MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Remarks on H. B. M. Screw Steam Frigate "Arrogant." By Chief Engineer, B. F. ISHERWOOD; U. S. Navy.

The *Arrogant* has long been considered the most successful application of an auxiliary screw to a war steamship. Having been furnished directly from her Chief Engineer with a number of her indicator cards, and accompanying data of speed, revolutions of screw, &c., I thought it might be of interest to steam engineers and ship constructors, to publish these results, giving additionally the full dimensions of *hull, engine, boilers, and screw*, obtained from the Chief Engineer of the vessel and other sources, in order that a correct opinion might be formed. As these results may be relied on, they will go far to correct some very exaggerated reports of the performance of this vessel, as well as to show the latest manner of using steam in the British Navy.

HULL.

Length between perpendiculars,	200 feet.
Length of keel for tonnage,	172 " 9½ inches.
Breadth, extreme,	45 " 8½ "
Breadth, moulded,	44 " 4 "
Depth of lower hold,	15 " 1 "
Mean draft, half coal in, and all other weights full,	19 " 0 "
Burthen,	1872 tons.
Displacement at 19 feet draft,	2470 "
Immersed amidship section at 19 feet draft,	587 square feet.

ENGINES.—Two of Penn's horizontal trunk, condensing engines, placed on board at Woolwich in 1848. The exhaust pipe, which is the highest part of the engines, is 4 feet 8 inches below the water line; the tops of the cylinders are 6 feet 11 in. below water line.

Diameter of cylinder, 60 inches, }
 " trunks, 24 " } equivalent to a diameter of 55 inches.

Stroke of piston,	3 feet.
Space displacement of both pistons per stroke,	98.99 cubic feet.
Diameter of main steam pipe,	18 inches.
Leading into steam pipe of diameter of	14 "
Diameter of eduction pipes,	18 "
Diameter of overflow pipes,	18 "
Extreme length of engine and boiler rooms, bulkhead to bulkhead, 56 feet.	

SLIDE VALVES.

Lead on top lid, or lid to cylinder cover,	3-16 inch.
Lead on bottom lid,	5-16 "
Carries steam on top stroke,	28 inches.
" bottom stroke,	26 "
Lead of exhaust on top lid of valve,	7½ "
" bottom lid of valve,	7½ "
Length of slide faces,	9 "
Length of ports,	5 7-16 "
Exhaust ports at bottom,	3½ "
" top,	3½ "

Note.—When steam is admitted into the top end of the cylinder, the exhaust port is open 3 15-16 inches; and when admitted into the bottom end, the exhaust port is open 3½ inches. The lead at the crank end of the cylinder is 5-16 inch, and at the cylinder cover end 3-16 inch.

SHAFTING.

Diameter of shaft at main bearing,	10½ inches.
" connecting shaft bearing,	9½ "
" screw propeller shaft at large end,	14 "
" " " small end,	9 "

Length of shafting from inside of stern post to forward part of coupling on crank shaft, 69 feet 1 inch.

BOILERS.—Four horizontal tubular boilers, placed in such a manner that the top of the steam chest is 3 feet 4 inches below the water line.

Number of tubes in each boiler,	264.
Outside diameter of tubes,	2½ inches.
Length of tubes,	5 feet 6 inches.
Length of each boiler,	12 " 3 "
Breadth " "	10 " 7 "
Height " "	7 " 4 "
Number of furnaces in each boiler,	3.
Length of each furnace, that is, of grate bars in each furnace,	5 feet.
Breadth " " " "	3 "
Area of total grate surface,	180 square feet.
" heating " in tubes,	3800·544 sq. ft.
" " " furnaces, &c.,	631·000 "

Area of total heating surface in the 4 boilers,	4434.544 sq. feet.
Extreme height of chimney when up above grates,	44 feet.
Length of upper or sliding part of chimney,	15 feet 8 inches.
Diameter of lower or fixed part of chimney,	5 " 3 $\frac{3}{4}$ "
" " upper or sliding part " "	5 " 1 $\frac{1}{2}$ "

Weight of water in boilers,	39 tons.
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Consumption of English bituminous coal per 24 hours, working with full power at sea with steam alone, in good weather, boiler pressure 5 pounds per square inch, cut off at $\frac{3}{4}$ ths the stroke from commencement, making $44\frac{1}{2}$ double strokes of piston per minute, initial cylinder pressure 18 pounds per square inch, 32 tons.

Sea water evaporated under the above circumstances by one pound of coal, inclusive of loss by blowing off at 3-32, and by waste of steam in clearance and nozzles, 6-836 pounds.

Coal consumed per hour per square foot of grate surface, .	16.600	"
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Weight of coal carried in bunkers, 260 tons, or sufficient for 8 days steaming at full power.

SCREW.—One true screw, placed at the stern in a sliding frame, so as to be raised out of water when the ship is under sail alone.

Diameter,	15 feet 6 inches.
Pitch,	15 " 0 "
Length on axis,	2 " 6 "
Number of blades,	2.
Helicoidal area of screw,	136 square feet.
Area of screw projected on a plane at right angles to axis,	61.85 "

RESULTS.

Speed of vessel at sea, under steam alone, in good weather, working at the reduced power used in calms and smooth water, viz: cutting off at about $\frac{1}{4}$ th from commencement of stroke, and having a mean effective pressure per square inch of pistons throughout the stroke of $7\frac{1}{2}$ pounds, making $33\frac{1}{2}$ double strokes of piston per minute, . 3-833 knots of 6082 $\frac{1}{2}$ feet.

Horses power developed by engines under the above circumstances,	223.99
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Speed of vessel at sea under steam alone, in good weather,
working with full power, viz: an initial pressure in cylinder
of 18 pounds per square inch, cutting off at $\frac{3}{4}$ ths the stroke
from the commencement, giving a mean effective pressure
throughout the stroke of $13\frac{1}{2}$ lbs. per square inch of pistons,
making $44\frac{3}{4}$ double strokes of piston per minute, 5.08 knots of 60S $2\frac{1}{2}$ feet.

Horsepower developed by engines under the above circumstances,	520.96
Slip of the screw under the above circumstances,	23.04 per cent.

INDICATOR DIAGRAMS FROM STEAM CYLINDERS. SCALE, 10 POUNDS TO THE INCH.

No. 1.—Taken August 4th, 1851. Sea smooth, and variable head airs; speed by patent log, 3.70 knots per hour; revolutions of the screw, 33 per minute; mean effective pressure per square inch of piston, 8.14 pounds. *Slip of the screw, 24.22 per cent.*

No. 2.—Taken August 5th, 1851. Moderate head swell, and airs ahead; speed by patent log, 4 knots per hour; revolutions of the screw, 24 per minute; mean effective pressure per square inch of piston, 7.48 pounds. *Slip of the screw, 20.49 per cent.*

No. 3.—Taken August 4th, 1851. Sea smooth; fore and aft sails set; speed by patent log, 5.8 knots per hour; revolutions of the screw, 34 per minute; mean effective pressure per square inch of piston, 7.69 pounds. *Negative slip of the screw, 15.29 per cent.*

No. 4.—Taken August 5th, 1851. Sea smooth; calms and head airs; speed by patent log, 3·80 knots per hour; revolutions of the screw, 34 per minute; mean effective pressure per square inch of piston, 7·35 pounds. *Slip of the screw, 24·46 per cent.*

No. 5.—Taken May 4th, 1850. Sea and wind not noted; speed by patent log, 4·20 knots per hour; revolutions of the screw, 40 per minute; mean effective pressure per square inch of piston, 8·08 pounds. *Slip of the screw, 29·04 per cent.*

No. 6.—Taken August 5th, 1851. Sea and wind not noted; speed by patent log, 4·20 knots per hour; revolutions of the screw, 51 per minute; mean effective pressure per square inch of piston, 12·99 pounds. *Slip of the screw, 44·34 per cent.*

No. 7.—Taken August 2d, 1851, leaving Gibraltar for Lisbon. Sea smooth, strong free wind, and all sail set; speed by patent log, 10·60 knots per hour; revolutions of the screw, 64 per minute; mean effective pressure per square inch of piston, 13·88 pounds. *Negative slip of the screw, 11·94 per cent.*

All the above diagrams, excepting No. 5, were taken on a passage from Gibraltar to Lisbon, with a mean draft of about 19 feet, and show the performance of the vessel under the most favorable circumstances, having a smooth sea and short run.

Under these favorable circumstances, the mean performance at sea, under steam alone, was for full power; that is, a mean effective pressure of $13\frac{1}{2}$ pounds per square inch of piston, and $44\frac{2}{3}$ double strokes of piston per minute, 5·08 knots; and for the reduced power used in calms and fine weather, viz: a mean effective pressure of $7\frac{2}{3}$ pounds per square inch of piston, obtained by cutting off at about $\frac{1}{3}$ th the stroke from the commencement, and $33\frac{2}{3}$ double strokes of piston per minute, a speed of 3·833 knots per hour. These are slow speeds, and would not by any means be considered satisfactory in our Navy. Every war steamship with us, having a less average sea speed than 9 knots per hour, is pronounced a failure, without regard to the comparative power of the machinery, consumption of fuel, and size of vessel. It is thus that nearly all our Navy steamships are failures; but fairly compared relatively, power with power, fuel with fuel, and size of vessel with size of vessel, I believe our Navy war steamships will be found to give higher results, both in the generation of steam, its mode of use in the engine, and application to the propelling instrument, than can be found elsewhere, at home or abroad.

These diagrams also show in a very striking manner, the effect of using sail in conjunction with the screw, and the existence of what is termed *negative slip*. A few remarks on this subject may be of use in this connexion; sufficient data being luckily furnished by a trial of the *Arrogant* in the Thames river.

January 8th, 1849, the *Arrogant*, drawing 16 feet 10 inches forward, and 18 feet 9 inches aft, was tried at the measured mile in the Thames river, and made at the rate of 7·25 knots per hour; revolutions of the screw, 63 per minute; mean effective pressure per square inch of pistons by indicator, 13·31 pounds; horses power developed by the engines, 672·7. *Slip of the screw, 22·23 per cent.*

August 2d, 1851, the *Arrogant*, leaving Gibraltar for Lisbon, made, in smooth water, strong free wind, and all sail set, 10·60 knots per hour by patent log; revolutions of the screw, 64 per minute; mean effective pressure per square inch of pistons by indicator, 13·88 pounds; horses power developed by the engines, 767·45. The screw had now what may be termed a *negative* slip of 11·94 per cent.; that is, the speed of the vessel was 11·94 per cent. *greater* than the speed of the screw.

It may now be supposed that the screw, instead of assisting the progress of the vessel, was retarding it by dragging. That this was not the case, however, and that the screw under the above conditions was still actually propelling the vessel, will become evident from a consideration of the performance of the vessel in the Thames river, as given in the paragraph above.

During that performance, with 63 revolutions of the screw per minute, (slightly less than 64,) and a mean effective pressure of 13·31 pounds per square inch of pistons, (slightly less than 13·38 pounds,) there was developed by the engines sufficient power, (672·7 horses,) after overcoming the screw resistances of the front edges of the blades, and surface friction on the water, and engine resistances of friction and load on air pump, and also friction of load on the engines, to drive the vessel 7·26 knots per hour.

During the performance on the 2d of August, when the screw made 64 revolutions per minute, the above named screw and engine resistances may be considered practically the same as with 63 revolutions. The power now developed by the engines was 767·45 horses. But if the speed of the screw were now really less than the speed of the vessel, and retarding it by dragging, the screw would be assisted in its revolutions by the reaction of the water caused by that greater speed of the vessel; consequently there would not be required to be exerted by the engines, in order to overcome the screw and engine resistances, as much power as was required when making the 63 revolutions in the Thames river; yet the total power now developed by the engines was greater than before, viz: 767·45, instead of 672·7, while a less power than before was required to overcome the screw and engine resistances. What then has become of the large remainder of this power? It must have been expended on some resistance, and the only resistances opposed to the power of a steam engine, in propelling a vessel by a screw, are the screw and engine resistances, the friction of the load, and the resistance of the vessel itself. We have seen, however, that but a small portion of the power developed by the engines was absorbed in overcoming the screw, engine, and friction resistances; the remainder therefore must have been expended in overcoming the resistance of the vessel; that is, in propelling the vessel; notwithstanding that the vessel was *apparently* going faster than the screw, and could not therefore be propelled by it. A little attention to what takes place in the passage of a body through water, will reconcile the contradiction.

It is familiar to all, that when a body passes through water, it leaves a vacuum behind, which is filled by the intruding water. It is impossible in any case, that this vacuum can be made and filled simultaneously; *time*

is required for the operation, and the effect of time is to generate a current, or give velocity to the intruding water: for as the water falls into the vacuity by its gravity, the speed of its current or its velocity will be proportional to the time required for the water thus to fall in. No matter how fine the after lines of a vessel may be, or how slow its speed, it must have, when in motion, *some* following current, and this current will be in some proportion to the fineness of the after lines and the speed of the vessel. The finer the lines and the less the speed, the less will be the velocity of the following current, because less time will elapse before the following water will have fallen in; or in other words, the following water will have a less distance to flow before it fills the vacuity.

An illustration of the same thing may be had by observing the eddy at the back end of a bridge pier placed in a current of water. A chip thrown into the current at the front end of the pier, close beside it, will not be carried straight on, but will close in behind the pier, and remain at rest.

With a hull of the *Arrogant's* proportions, moving through the water at the high velocity of 10·60 knots per hour, it is very probable the following current had a considerable velocity, and as the screw acted in and against this following current, it might have had a very *positive* slip, comparing the speed of the screw with the vessel's speed diminished by the speed of this current; while it had a *negative* slip, compared with the vessel's absolute speed through the water, supposing no following current to exist, and that the vessel and screw moved through the water in the same condition.

If the water were passing the screw at the vessel's speed, it would pass at the rate of 10·60 knots per hour; but if there were a following current of say 1·60 knots per hour, the water would only pass the screw at the rate of 9 knots per hour. The speed of the screw should therefore be compared with the latter rate, which, if it could be ascertained, would give the *true* slip of the screw, a slip that would always be found a *positive* one.

It must here be distinctly remembered, that a negative slip can only happen when the vessel has a high speed, and owes a considerable portion of it to a power additional to that applied to the screw, that of the sails, for instance; though it has frequently been reported to exist, when the vessel was being propelled by the screw alone. In these cases, it was manifestly the result either of inaccurate observations of distance gone, and revolutions made, or of a mistake in the pitch of the screw, reckoning it less than it actually was.

Supposing the motion of the vessel through the water to leave no vacuity behind it, the resistance of the vessel would occasion a certain positive slip of the screw. Now, suppose this vacuity to exist, the bow resistance of the vessel would be increased by it, and by consequence the slip of the screw would be increased. Now, suppose also, that by reason of this vacuity, a following current be generated, which striking the screw diminishes again the increased slip; it is evident that this following current cannot impart *more* power than was absorbed in generating it; that is to say, that its additional resistance to the screw can only equal the additional resistance at the bow, thrown upon the screw by the genera-

tion of this current. Under the most favorable circumstances, then, the slip would remain the same, either with or without the following current; but in practice it cannot at all retain this equality, for the whole of the power bestowed in generating the following current, and resident in it, cannot be re-applied to the screw; in fact, but a small quantity can be so regained. To say, that in a vessel propelled by a screw alone, the vessel's speed could surpass that of the screw, would be to say, that in the case of a man wheeling a wheelbarrow, the speed of the wheelbarrow surpassed that of the man.

For the Journal of the Franklin Institute.

An Account of the Explosion of the Steamboat "Brilliant." By A. C. JONES, ESQ., *Engineer.*

To the Committee on Publications.

GENTLEMEN:—Circumstances prevented my forwarding to you the account of the *last* explosion on the steamboat *Brilliant* at the time of its occurrence; it presenting some new features in recklessness, may even at this late day be acceptable to the readers of the Journal. As the same boat collapsed a flue last July, I will include both accidents (!) in this paper.

New boats are heralded with many safety contrivances; but not one states, (nor could many with truth,) that they have competent engineers. The advertisement of the new *Brilliant* ran thus:—"The *Brilliant* has more securities for the protection of passengers than any boat afloat, having the steam indicator, the water indicator, and in the event of fire, can flood the hold in an instant with steam, and is now offered to the public as the fastest boat on the river," &c.

The *Brilliant* was principally owned by planters on the "coast,"* and was intended to be one of the "crack packets;" from causes which it is not necessary to enumerate, she was not one of the "fast ones," unless the boilers were hard pushed; and to have this done, the captain being a "hot man," employed "hot engineers."†

On the third trip, at 6 A. M., about five miles below the town of Plaquemine, the inboard flue of the larboard outside boiler collapsed, scalding several and killing four or five men. No injury was done to the boat.

This is an extract from a newspaper of the day:—"Captain Hart intends remaining here until a full judicial examination is had of the boilers, and the cause of the collapse. He has demanded the examination

* Both banks of the lower Mississippi river are so termed.

† This is the name applied to those miscalled engineers, whose rashness, coupled with ignorance, leads them to increase the pressure by overloading the safety valve, and by the hardest kind of firing, force the boat, at the risk of all on board, to go a little faster than their predecessors had done before. Strange to say, this worthless tribe bid fair to drive prudent engineers off the river.