EXPERIMENTS WITH THE STEAM-CUTTER OF THE UNITED STATES STEAMSHIP "PENSACOLA."

By Chief Engineer ISHERWOOD, U. S. Navy.

The experiments described in this article were made with the steam-cutter of the United States steamship *Pensacola* by the writer during the time he was Chief Engineer of the Mare Island Navy Yard, California.

The principal object of the experiments was to ascertain the law of the variation of the resistance of the hull in function of its speed; incidental to which there was obtained the maximum power which the machinery could develop, and the corresponding speed of the vessel.

Before proceeding to the experimental data and to the analysis of their results in the cases of the different experimental speeds, there must be given the dimensions, proportions, etc., of the hull and of its machinery, and a description of the manner in which the data were obtained and the results deduced.

The cutter was an open boat constructed at the Mare Island Navy Yard of wood, and sheathed with copper.

HULL.

Extreme length,	38 feet 1 inch.
Length from forward edge of rabbet of stem to after side of sternpost, on load water-line,	35 feet.
Extreme breadth on load water-line,	8 feet 11 inches.
Depth from lower edge of rabbet of keel to top of gunwale at middle of length,	4 feet 3½ inches.
Depth from lower edge of rabbet of keel to load water-line,	<div> <div>Forward,</div> <div>Mean,</div> <div>Aft,</div> </div> <div> <div>1·600 feet.</div> <div>2·175 feet.</div> <div>2·750 feet.</div> </div>
Depth of keel below the lower edge of its rabbet,	<div> <div>Forward,</div> <div>Mean,</div> <div>Aft,</div> </div> <div> <div>0·400 foot.</div> <div>0·575 foot.</div> <div>0·750 foot.</div> </div>
Draught of water to load water-line,	<div> <div>Forward,</div> <div>Mean,</div> <div>Aft,</div> </div> <div> <div>2 feet.</div> <div>2 feet 9 inches.</div> <div>3 feet 6 inches.</div> </div>

Area of greatest immersed transverse section to load water-line,	12·53 square feet.
Area of load water-line,	207·62 square feet.
Area of the immersed external surface of the hull to load water-line,	332·85 square feet.
Displacement to load water-line,	269·00 cubic feet.
Displacement to load water-line,	7·700 tons.
Displacement per inch of draught at load water-line,	0·4953 ton.
Ratio of the area of the greatest immersed transverse section to the area of the cir- cumscribing parallelogram,	0·6461.
Ratio of the area of the load water-line to the area of the circumscribing parallelo- gram,	0·6653
Ratio of the displacement to the circumscrib- ing parallelopipedon,	0·3963
Ratio of the length to the breadth on the load water-line,	3·9252
Angle of dead-rise at the greatest immersed transverse section,	22½ degrees.
Weight of the hull and its fittings,	6,270 pounds.

ENGINES.

There are two vertical, direct-acting, non-condensing engines, one placed immediately behind the other, with the axes of the cylinders in the same vertical plane with the axis of the shaft. Each cylinder has a three-ported slide valve, unbalanced, and worked direct from the shaft by means of an eccentric and its rod. The valve of the forward cylinder is upon its after side, and of the after cylinder, upon its forward side. The starting and reversing are effected by turning the eccentrics to stops upon the shaft, by means of a mitre-gear and hand-wheel at the centre of the engines. Both cylinders are bolted to a horizontal flat plate of cast iron that forms their bottoms and is supported upon four cast iron standards which are bolted in turn to a bed-plate secured to the hull—two standards at each end of the bed-plate. The inner sides of each pair of standards are formed into guides for the crosshead. There are but two main pillow-blocks, and they are bolted to, and supported upon, the bed-plate. The forward crank-pin

is overhung. There is one plunger feed-pump, vertical, at the forward end of the bed-plate and supported upon it. This pump is worked direct from a pin in the crosshead of the forward engine. The distance between the axes of the cylinders is 22 inches. The cylinders and their valve-chests are without covering of any kind. The eccentrics are between the engines, and each one is directly below the valve-stem to which its rod is attached. The exhaust steam is delivered into the chimney of the boiler and forms an artificial draught. There is a heater for the feed-water which is heated by the exhaust steam to about 75 degrees Fahrenheit above the temperature of the sea-water whence it is taken.

The following are the principal dimensions :

Number of cylinders,	2.
Diameter of cylinders,	6 inches.
Diameter of piston-rods,	$1\frac{1}{8}$ inches.
Stroke of pistons,	6 inches.
Area of both pistons, exclusive of area of piston-rods,	55.554 square inches.
Space displacement of both pistons per stroke,	0.1919 cubic foot.
Breadth of steam-port,	$\frac{3}{8}$ inch.
Length of steam-port,	4 inches.
Area of steam-port,	2.5 square inches.
Breadth of exhaust-port,	$\frac{7}{8}$ inch.
Length of exhaust-port,	4 inches.
Area of exhaust-port,	3.5 square inches.
Diameter of connecting-rods in necks,	$1\frac{3}{16}$ inches.
Length of connecting-rods between centres,	1 foot $2\frac{1}{16}$ inches.
Diameter of crosshead journal,	$\frac{7}{8}$ inch.
Length of crosshead journal,	$1\frac{1}{2}$ inches.
Diameter of crankpin journal of after engine,	2 inches.
Length of crankpin journal of after engine,	$2\frac{1}{2}$ inches.
Diameter of crankpin journal of forward engine,	$1\frac{3}{8}$ inches.
Length of crankpin journal of forward engine,	2 inches.
Diameter of main journals,	$2\frac{1}{2}$ inches.
Length of main journals,	$2\frac{1}{2}$ inches.
Width of eccentric straps,	1 inch.
Diameter of eccentric rods,	$\frac{7}{8}$ inch.
Diameter of feed-pump (single acting and for both engines),	$1\frac{1}{4}$ inch.
Stroke of feed-pump plunger,	6 inches.

Diameter of valves (poppets) of feed pump,	1 inch.
Number of thrust collars,	5.
Inside diameter of thrust collars,	$2\frac{1}{2}$ inches.
Outside diameter of thrust collars,	$3\frac{3}{8}$ inches.
Width of thrust collars,	$\frac{1}{2}$ inch.
Length of crosshead guide-gibs,	3 inches.
Breadth of crosshead guide-gibs,	2 inches.
Thickness of side of cylinders,	$\frac{5}{8}$ inch.
Thickness of plate to which cylinders are bolted,	$1\frac{3}{16}$ inches.
Thickness of bed-plate,	$1\frac{1}{4}$ inches.
Length occupied by the engines in the forward and aft direction of the vessel,	3 feet $6\frac{1}{4}$ inches.
Breadth occupied by the engines in the athwartship direction of the vessel,	2 feet $3\frac{5}{8}$ inches.
Height of the engines above the bottom of the bed- plate,	3 feet 6 inches.

BOILER.

There is one boiler of the locomotive type, with iron tubes in direct continuation from the furnace to the chimney.

The front portion of the boiler is rectangular in plan with a semi-cylindrical top. The length of this portion is 2 feet 10 inches; breadth, 3 feet 6 inches, and height, 4 feet. Upon its top, at its centre, is a cylindrical steam-chest, 18 inches in diameter and 18 inches high. This front portion contains the furnace, 2 feet 3 inches long, 3 feet wide and 2 feet high above the top of the grate. The furnace top is horizontal; the grate is horizontal, and is fired from two doors, one in each side of the front portion of the boiler. The openings for these doors are rectangular, 12 inches wide and $8\frac{1}{2}$ inches high. The bottom of the grate is on the level of the bottom of the front portion of the boiler, and the ash-pit is of cast iron, placed 6 inches below the bottom of the grate.

The remaining portion of the boiler is cylindrical, 3 feet 1 inch in diameter, and 4 feet 4 inches in length, 10 inches of which form the back smoke-box, on the top of which the chimney is placed.

The tubes are eighty-two in number, 2 inches in external diameter, $1\frac{3}{4}$ inches in internal diameter, and $44\frac{1}{2}$ inches in length between tube plates. The least water space between the tubes is $\frac{3}{4}$ inch.

The boiler and steam-pipe are covered with thick felt.

The following are the principal dimensions and proportions of the boiler :

Extreme length,	7 feet 2 inches.
Extreme breadth,	3 feet 6 inches.
Extreme height, exclusive of steam-drum, . .	4 feet.
Extreme height, inclusive of steam-drum, . .	5 feet 6 inches.
Number of furnaces,	1.
Length of grate-bars,	2 feet 3 inches.
Breadth of grate,	3 feet.
Area of grate surface,	6·75 square feet.
Number of tubes,	82.
Outside diameter of tubes,	2 inches.
Inside diameter of tubes,	1 $\frac{3}{4}$ inches.
Length of tubes between tube-plates,	3 feet 8 $\frac{1}{2}$ inches.
Water-heating surface in the furnace, . . .	24·75 square feet.
Water-heating surface in the tubes, calculated for inside diameter,	139·29 square feet.
Water-heating surface in the back tube-plate, to 3 inches above furnace top,	4·16 square feet.
Total water-heating surface,	168·20 square feet
Steam superheating surface in the back tube- plate, above 3 inches above furnace top, . .	1·93 square feet.
Diameter of chimney,	9 $\frac{1}{2}$ inches.
Height of chimney above the level of the grate, .	11 feet.
Aggregate cross area of the tubes,	1·3700 square feet.
Cross area of the chimney,	0·4922 square foot.
Water space to 3 inches above furnace top, .	21·563 cubic feet.
Steam space above 3 inches above furnace top, in boiler proper,	17·723 cubic feet.
Steam space in the steam-drum,	2·650 cubic feet.
Total steam space above 3 inches above furnace top, .	20·373 cubic feet.
Ratio of the water-heating to the grate surface, .	24·9185 to 1·0000.
Ratio of the steam superheating to the grate surface, .	0·2859 to 1·0000.
Ratio of the grate surface to the cross area of the tubes,	4·9270 to 1·0000.
Ratio of the grate surface to the cross area of the chimney,	13·7139 to 1·0000.
Diameter of the blast-pipe (one orifice at base of chimney),	1 $\frac{1}{8}$ inches.

SCREW.

There is one brass screw. The forward and after edges of its blades, viewed in projection on a plane parallel to its axis, are parallel to each other and perpendicular to the axis.

The thickness of the blades, just above the fillet joining them to the hub, is $\frac{1\frac{3}{8}}{16}$ inch.

The following are the principal dimensions:

Diameter of the screw,	3 feet.
Diameter of the hub,	4 inches.
Pitch (uniform),	5 feet 4 inches.
Number of blades,	3.
Length of the blade on a line parallel to the axis,	0·8889 foot.
Fraction used of the pitch,	0·5000.
Helicoidal area of the blades,	4·8910 square feet.
Projected area of the blades on a plane at right angles to axis,	3·4904 square feet.

WEIGHTS OF THE MACHINERY.

	Pounds.
Weight of engines,	1460
Weight of line shaft,	195
Weight of stern stuffing box,	46
Weight of stern bearing,	21
Weight of screw,	140
Weight of boiler,	4515
Weight of cast iron ash pan under boiler,	253
Weight of boiler chimney and sundry pipes,	210
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Total weight of metal in machinery,	6840
Weight of water in boiler,	1342
Weight of felting, paint, etc.,	48
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Total weight of machinery,	8230

EXPERIMENTS MADE AT THE MARE ISLAND NAVY YARD, CALIFORNIA, WITH THE STEAM-CUTTER OF THE U. S.
STEAMSHIP "PENSACOLA."

The steam-cutter of the United States steamship *Pensacola*, having been thoroughly repaired—hull and machinery—a set of experiments was made with it at the Mare Island Navy Yard, at different speeds,

but with the same draught of water and trim, to ascertain its resistance at those speeds, the slips of the screw, and the indicated horsepower developed by the engines. These experiments were made during the month of December, 1870.

The base for the experiments, or the course passed over by the cutter during each run, was a straight line 8.955 feet long, as given by the very accurate survey of Mare Island. It extended from the northern side of the dry dock dolphins, or guard piers, to the northern side of the magazine wharf. This base was close under the lee of the high ground of the island. There was no breeze during the experiments, and the water was perfectly smooth. The velocity of the tide varied from nil to three geographical miles per hour.

Seven experiments were made at the speeds, respectively, of $6\frac{1}{2}$, $6\frac{3}{4}$, 7, $7\frac{1}{4}$, $7\frac{1}{2}$, $7\frac{3}{4}$ and 8 geographical miles per hour, as nearly as could be obtained. Each experiment consisted of six runs over the base, three in each direction, and the time of making them was selected when the tide had but little influence. The vessel's speed through the water, during each double run, was ascertained from the time of passing the ranging marks at the ends of the base.

Two indicators were used; one of them was kept permanently in position on one cylinder, and the other on the other cylinder, during the experiments. Each indicator communicated with both ends of its cylinder, and before use was put in perfect adjustment and had its spring tested.

A counter was attached to the screw-shaft, and registered the number of its revolutions.

In making the experiments, the cutter, at the intended speed, was brought opposite one end of the base and then run uniformly to the other, being kept in a straight line by an expert steersman. After passing the last end of the base a sufficient distance, the vessel was turned and the run repeated back in the same manner. The throttle-valve was always carried wide open during the turnings, as well as during the runs, and the steam pressure varied but slightly throughout an experiment, the supply of steam required being always within the capacity of the boiler to furnish, except at the speed of eight geographical miles per hour, which it was very difficult to maintain for even a single run.

From the commencement of each run to its end indicator diagrams were taken as rapidly as possible from each end of each cylinder. The

steam pressure in the boiler, as given by a spring gauge, was noted at the end of every minute.

An observer, stationed always at the same part of the vessel, gave the signal the instant he was opposite the ranges at the ends of the base; and, at the same moment, two other observers took, one the time to a second, and the other the number on the counter. Thus the time of making each run, and the number of revolutions made by the screw in that time, were exactly ascertained.

The results of the experiments will be found in the following table, in which, for convenience of reference, the quantities have been grouped and the lines containing them numbered. For the same reason, the columns containing the quantities for the different speeds have been lettered.

EXPLANATION OF THE TABLE.

After the experiments were concluded, and the mean pressure ascertained for each double run from the indicator diagrams taken during that run, a straight base line was divided into abscissæ representing the experimental speeds. From the end of each speed abscissæ an ordinate was erected at a right angle to the base, and on it was laid off, by scale, the indicated pressure belonging to that speed. A fair curve was then passed among the ends of those ordinates, leaving as many on one side as on the other. Again, the slips of the screw having been calculated for each experimental speed, were laid off on the same ordinates, and a fair curve passed among the ends of the ordinates in the same manner as before, leaving as many ends on the one side of the curve as on the other side. From these curves, and for the speeds given on line 1 of the following table, commencing at $6\frac{1}{2}$ geographical miles per hour and increasing by one-quarter of a mile up to 8 miles per hour, there were taken off, by scale, the quantities on lines 2 and line 5 of the table, being, respectively, the slip of the screw in per centum of its axial speed, and the mean gross effective or indicated pressure on the pistons in pounds per square inch, according to the indicator diagrams. Line 3 contains the thrust of the screw, calculated from the quantities on lines 10 and 11, in the manner hereinafter shown under the head of Distribution of the Power. Line 4 contains the number of double strokes made by the engines' pistons per minute, and of revolutions made by the screw in the same time.

They were calculated from the pitch of the screw and the quantities on lines 1 and 2.

Distribution of the Indicated Pressure on the Piston.—Lines 5 to 11, both inclusive, give (line 5) the mean gross effective or indicated pressure on the piston in pounds per square inch for the different experiments, and the remaining lines contain the distribution of that pressure.

Line 6 gives the pressure required to work the engines and shafting—*per se*—when the screw is removed. It was obtained by direct trial.

Line 7 contains the net pressure applied to the shaft, in pounds per square inch of piston. It is the remainder of the pressure on line 5 after deducting that on line 6.

Line 8 contains the pressure absorbed by the friction of the load, in pounds per square inch of piston. It is $7\frac{1}{2}$ per centum of the pressure on line 7.

Line 9 contains the pressure, per square inch of piston, expended in overcoming the resistance of the water to the surface of the screw blades. It is calculated from the quantity on line 16.

Line 10 contains the pressure, per square inch of piston, expended in the slip of the screw. It is calculated from the quantity on line 17.

Line 11 contains the pressure, per square inch of piston, expended in propelling the vessel. It is the pressure which remains after deducting from the pressure on line 7 the pressures on lines 8, 9 and 10.

Distribution of the Engine Power.—Lines 12 to 22, both inclusive, contain the gross-effective horses-power (line 12) developed by the engines, and their distribution. Lines 13 to 18, both inclusive, show the distribution of the power *absolutely*, that is, in horses-power; while lines 19 to 22, both inclusive, show this distribution in per centum of the net horses-power (line 14) applied to the shaft.

The distribution of the indicated or gross-effective horses-power developed by the engines has been calculated in the manner shown below under the head of Distribution of the Power.

The quantities on lines 19, 20, 21 and 22 are the per centum which the quantities on lines 15, 16, 17 and 18 are respectively of the quantity on line 14.

EXPERIMENTS WITH THE STEAM-CUTTER OF THE

BY CHIEF ENGINEER ISL

TABLE CONTAINING THE RESULTS OF THE EXPERIMENTS MADE WITH THE STEAM-CUTTER
NAVY YARD, CALIFORNIA, 1

No. of Line.		
1	Speed of the vessel per hour, in geographical miles of 6086 feet,	
2	Slip of the screw, in per centum of its speed,	
3	Thrust of the screw, in pounds, calculated from the piston pressure on lines 10 and 11,	
4	Double strokes of Engines' pistons, and revolutions of the screw, made per minute,	
5	DISTRIBUTION OF THE INDICATED PRESSURE ON THE PISTONS.	Mean gross-effective or indicated pressure on the pistons, in pounds per square inch,
5		Pressure required to work the engine, <i>per se</i> , in pounds per square inch of pistons,
7		Net pressure applied to the shaft, in pounds per square inch of pistons,
8		Pressure absorbed by the friction of the lead, in pounds per square inch of pistons,
9		Pressure expended in overcoming the resistance of the water to the surface of the screw blades, in pounds per square inch of pistons,
10		Pressure expended in the slip of the screw, in pounds per square inch of pistons,
11	DISTRIBUTION OF THE NET POWER.	Pressure expended in the propulsion of the vessel, in pounds per square inch of pistons,
12		Gross-effective or indicated horses-power developed by the engines,
13		Horses-power expended in working the engines, <i>per se</i> ,
14		Net horses-power applied to the shaft,
15		Horses-power absorbed by the friction of the lead,
16		Horses-power expended in overcoming the resistance of the water to the surface of the screw blades,
17	PROPORTIONAL.	Horses-power expended in the slip of the screw,
18		Horses-power expended in the propulsion of the vessel,
19		Per centum of the net power applied to the shaft, absorbed by the friction of the lead,
20		Per centum of the net power applied to the shaft, expended in overcoming the resistance of the water to the surface of the screw blades,
21		Per centum of the net power applied to the shaft, expended in the slip of the screw,
22		Per centum of the net power applied to the shaft, expended in the propulsion of the vessel,

EXPERIMENTS WITH THE STEAM-CUTTER OF THE UNITED STATES STEAMSHIP "PENSACOLA."

BY CHIEF ENGINEER ISHERWOOD, U. S. NAVY.

THE RESULTS OF THE EXPERIMENTS MADE WITH THE STEAM-CUTTER OF THE UNITED STATES STEAMSHIP "PENSACOLA," AT THE MARE ISLAND NAVY YARD, CALIFORNIA, IN DECEMBER, 1870.

	a	b	c	d	e	f	g
1. Vessel per hour, in geographical miles of 6080 feet,	6.50	6.75	7.00	7.25	7.50	7.75	8.00
2. Screw, in per centum of its speed,	21.450	23.038	24.802	26.833	28.761	30.649	34.248
3. Screw, in pounds, calculated from the piston pressure on lines 10 and 11,	272.559	314.348	364.516	427.914	497.109	571.166	650.413
4. Revolutions of Engines' pistons, and revolutions of the screw, made per minute,	157.9792	166.8047	177.0392	188.4532	200.2290	212.5335	224.5679
5. Effective or indicated pressure on the pistons, in pounds per square inch,	34.0000	38.7578	44.4897	51.0806	59.5470	68.2997	76.9957
6. Work done by the engine, <i>per sec</i> , in pounds per square inch of pistons,	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000
7. Applied to the shaft, in pounds per square inch of pistons,	32.0000	36.7578	42.4897	49.6866	57.5470	66.2997	74.9957
8. Overcoming the resistance of the water to the surface of the screw,	2.4000	2.7568	3.1867	3.7255	4.3160	4.9725	5.6237
9. Total resistance of the screw, in pounds per square inch of pistons,	3.4048	3.8228	4.3085	4.8792	5.5072	6.2057	6.9236
10. Expended in the slip of the screw, in pounds per square inch of pistons,	5.0192	5.6109	6.4506	7.4955	8.7230	10.1862	11.8632
11. Expended in the propulsion of the vessel, in pounds per square inch of pistons,	20.5760	23.2273	26.3139	30.6554	33.9988	38.2283	42.3051
12. Horse-power developed by the engines,	9.0080	10.8835	13.2596	16.3977	20.0719	24.4370	29.1082
13. Expended in working the engines, <i>per sec</i> ,	0.5239	0.5916	0.5901	0.6345	0.6741	0.7156	0.7561
14. Applied to the shaft,	8.4751	10.2919	12.6695	15.7632	19.3978	23.7214	28.3521
15. Overcoming the resistance of the water to the surface of the screw,	0.6359	0.7741	0.9498	1.1822	1.4548	1.7791	2.1264
16. Absorbed in overcoming the resistance of the water to the surface of the shaft,	0.9018	1.0737	1.2837	1.5484	1.8571	2.2209	2.6200
17. Expended in the slip of the screw,	1.4887	1.9523	2.5808	3.4970	4.6265	6.0444	7.6124
18. Expended in the propulsion of the vessel,	5.4517	6.5218	7.8432	9.5356	11.4594	13.6770	15.9933
19. Net power applied to the shaft, absorbed by the friction of the load,	7.50	5.50	7.50	7.50	7.50	7.50	7.50
20. Net power applied to the shaft, expended in overcoming the resistance of the water to the surface of the screw blades,	10.64	10.40	10.14	9.82	9.57	9.36	9.24
21. Net power applied to the shaft, expended in the slip of the screw,	17.56	18.91	20.43	22.10	23.85	25.48	26.85
22. Net power applied to the shaft, expended in the propulsion of the vessel,	64.30	63.19	61.93	60.49	59.08	57.66	56.41

MANNER OF CALCULATING THE DISTRIBUTION OF THE POWER DURING THE EXPERIMENTS.

To illustrate the manner of calculating the distribution of the indicated or gross-effective horse-power developed by the engines during the experiments, the following detail is given for the experiment in column **a** of the table.

The pressure required to work the engines and shafting, *per se*, being taken at 2 pounds per square inch of pistons, there is thus absorbed (line 13) 0·5299 horse-power.

Deducting from the gross-effective power (line 12) of 9·0080 horses developed by the engines this power of 0·5299 horse, there remains (line 14) the net power of 8·4781 horses applied to the shaft, of which $7\frac{1}{2}$ per centum or 0·6359 horse (line 15) is absorbed by the friction of the load.

The power expended in overcoming the resistance of the water to the surface of the screw blades (line 16), that is, in overcoming their skin resistance, calculated in the ratio of the square of the velocity, and for a value of 0·45 pound per square foot of helicoidal surface moving in its helical path with a velocity of 10 feet per second, amounts to 0·9018 horse.

The powers (0·6359 and 0·9018 horse) absorbed by the friction of the load and expended in overcoming the resistance of the water to the surface of the screw blades being deducted from the net power (8·4781 horses) applied to the shaft, there remain 6·9404 horses-power expended in the slip of the screw and in the propulsion of the hull. And, as the slip of the screw (line 2) is 21·45 per centum of its axial speed, the power expended in it is ($6·9404 \times 0·2145 =$) 1·4887 horses (line 17) leaving ($6·9404 - 1·4887 =$) 5·4517 horses (line 18) expended in the propulsion of the simple hull.

Collecting the foregoing, we have the following distribution of the power, namely :

	Horses-power.	Per cent.
Gross-effective or indicated power developed by the engines,	9·0080	
Power required to work the engines and shafting, <i>per se</i> ,	0·5299	
Net power applied to the shaft,	8·4781	or 100·00

Power absorbed by the friction of the load,	. 0.6359 or	7.50
Power expended in overcoming the resistance of the water to the surface of the screw blades,	. 0.9018 “	10.64
Power expended in the slip of the screw,	. 1.4887 “	17.56
Power expended in the propulsion of the vessel,	. 1.5717 “	64.30
Totals,		<hr/> 8.4781 or 100.00 <hr/>

THRUST OF THE SCREW.

The thrust of the screw during the foregoing performance can be calculated from the piston pressures on lines 10 and 11, the sum of which reduced in the ratio of the length (one foot) of the double stroke of the pistons to the pitch ($5\frac{1}{3}$ feet) of the screw, and multiplied by the aggregate number of square inches in the two pistons, will give the thrust of the screw in pounds; or, what is the same, the statical resistance of the vessel in pounds at the experimental speed.

In the case of experiment **a**, the sum of the piston pressures on lines 10 and 11 is 26.1952 pounds per square inch, and, as the aggregate area of the two pistons is 55.554 square inches, the thrust of the screw, or resistance of the vessel, is $\left(\frac{26.1952}{5\frac{1}{3}} \times 55.554 =\right)$ 272.859 pounds (line 2).

RESULTS OF THE EXPERIMENTS.

The mean steam pressure in the boiler during the experiment recorded in column **a** of the preceding table was 50.42 pounds per square inch above the atmosphere; during the experiment recorded in column **b**, 57 pounds; during the experiment recorded in column **c**, 64 pounds; during the experiment recorded in column **d**, 72 pounds; during the experiment recorded in column **e**, 79.75 pounds; during the experiment recorded in column **f**, 87 pounds; and during the experiment recorded in column **g**, 94 pounds.

§ The temperature of the feed-water before entering the heater was 55 degrees Fahrenheit; and when entering the boiler, 130 degrees Fahrenheit.

§ The resistances of the hull at different speeds varied in a much higher ratio than the square of the speed, as will be seen by the following comparison, in which they are given both proportionally for the square of the speed, and also proportionally as ascertained by experiment and deduced from the quantities on line 3 of the preceding table.

Column of the table.	Speeds of the vessel in geographical miles per hour.	Squares of the speeds, proportionally.	Experimental resistances, proportionally.
a	6.50	1.0000	1.0000
b	6.75	1.0785	1.1525
c	7.00	1.1599	1.3359
d	7.25	1.2440	1.5683
e	7.50	1.3311	1.8219
f	7.75	1.4216	2.1043
g	8.00	1.5147	2.3837

The power of the speed of the vessel, in which its resistances increased from 6.50 geographical miles per hour to each of the experimental speeds, is as follows :

Speed of the vessel in geographical miles per hour.	Power of the speed in which the vessel's resistances increased.
6.50	—
6.75	3.7571
7.00	3.9090
7.25	4.1203
7.50	4.1906
7.75	4.2300
8.00	4.1829

The power of the speed of the vessel, in which its resistances increased for each experimental increment of speed of one-fourth of a geographical mile per hour, is as follows :

Speed of the vessel in geographical miles per hour.	Power of the speed in which the vessel's resistances increased from one experimental speed to the next greater.
6.50 }	3.7571
6.75 }	
6.75 }	
7.00 }	4.0756
7.00 }	
7.25 }	4.5708
7.25 }	
7.50 }	4.4190
7.50 }	
7.75 }	4.3990
7.75 }	
7.75 }	
8.00 }	3.9225

According to the above, the power of the speed in which the vessel's resistance gradually increased from one experimental speed to the next greater, gradually rose until it became a maximum at the speed of 7.25 geographical miles per hour, from which to the speed of 8.00 geographical miles per hour it gradually declined.

During the different experiments the trim of the vessel changed with each change of speed, and in a very marked manner; the bow rising and the stern falling with each increase of speed. Notwithstanding the sharpness of the bow, the vessel, even at her lowest speed, carried a wide and high wave before her.

At the lowest speed there was a hollow or marked depression in the water a little abaft the stern, followed immediately by a corresponding wave or elevation of water above the general level, and with each increase of speed this hollow became deeper and deeper, and farther and farther from the stern, while the wave which followed it became higher and higher, and also more and more distant. At the highest speed the gunwale at the stern of the cutter was below the general level of the water, so that the persons sitting in the stern sheets appeared to an observer on shore to be standing waist-deep in the water, the cutter's stern being invisible.

There was not only this great alteration of the vessel's trim observed, but also that she began at medium speed to rise bodily above her mean draught of water when at rest, the bow becoming disproportionately high out of water.

The above phenomena, no doubt, exist for all vessels, be their size and form what they may, when their speed exceeds the limit at which their resistances increase in the ratio of the squares of the speeds; but this limit being farther and farther removed as the hull has greater length and finer form, is not in large and well-modeled vessels reached with the ordinary speeds of practice; but when even such vessels are driven beyond the speed of about 12 geographical miles per hour the appearances described make their influence felt.

The first cause of this marked change of trim with the increasing speeds of the cutter was the shortness of her after body comparably with her draught of water aft. Now, the water replacing at the vessel's after body that which was displaced at her fore body, comes from the plane of greatest pressure, which is the plane passing horizontally through the lower edge of the rabbet of the keel, and it rises solely by the force of gravity, the weight of the adjoining column of

water measured from the plane referred to up to the water level, forcing it upwards, and it rises with the same velocity no matter what may be the vessel's speed. But, as the vessel's speed increases, the ascending mass of water cannot reach the after body in time to support it in the position it had when at rest, and, consequently, this after body must drop until it does meet the ascending mass of water, and obtains thereby sufficient floatation. The greater the speed of the vessel, the farther the after body must drop, and with each dropping the resistance of the vessel must increase. As long, however, as the speed of the vessel is such, relatively to her length of after body and draught of water aft, that the ascending mass of water can reach the after body in time, there will be no dropping at the stern, and the vessel's resistance up to that speed will be in the ratio of the squares of the speeds.

The phenomena, as regards the bow, are influenced by the length of the fore body relatively to the speed. The displaced water rises vertically (that being its line of least resistance) along the sides of the fore body, and spreads out over the general level, the height of the rise and the area for the spreading out being measured, other things equal, by the length of the side of the fore body. When the speed of the vessel is increased to such a degree that the wave of translation does not move swiftly enough to keep out of the way of the vessel, the latter rises upon it as upon an inclined plane, and emerges bodily above her mean draught of water when at rest, thus offering a less external wetted surface and a less greatest immersed transverse section to be driven by the engines. In this way the decreased power of the speed in which the resistance of the vessel increased at the higher rates of speed may be explained.

The resistance of the hull is composed of two parts; one, that of her external immersed or wetted surface; the other, that of her form abstracted from this surface resistance. The first may be called her resistance in function of surface, and the last her resistance in function of form. The first may be approximated with reasonable accuracy by calculation; the last must be ascertained experimentally.

The experiments with the *Pensacola's* steam-cutter allow this separation of these two resistances to be made in her case, and each to be ascertained for the different experimental speeds of the vessel.

The speed with which the watery molecules glide over the wetted surface of the hull is less than the speed of the vessel, owing to the

inclination of her lines to her longitudinal axis, and, in the case under examination, these two speeds may be taken to be in the ratio of 0·974 to 1·000. Assuming the wetted surface not to change in area during the experiments, it is 332·85 square feet; each square foot of which, when moving with the velocity of 10 feet per second, has the resistance of 0·45 pound, which resistance increases and decreases with the square of the velocity. Calculating with these data the resistance of the external immersed or wetted surface of the hull for each experimental speed, and deducting it from the resistance of the hull at each of these speeds (line 3 of the table), the remainder will be the resistance in function of form. And it is evident that, as the resistance in function of surface varies with the square of the vessel's speed, all the increased resistance above that ratio must be due to the form alone.

In the following table will be found the results of these calculations, the resistance of the vessel in function of surface and in function of form being given separately :

Speed of the vessel in geographical miles per hour.	Total resistance of the vessel in pounds.	Resistance of the vessel in function of surface alone, in pounds.	Resistance of the vessel in function of form alone, in pounds.	Per centum which the resistance of the vessel in function of surface is of her total resistance.	Per centum which the resistance of the vessel in function of form is of her total resistance.
6·50	272·859	171·484	101·375	62·85	37·15
6·75	314·348	184·965	129·383	58·84	41·16
7·00	364·516	198·445	166·071	54·44	45·56
7·25	427·914	213·590	214·324	49·91	50·09
7·50	497·109	228·402	268·707	45·95	54·05
7·75	574·166	243·846	330·320	42·47	57·53
8·00	650·413	259·723	390·690	39·93	60·07

The power of the speed of the vessel in which its resistances in function of form alone increased for each experimental increment of speed of one-fourth of a geographical mile per hour, is as follows :

Speed of the vessel in geographical miles per hour.	Power of the speed in which the ves- sel's resistances in function of form alone increased from one experi- mental speed to the next greater.
6.50 }	6.4745
6.75 }	
6.75 }	6.8719
7.00 }	
7.00 }	7.2727
7.25 }	
7.25 }	6.6660
7.50 }	
7.50 }	6.3047
7.75 }	
7.75 }	5.2812
8.00 }	

The quantities on line 22 of the table show the proportion of the net horse-power developed by the engines applied to the screw shaft, which was utilized in the propulsion of the vessel. They consequently represent the relative economic efficiency of the screw, referred to the net horse-power, at the different speeds of vessel. Had the resistances of the vessel been in the ratio of the squares of its speeds, the quantities on line 22 would have been equal; the decrease of the screw's efficiency with the increase of the vessel's speed, is due to the fact that the resistance of the vessel increased in a higher ratio than the square of its speed, while the resistance of the watery fulcrum to the screw blades increased only in the ratio of the square of the number of their revolutions in equal time, and that the number of these revolutions, *ceteris paribus*, is in the direct ratio of the speed of the vessel; that is to say, if the resistance of the vessel is as the square of its speed, the number of revolutions of the screw in equal time will be as the speed of the vessel.

As the resistance which the screw experiences from its watery fulcrum, other things equal, is as the square of the number of its revolutions in a given time, and as the vessel's speed is as the number of revolutions made by its screw in equal time, provided the resistance of the vessel increased as the square of its speed, then the resistances of the screw and of the vessel, in this case, would increase in the same duplicate ratio of the speed, and the slip of the screw would consequently remain constant, and its economic efficiency undergo no change.

But if the vessel's resistance increased in a higher ratio than the square of its speed, the resistance of the screw remaining in the ratio of the square of its revolutions in equal time, then the slip of the screw would increase with increased speed of vessel, and become greater and greater as that speed became greater and greater, and the screw would have, in consequence of these increasing slips, less and less economic efficiency.

The loss of economic efficiency by the screw, primarily caused by increased slip, includes not only the loss due to the increased slip, *per se*, but also that which is due to the increased resistance of the water to the screw surface, or, in other words, to the increased skin resistance of the blades, because, in order that the vessel make a given speed, more revolutions of the screw will be required in equal time with the increased slip of the screw, whose corresponding surface loss will be as the squares of the number of revolutions made in equal time.

Fall of a Market Roof in Paris.—On a cold night of last December, when the thermometer stood at -15° (5° F.), the metallic roof of St. Martin market suddenly fell. It was built upon rigid supports and seems to have been sufficiently strong. The cause of the fall was therefore a mystery, and the French engineers are discussing the subject with much interest. They very generally agree in regarding the rigidity of the supports as a defect and in thinking that the extremities of every beam should be allowed sufficient lateral play to prevent any injurious effect, either from contraction by cold or from expansion by heat.—*Chron. Indust.* C.

Temperature of Frozen Lakes.—F. A. Forel has made a series of observations on the Swiss lakes, similar to that of Buchanan at Loch Lomond. He finds that the limit of the superficial chill is much greater than has been hitherto supposed, extending in some cases even to the depth of 110 metres (120·3 yards). The penetration of the cold into the upper layers takes place very gradually and progressively. It does not appear to be accomplished either by convection or by mechanical mixture under the action of waves and currents, but may perhaps be connected with conductivity and radiation. Observations extended over an interval of forty days showed a great uniformity of temperature, but at no time was the uniformity complete throughout the whole depth of the lakes.—*Comptes Rendus.* C.