-board, or to the screw. Still, the amount of power obtained by the jet was less affected by deviations from the most useful velocity, than in the case of the paddle, or the screw ; and there might be found to be practical advantages, which would render the plan of the jet advantageous in numerous cases.

With respect to the unbalanced pressure of reaction, by the flow of water through the side of a vessel at rest, it was argued, that all attempts to explain the subject by reference to hydro-

static principles, were fallacious, and that experiment alone could determine the results. Whitelaw, in his account of the reaction water-mill, had shown, by experiment, that the reaction was measured by the weight of a column of water of twice the head, when the orifices were at rest.

A recent experiment on the reaction pressure, was also described. A cylinder was fitted with a jet pipe in the side, at the bottom, of the form of the 'vena contracta.' It was suspended from a considerable height, so as to hang freely, and was filled with water, which was kept up to a constant level; when the water was permitted to flow out freely, an unbalanced pressure, of once and a half the hydrostatic pressure under that head, was indicated on a balance, applied against the opposite side, as measured on the small section of the 'vena contracta.'

With respect to the formula, showing that the maximum useful effect was only half the power expended, it was considered, that the conditions of the formula did not meet the case of the propeller; for it was assumed, that the engine-power was available only for expelling the water, and that the mass of the vessel necessarily discharged the duty of taking up the water. Now, the facts were stated to be, that the machine not only discharged the water, but it also previously drew it into the vessel by exhaustion; and it was contended, that, under these circumstances, the maximum effect was obtained, when the speed of the vessel was equal to that of the effluent water, and amounted to 100 per cent. of the engine-power, minus frictional resistances.

In fine, though much difference of opinion was expressed, as to the mode of action and the economy of Ruthven's propeller, it was agreed, that in numerous situations, the new propeller might be found to possess practical advantages over the paddle and the screw; and that the subject demanded to be further investigated, both theoretically and experimentally.

March 14 and 28, 1854.

JAMES SIMPSON, President,
in the Chair.

THE discussions upon the Papers, No. 910, "Account of the Deep-Sea Fishing Steamer 'Enterprise,' with Ruthven's Propeller," by Mr. D. K. CLARK, and No. 904, "On the French