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CONTRACT TRIAL OF THE U. S. ARMORED CRUISER *MAINE*.

BY CHIEF ENGINEER A. W. MORLEY, U. S. NAVY.

The *Maine*, a twin-screw armored cruiser of about 6,650 tons displacement, was built at the Navy Yard, New York, from designs furnished by the Bureau of Construction and Repair of the Navy Department, and is the largest vessel ever built in one of our Navy Yards. In external appearance, and in arrangement of battery, she resembles the Brazilian ship *Riachuelo*, but she is larger and has thicker armor and heavier guns than the *Riachuelo*. The original design contemplated a bark rigged vessel, but as her construction proceeded, the design was so altered that she now has two military masts only.

The machinery was built by N. F. Palmer, Jr., & Co., the Quintard Iron Works, New York City, from designs furnished by the Bureau of Steam Engineering of the Navy Department, the contract price being $735,000. The contract called for an indicated horse power of 9,000 for the main engines and the air and circulating pump engines, with a premium of $100 to be paid for each indicated horse power in excess of the requirement, and a penalty of like amount to be deducted for each horse power below that amount.

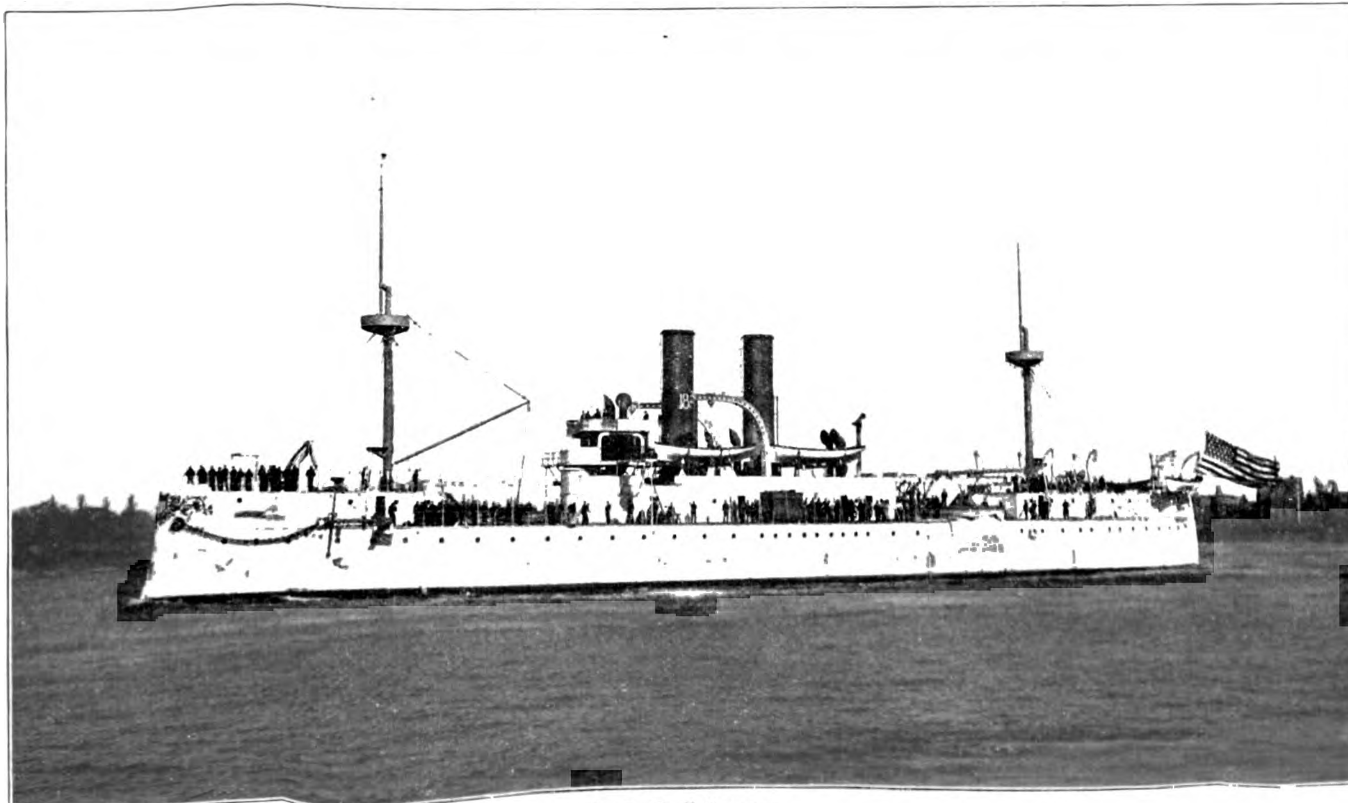
Her keel was laid on the 11th of October, 1888, and her hull launched on the 18th of November, 1890. The contract for the construction of the machinery was signed on the 3d of April, 1889, and the engines erected in the shop and operated on the 31st of August, 1891, when an official exhibition of the engines in operation was given by the contractors, the power for working them being furnished by the turning engines. An official dock trial was made on the 21st and 22d of July, 1893, an account of which has already been published in the JOURNAL.

HULL.

The hull is constructed of mild steel, and all of the material used is of domestic manufacture. The outside keel plate is $\frac{5}{8}$ inch, the inner plate $\frac{1}{2}$ inch, and the vertical keel $\frac{1}{2}$ inch thick. The outer bottom plating is $\frac{1}{2}$ inch thick, with a double sheer strake; the plating of the inner bottom is $\frac{5}{16}$ inch thick. The frames are spaced 4 feet throughout the length of the double bottom and 3 feet at the ends.

She is divided into 198 water tight compartments, and has a double bottom extending from frame 18 to frame 67, a distance of 196 feet, and running up to the shelf for the armor belt. In the wake of the double bottom there are 4 longitudinals on each side, and under the engines and boilers intermediate longitudinals are introduced.

For pumping and draining the compartments and the double bottom there is a 12-inch main drainage pipe on the starboard side, and a 5-inch secondary drainage pipe on the port side, extending from the compartment forward of the double bottom to the after engine compartments. Each of these pipes has branches leading to a main drainage cistern located under the starboard engine room. Suctions from the main circulating pumps and from the engine room bilge pumps are made to the main cistern.



U. S. S. "MAINE."

There are twenty coal bunker compartments, ten on each side of the vessel, extending down from the protective deck, with wing bunkers at each end of each fire room, and which extend inboard to the fronts of the boilers. The total capacity, in tons of 42 cubic feet, is 825 tons. The bunkers are filled through trunks leading down from the main deck, delivering directly into the several main compartments and into the wing bunkers, being so arranged that but little trimming of the coal is required until the bunkers are nearly filled. Escape trunks have been constructed leading from each bunker into the fire rooms above the boilers, and offer ready ingress and egress while coaling.

The ashes from the fire rooms are discharged through a single chute, located within the central superstructure deck, opposite the athwartship bulkhead dividing the fire rooms; it leads down from the main deck and passes through the side just above the armor belt.

DIMENSIONS OF HULL.

Length between perpendiculars, feet	310
Length over all, feet and inches	324-4
Beam, extreme, at L.W.L., feet	57
Draught, mean, normal, feet and inches	21-6
Area immersed midship section, square feet	1,077
Displacement, tons, at 21 feet 6 inches	6,650.
Tons per inch	32.32
Center of buoyancy above base line, feet and inches	12- 3½
buoyancy aft of midship section, feet and inches	2-11
gravity above base line, feet and inches	3- 1
Transverse metacenter above C. B., feet	12.
Longitudinal metacenter above C. B., feet	324.
Coefficient of displacement, prismoidal, feet	0.596
displacement, cylindrical, feet	0.669
midship section, feet	0.878
L.W.L., feet	0.747
Area of L.W.L. plane, square feet	13.560
Wetted surface, square feet	23,770

ARMOR.

For a length of 180 feet amidships there is a water-line belt of vertical Harveyized steel armor, extending from 3 feet above to 4 feet below the water line, 12 inches in thickness from the top to one foot below the water line, whence it tapers to 7 inches at the bottom. The wood backing is 8 inches thick, and the plating behind this is in two thicknesses of ½ inch each, stiffened by horizontal angle bars 6 by 3½ inches, and by plates $\frac{5}{16}$ inch thick worked intercostally between the vertical frames, and connected with them by angle bars 2½ by 2½ inches.

The bolts for securing the armor are 2 and 2.8 inches in diameter, with nuts and India rubber cups and washers on the inner ends of the bolts. The wood backing is secured to the skin plating by bolts 1⅛ inches in diameter.

At the forward end of the armor belt there is an athwartship bulkhead of steel, 6 inches in thickness, with the backing generally arranged as for the side armor.

The protective deck, constructed in two layers of 1 inch each, extends from the armored bulkhead to the after end of the side armor, whence it slopes below the water line with a thickness of 3 inches.

There is an armored conning tower built of steel, 10 inches thick, elliptical in shape, from which an armored tube, 4½ inches thick, extends down to the armored deck to protect the steering gear, voice tubes, electric wires and connections of the engine room telegraphs.

There are two revolving turrets, each fitted for two 10-inch guns, constructed at sufficient height to admit the guns in each turret being fired simultaneously on a line parallel with the center line of the ship, each having an unobstructed fire through an angle of 180 degrees on one side, and through an angle of 64 degrees on the opposite side.

Each turret has 8 inches of Harveyized steel armor, with plate backing, frames, &c.

The revolving parts of the turrets, and the spaces for working and loading the guns, are protected by a fixed barbette of mild steel armor, 12 inches in thickness, fitted to a wood and steel plate backing and secured by bolts and nuts, as described for the side armor.

ARMAMENT.

There are two 10-inch breech loading rifles in the forward and two in the after turret, the turrets and guns being worked by hydraulic gear. Besides these, there are six 6-inch breech loading rifles, two mounted forward inside the superstructure deck firing directly ahead, two abaft the cabins firing directly astern, and one on each side on the central superstructure deck.

The 10-inch and the 6-inch guns can all be fired in broadside, throwing a weight of projectile on each side of about 2,400 pounds at one discharge.

The 6-inch guns are worked by hand, on central pivot carriages, and are protected by steel shields, 2 inches thick.

The secondary battery consists of seven 6-pounder Driggs-Schroeder rapid-fire guns; four 1-pounder Hotchkiss; four 1-pounder Driggs-Schroeder, and four machine guns (Gatling).

There are four tubes for Whitehead torpedoes, two on each side, discharging directly from the berth deck.

MACHINERY.

Main Engines.—There are two vertical, inverted cylinder, direct-acting, triple expansion engines, placed in water tight compartments, and separated by a fore-and-aft bulkhead. The high pressure cylinder of each engine is placed aft and the low pressure cylinder forward, the latter being so arranged that it can be disconnected when working at low power and the high and intermediate pressure cylinders used under economical condition as a compound engine. All of the cylinders are steam jacketed on top, sides and bottom. The main valves are of the single ported piston type, made of composition, in two parts, and all interchangeable. There is one for each high pressure cylinder, two for each intermediate and three for each low pressure cylinder, all worked by Stephenson link motion with double bar links. The high pressure valves are fitted with balancing pistons working in cylinders cast on the upper cover of each high pressure valve chest, with live steam on the under side of the piston and the upper side connected with the intermediate receiver. Each high pressure valve is worked direct, and the intermediate and low pressure valves by rock shafts, each rock shaft being connected to its link by an equalizing bar, the upper end of which is carried by a radius link of such length as to minimize the slip of the link block. The cut-off may be varied from 0.5 to 0.7 of the stroke, each reversing arm being made with a slot, fitted with a composition block, which is adjustable by a screw and hand wheel.

The reversing gear of each engine consists of a steam cylinder, and a hydraulic controlling cylinder placed vertically and acting directly on an arm fixed on the reversing shaft. The valve of the steam cylinder is of the piston pattern, connected to a by-pass valve on the hydraulic cylinder, and is worked by a continuation of the stem of the steam piston valve. These valves are worked by a system of levers, the primary motion of which is derived from the hand lever at the working platform, and the secondary motion from a pin on the reversing arm. There is also a pump for reversing by hand, the by-pass pipes of the hydraulic cylinder, which pass through the valve-box of the hand pump, being so arranged as to leave the hand arrangement always in gear. The diameter of the steam reversing cylinder is 20 inches, the diameter of the controlling cylinder 10 inches, and the stroke 27 inches.

Each engine is fitted with a throttle valve consisting of two gridiron slide valves placed horizontally, one above the other. The lower slide valve is actuated by a steam cylinder and a hydraulic controlling cylinder, placed horizontally and acting directly on the spindle of the valve. The steam piston is operated by a piston valve, which is controlled by a floating lever so fitted that the throttle valve will follow the movement of a hand lever at the working platform. The upper slide valve is worked by a screw stem, the gear operating the stem being worked by a hand wheel at the working platform. The steam actuated throttle valve is intended for use in quick working, and the hand-moved valve for fine adjustment.

Each main cylinder is fitted with starting valves of the piston type, each complete in itself, with both steam and exhaust ports, and worked by a lever at the working platform, the levers being placed in the same order as their respective valves, and arranged to move in the same direction as the desired motion of the piston.

The main steam pistons are of composition, with double shells, and are each fitted with two packing rings, $\frac{5}{8}$ inch wide and $\frac{5}{8}$ inch deep, set out by steel springs bearing against a flanged floating ring fitted to have an easy play in the piston. The piston rods are of forged steel, the lower end of each rod being enlarged to form a crosshead and fitted with an adjustable brass and a composition cap. The connecting rods are of forged steel, $72\frac{3}{4}$ inches between centers. The crosshead end of each rod is forked to span the crosshead brasses, and each eye at the end split and fitted with a bolt for gripping the crosshead pin. Each crosshead is fitted with a wrought-iron slipper, dovetailed and shrunk on and further secured by tap-bolts. A composition guide, 22 inches long by 20 inches wide, in two parts, is fitted to each slipper, secured at the lower end by a flange and studs, and at the upper end by square headed bolts in slotted holes. The crosshead guides are of cast iron, and are hollow for water circulation.

The engine frames consist of hollow wrought steel columns, excepting a single inverted Y column supporting the intermediate cylinder. The columns are stayed by horizontal steel brace rods and by athwartship diagonal braces, the braces being set taut by nuts on each side of lugs. The engine bed-plates are of cast steel, in three sections, flanged and bolted together.

The crosshead gibs and all of the principal brasses of the main engines are fitted and lined with Parson's white metal.

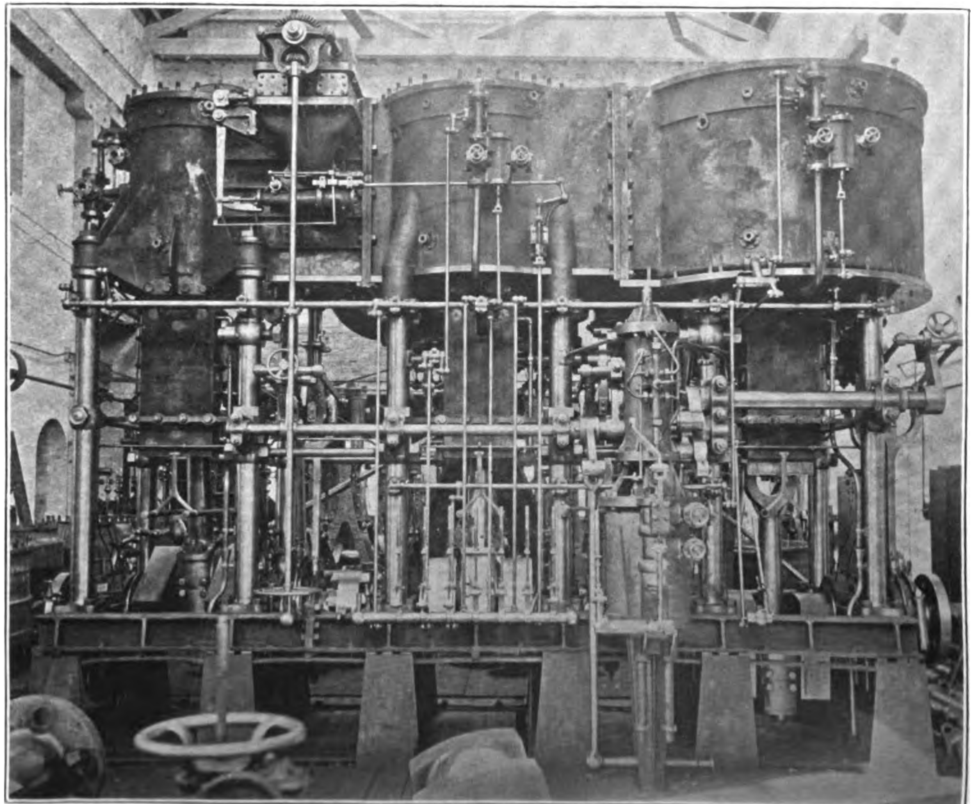
All working parts of the machinery are fitted with efficient lubricators. A number of distributing oil tanks are fitted on the sides of the cylinders, and are supplied by a pump from the main oil tanks. The pipes from the distributing tanks are led to manifolds, which are fitted with adjustable valves, sight feed cups, and tubes leading to all the journals of the moving parts of the engines, excepting the main bearings, which are supplied with oil from a single distributing tank, with separate closed manifolds, valve adjustment, sight feeds and tubes for each part to be oiled, so that when necessary, oil can be supplied to the journals under a head, there being four tubes leading to each journal. Each main crank pin is also additionally provided with a centrifugal oiling device, fitted on the face of each crank.

There is a globe oil cup for each piston rod, and one for each end of each valve stem, also one for each piston valve, and connected with a small hand pump for ensuring the oil running to the place desired. The eccentrics are lubricated in all positions. Efficient sight feed oil cups are fitted to each main steam pipe, and on each air and circulating pump, blowing, main feed, and bilge pump engine.

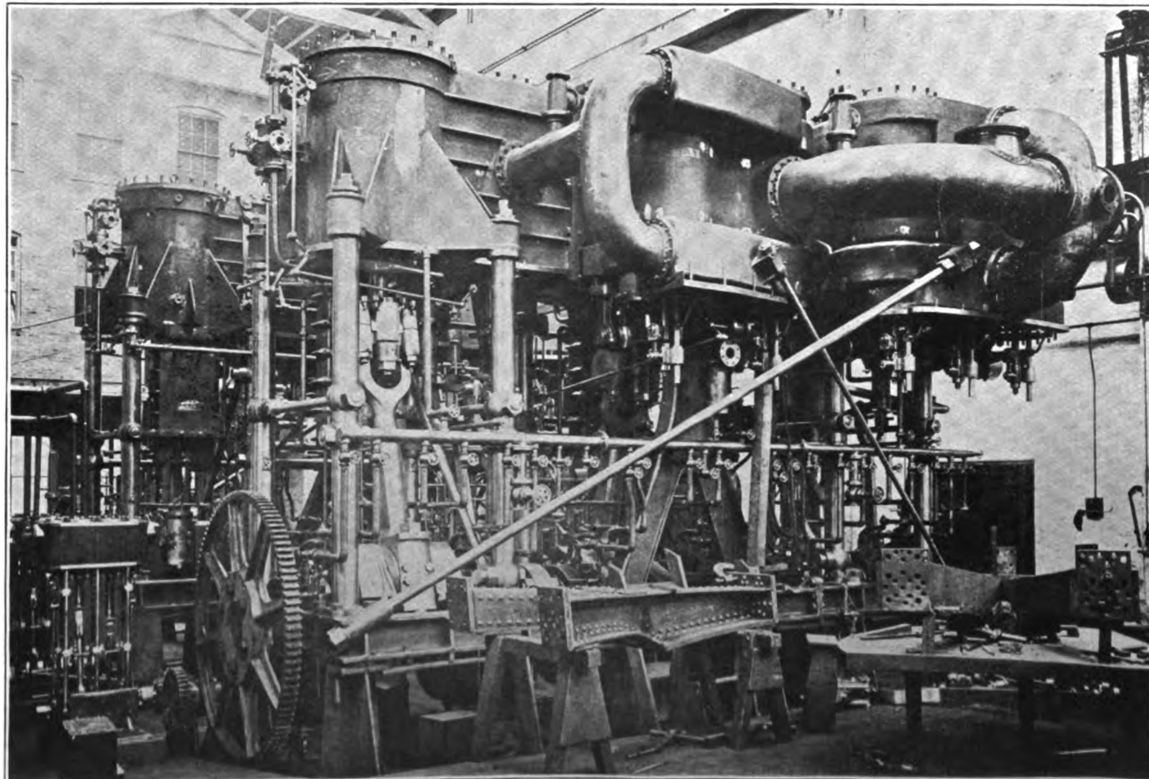
The main engine straightway stop valves are arranged to be worked from the engine room, and are also fitted with gear for operating them from the berth deck. The screw stop valves fitted in the main steam pipes immediately inside the engine rooms are fitted with gear for working them from both engine rooms.

The following are some of the principal dimensions and ratios of the machinery, viz:

Number of cylinders (each engine)	3
Diameter of H.P. cylinder, inches	35½
I.P. cylinder, inches	57
L.P. cylinder, inches	88
Stroke of all pistons, inches	36
Diameter of H.P. valves (one for each cylinder), inches	22
I.P. valves (two for each cylinder), inches	22
L.P. valves (three for each cylinder), inches	22
Area of H.P. steam port for maximum opening, top, square inches	104.260
bottom, square inches	132.352
I.P. steam port for maximum opening, top, square inches	134.576
bottom, square inches	260.640
L.P. steam port for maximum opening, top, square inches	449.604
bottom, square inches	508.248
H.P. exhaust port for maximum opening, top, square inches	203.
bottom, square inches	203.
I.P. exhaust port for maximum opening, top, square inches	406.
bottom, square inches	406.
L.P. exhaust port for maximum opening, top, square inches	609.
bottom, square inches	547.14
main steam pipe (12 inches diameter), square inches	113.1
H.P. steam pipe (13 inches diameter), square inches	132 7
I.P. steam pipe (20 inches diameter), square inches	314.2
I.P. exhaust pipe, to condenser (16 inches diameter), square inches,	201.06
L.P. exhaust pipe, (28 inches diameter), square inches	615.75
Volume swept by H.P. piston per stroke, mean, cubic feet	20.30



ENGINES OF THE "MAINE."



ENGINES OF THE "MAINE."

Volume swept by I.P. piston per stroke, mean, cubic feet	52.84
L.P. piston per stroke, mean cubic feet	126.39
Clearance, in cubic feet, H.P. cylinder, top	4.974
bottom	4.744
I.P. cylinder, top	10.161
bottom	9.094
L.P. cylinder, top	22.376
bottom	17.344
per cent., H.P. cylinder, top	24.12
bottom	23.74
I.P. cylinder, top	19.113
bottom	17.314
L.P. cylinder, top	17.65
bottom	13.76
Ratio of net area of H.P. to I.P. pistons	1 to 2.578
I.P. to L.P. pistons	1 to 2.383
H.P. to L.P. pistons	1 to 6.144
Diameter of piston rods, inches	6¼
Length of connecting rods between centers, inches	72⅝
Diameter of connecting rods, inches	6¼ and 10

Shafting.—The shafting is of steel throughout. The crank shafts are each in three sections, all alike and interchangeable, with coupling discs forged on. There are two journals for each section, and beyond the after journal, on each section, is a seating, 13½ inches in diameter, for the eccentrics. The cranks are placed at angles of 120 degrees with each other, the sequence being H.P., I.P. and L.P. The hole in the thrust shafts is enlarged for a short distance at the after end in order to accommodate the nut on the central stud of the inboard propeller shaft. The propeller shafts are each in two sections, and are cased with composition where they pass through the stern tubes and stern brackets. The forward end of the forward section is fitted with a sleeve for coupling to the thrust shaft; this sleeve is secured by five keys, each 2½ inches wide and 2 inches thick, which, with the sleeve, are held in place by a wrought-iron washer 15½ inches diameter and 2 inches thick. This washer is secured to the shaft by a central stud and nut, which take up the thrust in backing. All the shaft couplings are fitted for six 3¼-inch bolts. The shaft casing is ⅝ inch thick.

The principal dimensions of the shafting are:

Crank shaft, diameter, inches	13
diameter of hole through, inches	4
length of each section, feet and inches	7– 9
journals, length of each, inches	13
couplings, diameter, inches	26
thickness, inches	3¼
coupling bolts, diameter, inches	3¼
Crank pins, diameter, inches	14
length, inches	14
diameter of hole through, inches	4
Crank webs, width inches	17½
thickness, inches	9
Thrust shaft, diameter, inches	12¾
diameter of hole through, inches	6
length, feet and inches	12– 5
collars, number	11
outside diameter, inches	17¼
depth, inches	2
thickness, inches	1⅝
space between, inches	2⅛
thrust surface, each shaft, square inches	996.91
Propeller shafts, diameter of forward, inches	13⅜
length of forward, feet and inches	21– 0⅜
diameter of hole through, inches	6¾
after, inches	13¼
length of after, feet and inches	26–11½
diameter of hole through, inches	6½
coupling sleeve, diameter, inches	27
length, inches	15
Casing, length of on shaft through stern tube, feet and inches	18– 3
bracket bearing, feet and inches	5– 4
Bearing in stern tube, forward end, length, inches	31
after end, length, inches	32
in brackets, length, inches	48
Length, total, of shafting for each engine, feet and inches	84– 3
crank shaft bearings, feet and inches	6– 6

Shaft Bearings.—The crank shaft brasses are cylindrical, in two parts, turned to fit the caps, and have an adjustable composition chock with wedge for the vertical alignment of the shaft. Each set of brasses is fitted with channel shaped clamping pieces to prevent them pinching the journals, the upper ones being extended to prevent the brasses from turning in their bearings. Each thrust bearing is in two parts, of cast iron, with white metal linings, the lower part turned to fit the pedestal. The end and side walls of the pedestals form an oil trough with stuffing boxes for confining the oil. Inside this trough, both forward and abaft the thrust collars, is an adjustable composition bearing, 8 inches long, for taking the weight of the shaft. Each oil trough is fitted with pipe coils for the circulation of cooling water through the oil.

Main Condensers.—The main condensers, one in each engine room, are cylindrical, and made of composition, each in three principal sections. The circulating water passes through the tubes and the steam around them. In addition to the connections for the main, the intermediate and the auxiliary exhaust pipes, each condenser is fitted with a salt spray in the exhaust passages, a copper tank and pipes for admitting an alkaline solution, and a branch steam pipe leading to the bottom of the shell for cleaning the tubes by boiling. Each condenser is also arranged to be used as an auxiliary condenser, and the one in the port engine room is connected with the evaporators for supplying waste of water in the boilers. There is also a connection from the channel way leading from each condenser to its air pump, by means of which the water of condensation may be taken by any of the feed pumps when the condensers are used for auxiliary purposes alone. In the latter case the combined air and circulating pumps will not be used, but the condensing water will be supplied by an auxiliary centrifugal circulating pump, hereinafter described.

The principal dimensions of the condensers are:

Length over all, feet and inches	10–5
Diameter of shell, inside, feet and inches	6–6
Thickness of shell, inch	$\frac{7}{16}$
Tubes, number in each condenser	5,141
exposed length, feet and inches	8–4
diameter, outside, inch	$\frac{5}{8}$
thickness, 20 B. W. G., inch	.035
Condensing surface, each condenser, square feet	7,009.96
per I.H.P. (total)	1.509
Ratio of condensing surface of two condensers to heating surface of eight boilers	1 to 1.35

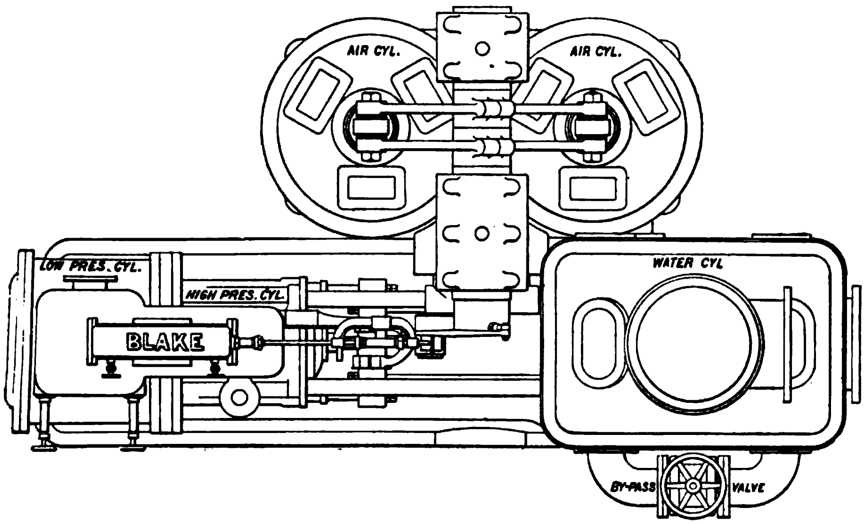
Air and Circulating Pumps.—There is one combined air and circulating pump for each main engine, built by the Blake Manufacturing Company. The air pumps are double, vertical, single-acting and are connected to a horizontal, double-acting circulating pump, all operated by a horizontal compound engine. The air-pumps are worked by an overhead beam and rock shaft, connected through an arm and link to the piston rod of the engine.

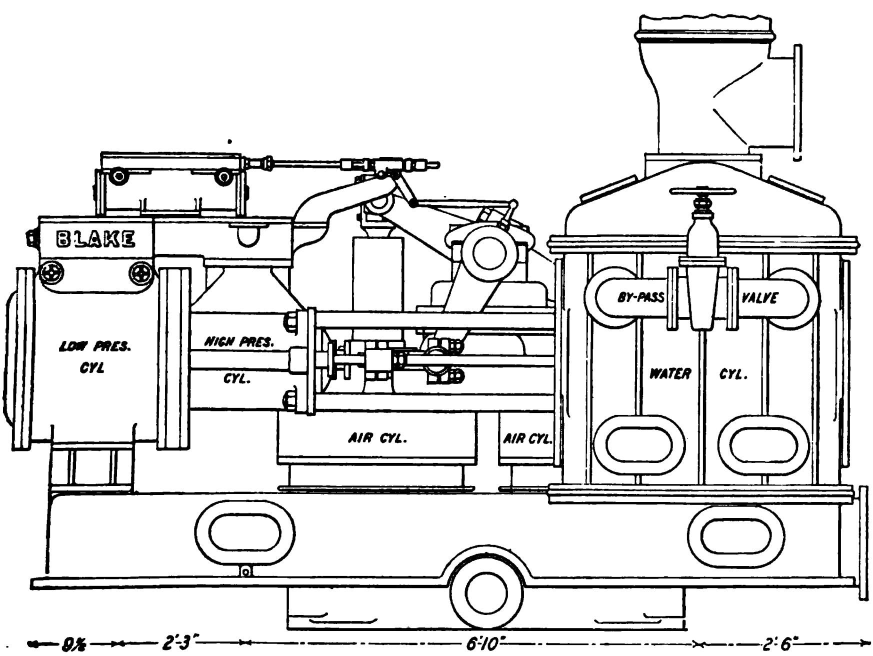
Diameter of H.P. steam cylinder, inches	12.
L.P. steam cylinder, inches	24.
air pump cylinders, inches	30.
circulating pump cylinder, inches	31.
Stroke of all cylinders, inches	18.5
Diameter of suction and delivery pipes, inches	15.
Area of 12 foot valves of each air pump, square inches	162.
10 air pump bucket-valves of each pump, square inches	135.4
10 delivery valves of each air pump, square inches	135.4
18 foot valves at each end of each circulating pump, square inches,	243.72
18 delivery valves at each end of each circulating pump, square inches	243.72

Auxiliary Centrifugal Circulating Pumps.—Connected with each main condenser is also an auxiliary centrifugal circulating pump, driven by a vertical, simple, double-cylinder, direct-acting engine, and together with the combined air and circulating pumps arranged to draw from the sea, from the bilge of either or both engine rooms, and from the main drainage cistern, and to discharge directly overboard, or through the condenser.

Diameter of steam cylinders (2), inches	8
Stroke, inches	7
Diameter of pump runner, inches	36
suction and delivery pipes, inches	12
Capacity of pumps, in gallons, per minute	3.500

Screw Propellers.—The propellers are made of manganese bronze, and are four-bladed true screws. The blades are adjustable, and each is bolted to the boss by nine tap bolts of manganese bronze, 2½ inches in diameter, secured by lock plates, the recesses for the bolt heads being covered by finished composition plates secured by countersunk screws. The bosses are spherical, and are fitted with conical tail pieces.


AIR CYL.
AIR CYL.
LOW PRES. CYL.
HIGH PRES. CYL.
BLAKE
WATER CYL
BY-PASS
VALVE


BLAKE
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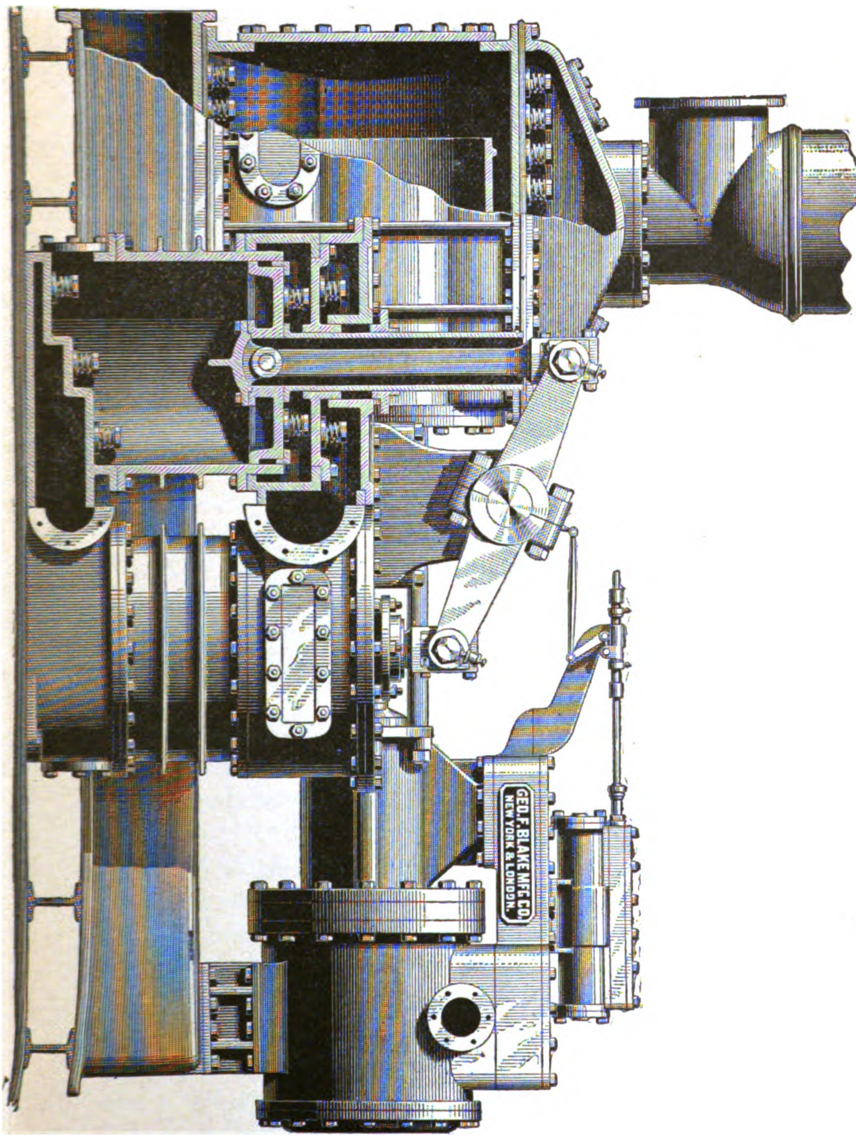
CYL.
2'-3"
6'-10"
2'-6"


GEO. F. BLAKE MFG. CO.
NEW YORK & LONDON.

Diameter of propellers, feet and inches	14– 6½
boss, inches	48
Length of boss, inches	36¾
Number of blades	4
Greatest width of blade, at radius of 3 feet 7½ inches, feet and inches	3– 9¾
Pitch, limits of adjustment, feet	15 to 17
as set on trial, feet, starboard	16.08
port	16.114
Area, helicoidal, each screw, square feet	65.5
projected, of each screw, square feet	54.79
disc, of each screw, square feet	166.08
Ratio of pitch to diameter, starboard	1.105
port	1.108
disc area of both screws to area of I.M.S	.307
Distance of center of boss above lowest point of keel, feet and inches	8–1
Immersion of tip of blades at draught of 21 feet 6 inches, feet and inches	6–2

Boilers.—There are eight single-ended steel boilers of the horizontal return fire tube type, with three corrugated furnaces in each boiler, and a separate combustion chamber for each furnace. The longitudinal joints of the shells are treble riveted, with double butt straps, and the circumferential joints lapped and double riveted. Each head of each boiler is made of three plates, the upper one of which is curved back to meet the shell. The heads are flanged outwardly at the furnaces and inwardly at their circumference, and the combustion chamber sheets rounded at the top.

The boilers are placed in two equal groups in two water-tight compartments, with a central fore-and-aft fire room in each compartment. There is one smoke-pipe, oval in cross section, for each group of boilers; the lower part is shaped to connect with the uptakes, each of which is carried up clear of the upper deck and constructed with athwartship and fore-and-aft division plates for the purpose of keeping separate the gases from the boilers on the opposite side of the fire room as well as those from adjacent boilers.

There is an 8-inch self-closing stop valve on each boiler, fitted with suitable gear for operating it from the berth deck. A screw sleeve with hand wheel is provided for closing the valve, and a spindle with handle for opening. Auxiliary stop valves, 5 inches in diameter, have been placed on each of the two extreme forward and after boilers only. Each boiler has two 4½-inch locked, spring safety valves, the two valves being in one case; they are fitted with mechanism for lifting by hand from the fire rooms, and also for operating them from the main deck, and the arrangement is such that the valves are raised in succession.

The furnaces are fitted with the ordinary fixed cast-iron grates with cast-iron bearing bars.

For circulating the water in the boilers while raising steam, the auxiliary feed pump in each fire room has been connected to draw water from each boiler through its bottom blow valve and to deliver through the auxiliary feed pipe and check valve into an internal feed pipe.

Particulars of one Boiler.—

Steam pressure for which designed, pounds	135
Test pressure, by application of heat to water, pounds	225
Diameter, feet and inches	14– 8
Length, feet	10
Furnaces, corrugated, number	3
diameter, external, inches	46
internal, inches	42
Grate, length of, feet and inches	6–10
Tubes, outside diameter, inches	2¼
length between tube sheets, feet and inches	6– 7
spacing, horizontally, inches	3½
vertically, inches	3¼
number of stay	118
ordinary	401
total number	519
thickness of stay (No. 6 B. W. G.), inch	.203
ordinary (No. 12 B. W. G.), inch	.109
Combustion chambers, depth, feet and inches	2–8
height, above back end of grates, upper, feet and inches	6–1
height, above back end of grates, lower, feet and inches	7–9
Thickness of shell plates, inches	$1\frac{1}{32}$
tube sheets, inch	¾
front head above tubes, inch	$\frac{13}{16}$
below tubes, inch	$\frac{11}{16}$
back head, upper plate, inch	$\frac{15}{16}$
middle and lower plates, inch	$\frac{11}{16}$

Thickness of combustion chambers, inch	$\frac{1}{2}$
furnaces, inch	$\frac{1}{2}$
Rivets in shell sheets, diameter, inches	$1\frac{1}{8}$
Braces above tubes, number	20
diameter, inches	2
below tubes, number	13
diameter, inches	$1\frac{9}{16}$
Screw stays, diameter inches	$1\frac{1}{16}$
pitch, inches	7
Heating surface, tube, square feet	2,012 64
plate, square feet	364.28
total, square feet	2,376.92
Grate surface, square feet	71.73
Area through tubes, square feet	11.73
Area over bridge walls, square feet	11.38
Volume of furnaces and combustion chambers above grates, cubic feet	275.55
Area of water surface, water 6 inches above tubes, square feet	127.57
Steam room, water 6 inches above tubes, cubic feet	374.
Water in boiler, pounds	40,828
Smoke pipes, number	2
height above lower grates, feet and inches	75–4
area of each, square feet	40.27
Stop valves, main, diameter, inches	8
auxiliary, diameter, inches	5

Total for eight Main Boilers.—

Grate surface, square feet	573.84
Heating surface, tube, square feet	16,101.11
plate, square feet	2,914.23
total, square feet	19,015.34
Area through tubes, square feet	93.85
over bridge walls, square feet	91.04
of water surface, square feet	1,020.56
Volume of steam room, cubic feet	2,992.
furnaces and combustion chambers above grates, cubic feet	2,204.40

Ratios.—

Tube H.S. to G.S.	28.058 to 1
Plate H.S. to G.S.	5.078 to 1
Total H S. to G.S.	33.137 to 1
Area through tubes to G.S.	1 to 6.113
of smoke pipe to G.S.	1 to 7.12
Water surface to G.S.	1.77 to 1
Steam room to G.S.	5.214 to 1

Forced Draft.—The forced draft system in each boiler compartment consists of two Sturtevant blowers, which discharge into separate main air ducts under the fire room floors, from which a branch duct leads to the ashpit of each furnace, each duct being fitted with a door in front of the ashpit, and each branch with a damper; each main air duct is also fitted with a damper close to the blower. The main air ducts are so arranged that either blower can deliver to the furnaces on both sides of the fire room.

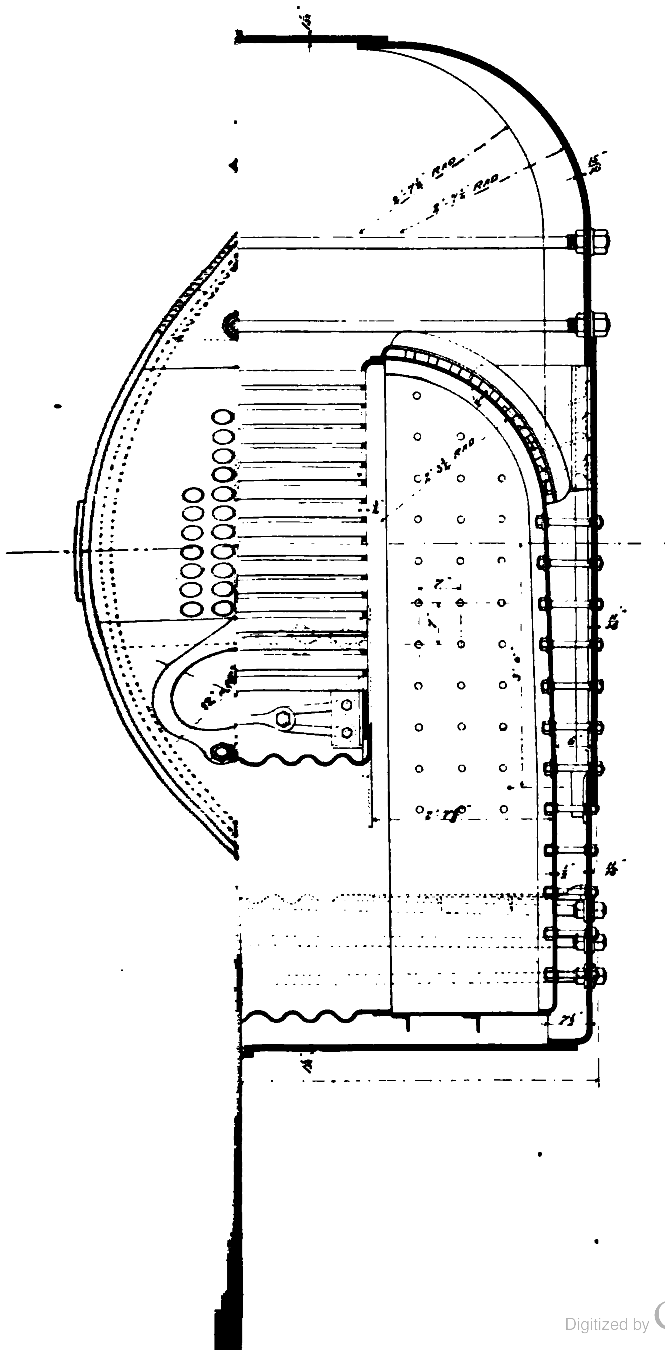
The damper regulating the draft to each furnace is not only so fitted that the amount of opening can be quickly and easily graduated, but is provided with a lever for preventing the furnace door from being opened while the damper is open, thus preventing the escape of gases and flame out of the furnace when its door is opened.

The fire rooms are well ventilated by the arrangement of light iron screens fitted overhead in each compartment, so that all air going to the blowers is taken from the fire room below them, fresh air from the hatch at the farther end of the fire room being supplied at a low level in front of the boilers.

Blowers.—Each blower is driven by an inclosed, double-cylinder, Sturtevant direct-acting engine, with the cylinders placed below the shaft, the throttle valve of each engine being arranged to be worked from the fire room floor. Each blower is capable of supplying to the fires continuously 25,000 cubic feet of air per minute at the speed of 545 revolutions.

Diameter of steam cylinders, inches	6
Stroke, inches	5
Diameter of fan, inches	56
Width of fan, inches	30

Feed Pumps.—There are in each fire room two vertical, duplex, double-acting feed pumps of the Blake patent, one for the main and one for the auxiliary feed. The main and auxiliary systems of feed pipes are arranged to be connected at will, and all the feed pumps are arranged to draw from the feed tanks and to supply any boiler. Each main feed pump is arranged to draw from the feed tanks and air pump channel ways only, and to



deliver into the main feed pipe only. Each auxiliary feed pump is arranged to draw from the sea, the feed tanks, the air-pump channel ways, the bilge, the air ducts, or the boilers at will, and to deliver either into the auxiliary feed pipe, the main feed pipe, the fire main, the pipe connecting the tanks of the hydraulic pumping engines, or overboard through a sea valve in its own compartment. These pumps have their steam cylinders adapted for use as fire pumps with steam of 60 pounds pressure. Dimensions of main and auxiliary feed pumps, steam cylinders, 10 inches; water cylinders, 6 inches; stroke, 12 inches.

Feed Tanks.—There is in each engine room a feed tank of 550 gallons capacity. Each tank is fitted with an overflow pipe leading to the bilge, so arranged that any water passing down it may be seen. Each feed pump suction from the tank is provided with a balanced valve operated by a float in the feed tank, so fitted that it will allow no air to enter the feed pipes. The upper portion of each tank is fitted as a filter, provided with sponges, and into which the water from the air pumps is delivered.

Other Auxiliary Machinery.—There is in each engine room a horizontal, single cylinder, double-acting Blake pump, 14 by 8 by 12, with suctions from the sea, the bilge of the compartment abaft the engine rooms, the secondary drain pipe, and the main drainage cistern, and arranged to deliver into the fire main and overboard.

There is also in each engine room a horizontal duplex Blake pump, 7½ by 4½ by 10, which has a suction from the sea only, and which delivers into the engine room water service and the fire main.

For turning the main engines there is in each engine room a double cylinder, vertical, simple engine, with cylinders 6 inches diameter and 8 inches stroke. This engine drives by worm gearing a second worm which is made to mesh with a worm wheel on the main engine shaft. It is fitted with piston valves, and controlled by a piston reversing valve. The shaft of each engine is squared at the end and fitted with a ratchet wrench for turning by hand.

For ventilating the engine rooms, there is in each a Sturtevant fan having a capacity of 10,000 cubic feet per minute. They are driven by double cylinder, vertical, simple engines having cylinders 3½ inches in diameter and 2½ inches stroke. The fans are 36 inches in diameter, and have a width of 15 inches. There is also a ventilating fan located on the upper platform deck, between the engine and fire rooms, operated by engines similar to the forcing blowers, and arranged to exhaust the air from the forward end of each engine room.

In the central hatch of each fire room there is a simple, self-controlling, double cylinder, vertical ash hoisting engine of the Williamson type, fitted with a reversing gear which can be worked from the fire rooms or from deck. The cylinders are 4½ inches diameter and 4½ inches stroke. The ashes are discharged overboard on the starboard side through an inside pipe 15 inches in diameter.

In the two middle compartments of the berth deck there are two Sturtevant fans for ventilating the ship, one forward on the port side, the other aft on the starboard side, and both arranged for exhausting and supplying air. They are operated by double cylinder, vertical, simple engines with cylinders below the shaft. The cylinders are 4 inches in diameter and the stroke 3 inches. The fans are 42 inches in diameter and 17 and 21 inches wide, and have a capacity of 8,800 cubic feet per minute.

Steam Traps.—The separators in the engine and fire rooms, the jackets of main engine cylinders, air and circulating pump cylinders, the radiators, and the main and auxiliary steam pipes, are fitted with the Dinkel traps, with by-pass pipes and valves arranged for quickly overhauling them.

On each side of the vessel, and running nearly the length of the engine department, there is a main drainage pipe of 2½ and 3 inches diameter leading to the feed tanks, into which the condensed water from all traps is delivered. This pipe also has a branch to a sea valve in each engine room.

Revolution Counters and Indicators.—In each engine room there are two revolution counters of the continuous rotary type, one having a reciprocating motion, the other worked through gearing from the main shaft; the same gearing operates two revolution indicators for indicating the speed of both main shafts, one being located in the opposite engine room.

Steering Engines and Gear.—Located in the after part of the ship, well below the protective deck, is a horizontal, self-controlling, double cylinder, simple, combined hand and steam steering engine of Williamson Bros.' patent, with cylinders 13 inches diameter and 10 inches stroke. The power of the engine is transmitted to a chain drum by cut worm gearing of the Albro Hindley patent. The drum is fitted with positive clutches and is made to fit corresponding clutches on the worm wheel for the transmission of the engine power from the worm wheel to the drum. Automatic gear is fitted on the engine and is operated through a cut spur gear.

When steering by steam, a clutch detaches a spur pinion on the automatic shaft, so that this pinion automatically closes the steam valve. When steering by hand, the drum is screwed out of contact with the clutches on the worm wheel, and the clutch on the automatic shaft is thrown into contact with the spur pinion.

The engine is capable of putting the helm hard over from amidships in ten seconds, when the vessel is steaming at a speed of 17 knots. It can be operated either at the engine, from the conning tower, the pilot house, the bridge or the superstructure deck.

Steam Capstan and Windlass.—On the main and superstructure decks forward, there is fitted a steam capstan and windlass, built by the American Ship Windlass Company, Providence, R. I. The capstan is so fitted that by means of it the windlass can be worked by hand, or the capstan may be entirely disconnected from the windlass. The engine for driving the windlass is double cylinder, vertical, direct acting simple, and is fitted with reversing gear. The diameter of the cylinders is 12 inches, and the stroke 12 inches.

The windlass is fitted with two wild cats, each fitted so as to be easily thrown into and out of gear by a locking device, and controlled by a friction brake, the levers of the brake and locking device being arranged to be within reach of one person.

The windlass is capable of raising both bower anchors at the rate of six fathoms per minute with steam of 80 pounds pressure, and of exerting an aggregate stress of 280,000 pounds on both bower chains with steam of 130 pounds pressure at the boilers.

Winches—There are in all five double-cylinder, reversible steam winches: two boat winches of 4 tons capacity, cylinders 5 by 6 inches, located in the central compartment on the berth deck; two coaling winches, 5 by 8 inches, located on the superstructure deck, and one special reversible winch of 14 tons capacity for hoisting the torpedo boats, cylinders 7 by 8 inches, located on the after part of the middle superstructure deck.

Engineers' Workshop.—This is located in the middle compartment on the starboard side of the protective deck, and is fitted with a vertical, single cylinder engine, 5 by 6 inches, for driving the workshop tools, which comprise

One completely fitted 16-inch and 32½-inch swing, back-geared engine lathe, with gap of 18 inches length, with range of screw cutting of 1 thread in 2½ inches to 36 threads to 1 inch;

Also, one 12-inch swing, back-geared engine lathe, complete, with screw cutting gears for cutting from 3 to 40 threads to the inch, with additions of patent variable feed, giving a range from 28 to 260 cuts per inch;

Also one 15-inch traverse hand and power shaping machine, fitted with swivel chuck arranged to be fastened to either the face or angle plates, and having all the adjustments of a first class machine;

Also one double geared hand and power drilling machine, geared for variable speeds, to drill holes from ⅛ inch to 2 inches.

Distilling Apparatus.—Consists of two Baird vertical coil evaporators, and two Baird No. 3½ double coil distillers, having a combined capacity of 5,000 gallons of potable water per 24 hours. The evaporators are connected with the port main condenser for supplying the waste of water from the boilers.

There is a No. 7 Davidson light service pump, 7 by 7 by 10 inches, for circulating the cooling water through the distillers, the water, after leaving the distillers, being discharged either directly overboard or into the flushing pipe leading forward to the officers' and crew's water closets. By-pass pipes and valves are fitted for discharging directly into the flushing pipes when the distillers are not in operation.

There are also two Davidson pressure pumps, 3½ by 2 by 4 inches, one to draw from the sea for feeding the evaporators, and one to draw the condensed water from the evaporator coils and deliver into the auxiliary feed pipe. These pumps are also arranged to draw from the evaporator shells and deliver overboard, and from the distillers and deliver into the feed pipes. There is one Davidson special pump, 2¼ by 4 by 3 inches, to draw from the filters only and to deliver into the ship's tanks only.

Wash Room Pump.—In the forward boiler compartment there is a No. 00 Blake pump, 3 by 1¾ inches, connected to draw from the main feed suction pipe and the wash water tanks in the forward fire room, and to deliver into these tanks and into a tank in the firemen's wash room.

Electric Plant.—The generating plant consists of two independent, vertical, double-cylinder, simple and direct-acting engines, cylinders 13½ inches diameter and 6 inches stroke, each capable of developing 52 mechanical horses power with a steam pressure of 60 pounds per square inch.

The armatures are carried on an extension of the engine shafts, and are Gramme rings, smooth core, with stranded, twisted conductors for the purpose of breaking up eddy currents.

The field is four-pole compound wound, with a frame of low steel, allowing a high magnetic density. The commutators are cross connected for two copper gauze brushes.

The dynamos are designed to develop 400 amperes at 80 volts full load, at an armature speed of 400 revolutions per minute with an allowance of 2 per cent. variation of this speed, or any change from full load to 20 per cent. of the same, or 5 per cent. on changing from no load to full load, or the reverse. This regulation is obtained by means of a fly-wheel governor varying the point of cut-off. The electric efficiency is 82 per cent.

The above plant furnishes power for 500 16-candle power incandescent lamps, four search lights (two of 60,000 to 70,000 candle power, and two of 80,000 to 90,000 candle power), and for one 2-horse power motor for the ventilation of the dynamo compartment.

Dimension of space for each engine: Length, 9 feet; width, 4 feet; heighth, 5 feet 8 inches.

To provide against disablement from water entering the cylinders and chests, this plant has been fitted with separate independent steam pipes, extra stop valves on the boilers, centrifugal separator with traps and drains in each branch steam pipe to the engines, and swinging check valves in each exhaust pipe.

Hydraulic Plant.—There is an hydraulic pumping plant for each turret to supply water for revolving the turrets, hoisting ammunition, and for loading and working the guns, in elevating and depressing them to range. Each plant is located beneath the protective deck, well below the water line, and consists of two horizontal Blake duplex, double outside plunger pumps, making four such pumps in all. The pressure pipes of the two plants are so connected that each set of pumps can be used on either or both turrets.

There is a steam hydraulic accumulator, consisting of a steam cylinder and a water plunger so connected with the pumping engines that the movement of the steam piston and plunger actuates the throttle valves of the hydraulic pumping engines, suitable levers and connections being provided so that the throttle valves may be adjusted to the working conditions of the plant. There are no valves in the accumulators except a stop valve for shutting off steam when the plant is not in use.

Particulars of Each Pumping Plant.—

Steam cylinders, number	2
diameter, inches	20
stroke, inches	12
Water plungers, number	4
diameter, inches	6
stroke, inches	12
Accumulator, steam cylinder, diameter, inches	30
water plunger, diameter, inches	10
stroke, inches	34

The combined capacity of the pumps for each turret is 550 gallons per minute at a pressure of 600 pounds per square inch, this specified duty to be performed with 100 pounds steam pressure at the pump throttle. The piping conveying the water under pressure is of wrought-iron screwed into wrought-iron flanges, each pair of flanges having annular recesses and corresponding projections, both of which are corrugated, the joints being made perfectly tight by a thin gasket of lead.

The water under pressure, after leaving the accumulators, passes up into the turret by means of a center tube, surrounded by an "all round" connection, from which branches lead to the various hydraulic cylinders used for operating the guns, and also to a reversing valve for the hydraulic engines that revolve the turrets.

Turret Turning Engines.—There are two hydraulic turret turning engines in each turret, placed in opposite positions and each driving a pinion gearing into an internal circular rack, permanently fixed to the vessel. Each engine consists of three single-acting, vibrating hydraulic cylinders, fitted with hydraulic packed plungers, each 8 inches diameter and 10 inches stroke, which revolve a vertical crank shaft fitted with the pinion which meshes into the circular rack.

The valve chest is placed directly and centrally over the crank shaft, and is connected with each cylinder by the pipe through which the water is conducted to the cylinders. The valve chest consists of an outer casing with water passages and ports, fitted with a conical distribution valve which is driven by and revolves with the crank shaft of the engine.

This valve is held in its seat by a spring which may be adjusted so as to relieve the valve from extraordinary pressure. Equalizing plungers which will yield to any variation in the volume of the water, and which will also act in the same capacity as air chambers in preventing water ram in the pipes, have been provided upon each of the pipes connected with the engines. The rotation of the turrets and the operation of the guns are readily controlled by hand wheels and levers placed at the sighting stations within the turrets.

Torpedo Boats.—Forming a part of the complement of boats for this vessel are two torpedo boats, the design of which was prepared by the Navy Department, that for the hull by the Bureau of Construction and Repair, and that for the machinery by the Bureau of Steam Engineering.

The general dimensions of the hulls are:—

Length over all, feet and inches	61–8
on load water line, feet and inches	58–6
Beam at water line, feet	9
Freeboard, feet and inches	2–5
Draught, mean, feet and inches	2–2
extreme, feet and inches	3–3
Displacement (about), tons	14 8

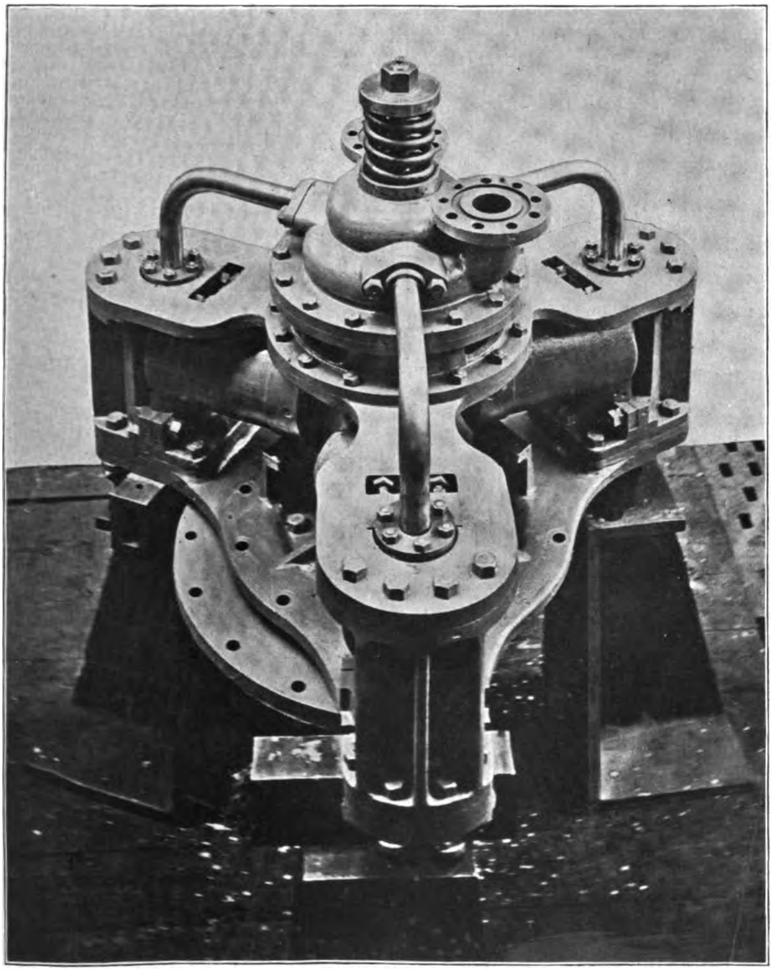
The hulls are of steel, the outside plating worked flush, with seam strips on the outside. The decks are of steel plate covered with linoleum.

In addition to the torpedo armament, which consists of a bow tube for discharging an 18-inch Whitehead torpedo, each boat is provided with a 1-pounder rapid-fire gun.

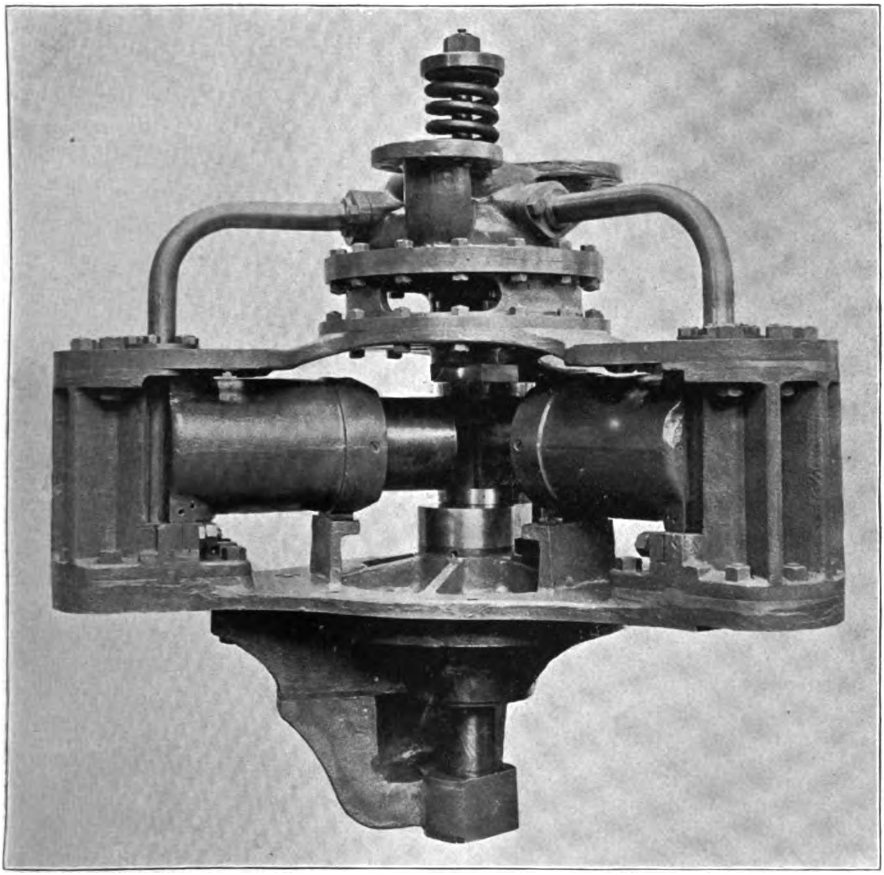
There is one engine of the quadruple expansion type working a single screw; it is vertical, inverted, direct-acting, with the cylinders placed in order of size over the shaft, the high pressure cylinder being forward. The cylinders are 6, 8$\frac{3}{8}$, 11$\frac{3}{4}$ and 15$\frac{3}{4}$ inches in diameter with 8 inches stroke of piston; they are fitted with one piston valve each, except the low pressure, which has a double ported slide. The high pressure valve is made without rings, but the other piston valves have broad adjustable rings. All the valves are worked by three Stephenson links, the two forward valves being operated by the same link.

The shafting is forged, of mild, open-hearth steel, and is hollow, 3 inches diameter with a 2$\frac{1}{4}$-inch hole through it. The crank shaft is in one piece, with the cranks of the high and first intermediate pressure cylinders opposite each other, and those of the second intermediate and low pressure also opposite each other and at right angles to the first two. The framing of the engine, and the working parts generally, are of forged steel.

The condenser, 15$\frac{3}{8}$ inches in diameter, is made entirely of



Turret Turning Engine.



Turret Turning Engine.

composition and copper, and has a cooling surface of 150 square feet. The tubes, which are ⅝ inch in diameter, have an exposed length of 5 feet.

The air pumps are two in number, double-acting, of the Bailey type, previously described in the JOURNAL, and are worked by gearing off the forward end of the crank shaft.

The circulating pump is of the centrifugal type, driven by an independent engine with steam cylinder 2 inches in diameter, and 1½ inches stroke, the diameter of the pump runner being 8¾ inches. The circulation of water through the condenser, when going ahead or astern is maintained by means of scoops over the injection and outboard delivery openings.

There is in each boat one Mosher water-tube boiler, designed for a working pressure of 250 pounds per square inch. It consists of two steam drums placed above two water drums, and connected with them by 440 generating tubes of drawn steel, one inch in external diameter and No. 15 B. W. G. thick, so arranged as to form an arch over the grate, and connected so that the boiler is practically divided into two parts. The steam and water drums are further connected at the front end by return pipes, 4-inch pipe size. The water drums are of special tubes, 8-inch pipe size.

Each boiler has a single furnace with two furnace doors.

The smoke-pipes, two for each boiler, are placed far enough apart on opposite sides to allow the torpedo boom to be rigged out between them.

The sides and top of the boiler are encased and protected by asbestos, ½ inch thick, hair felt ½ inch thick, and by galvanized sheet iron No. 24 gauge, cleaning holes being provided in the casing so as to get at all parts of the tubes with brushes or cleaners.

The forced draft system consists of one blower discharging into a closed fire room.

The main feed pump is located in the fire room, and there is a smaller auxiliary feed and bilge pump in the engine room arranged to deliver into the main feed pipe. There are two fresh water tanks of a combined capacity of 90 gallons.

The grate surface in each boiler is 13.12 square feet, and the heating surface 517.8 square feet.

Steam Cutters.—There are two steam cutters, one 33 feet, and the other 28 feet long. The engine of the 33-foot boat is Type G, Bureau of Steam Engineering design, compound, with cylinders 4 by 8 by 6 inches, and was built at the Portsmouth Navy Yard. The boiler is of the Towne type, size A, and has 6.5 square feet of grate, and 150 square feet of heating surface.

The engine of the 28-foot boat is type B modified, Bureau of Steam Engineering design, compound, with cylinders 3½ by 7 by 6 inches, and was built at the Navy Yard, New York. The boiler is of the Towne type, and has 6 square feet of grate, and 107 square feet of heating surface.

Both cutters have keel condensers, independent combined air and feed pumps, and duplex feed pumps.

WEIGHT OF MACHINERY.

The propelling machinery, including engines, boilers and appurtenances, fixtures in engine and fire rooms, smoke pipes, ventilators, distilling apparatus, tools in workshop, heating apparatus, and water in boilers, condensers, pumps, pipes and stern tubes, but not including stores, spare parts, capstan, windlass, turret turning gear, steering gear or winches, is 891.92 tons.

The important detailed weights are:

	Pounds.
Bed plates, shaft bearings, brasses and caps	41,808
Thrust bearings	8,702
Stern and bracket bearings	13,543
Engine framing and crosshead guides	25,617
Cylinders, covers, relief and starting valves, etc	160,673
Pistons, with rods, crossheads and nuts	31,477
Connecting rods and journal brasses	16,751
Valves, stems and crossheads	10,348
Rock shaft, arms and links	6,724
Main links, eccentric rods and straps	9,751
Crank shafts and eccentrics	31,106
Thrust shafts	11,629
Propeller shafts	44,313
Propellers	35,870

Reversing engines, shafts, arms, etc.	14.943
Separators, engine rooms	3.602
Separators, fire rooms	1,545
Feed tanks	5.436
Main condensers	43.746
Combined air and circulating pumps and connections	72,768
Centrifugal circulating pumps and connections	8,800
All sea valves and sea pipes	12,148
Main steam piping	20,512
Auxiliary steam piping	20.957
Main exhaust piping	13.757
Auxiliary exhaust piping	14.777
Working levers and gear	736
Throttle valve engines and valves	5.934
Engine room, fire and bilge pumps and piping	10,924
Turning engines and gearing	9,876
Engine room blowers and ducts	4.816
Fire room blowers and ducts	33.533
Drain pipes and traps	15.463
Clothing and lagging	39,620
Boilers and attachments	637,565
Smoke pipes and uptakes	83.763
Main and auxiliary feed pumps	8,564
Main and auxiliary feed pump piping	12,988
Boiler stop valves and gear	4.075
Safety valves and gear	4.776
Distilling plant	10,759
Workshop machinery	5,613
Steam winches	9,700
Steam windlass and capstan	46,893
Steering engines and gear	10,224
Ash-hoisting engines and gear	2,186
Fire main	6,785
Radiators and piping	12,314
Flooring, ladders and platforms	57.982
Ventilators and ash-hoists	14.337
Lubricators	3.341
Water in boilers	315.960
Water in condensers	13,910
Water in pumps and pipes	18,109
Water in stern tubes	979
Duplicates and spare parts	32,825
Water service	3.813
Hydraulic plant (estimated when completed, 43 tons)	95.530

LIST OF THE STEAM MACHINERY ON BOARD THE U. S. S. *MAINE.*

Main Engines.

		No. of Cylinders.
2	Propelling engines, vertical, triple expansion, . .	6

Main Engine Auxiliaries.

2	Combined air and circulating pumps, Blake, horizontal, compound; air pump cylinders (2 each) single-acting,	4
2	Centrifugal circulating pumps, vertical, ...	4
2	Main feed pumps, Blake, vertical, duplex, . . .	4
2	Auxiliary feed pumps, Blake, vertical duplex, . .	4
4	Forced draft blowers, Sturtevant, vertical, . . .	8

General Auxiliaries.

2	Fire and bilge pumps, Blake, horizontal, . . .	2
3	Ventilating fans, engine room, Sturtevant, vertical, .	6
2	Ventilating fans for ship, Sturtevant, vertical, . .	4
2	Dynamo engines, vertical, ...	4
4	Evaporator and distilling pumps, Davidson, horizontal,	4

Special Auxiliaries.

1	Steering engine, Williamson, horizontal, . . .	2
1	Capstan and windlass engine, American Ship Windlass Co., vertical, ...	2
2	Auxiliary pumps, Blake, fire and water service, horizontal, duplex, ...	4
5	Steam winches, American Ship Windlass Co., horizontal and inclined, ...	10
2	Ash-hoisting engines, Williamson, vertical, ...	4
2	Turning engines for main engines, vertical, . . .	4
2	Reversing engines, main engines, vertical, . . .	2
2	Throttle valve engines, horizontal, ...	2
4	Hydraulic outside plunger pumps, Blake, horizontal, duplex, ...	8
2	Steam hydraulic accumulators, ...	2
1	Wash water tank pump, Blake, horizontal, . . .	1

1	Workshop engine, vertical,	1
2	Torpedo boat engines, quadruple, vertical,	8
2	Torpedo boat feed and bilge pumps, Davidson,	2
2	Torpedo boat blowing engines, vertical,	2
2	Torpedo boat circulating pumps,	2
2	Torpedo boat feed pumps, Davidson,	2
2	Propelling engines, steam launches, compound, vertical,	4
2	Feed pumps, steam launches, horizontal, Worthington,	4
2	Air pumps, steam launches, horizontal,	2
1	Air compressor for torpedo tubes,	1
		119

OFFICIAL TRIAL.

The official trial for horse power took place on the 17th of October, 1894, in Long Island Sound. The *Maine* left her anchorage off New London Light at 12 Meridian, and proceeded out through the Race, and when off Watch Hill was turned and headed to the westward in order to make as nearly as practicable a straightway run for the four consecutive hours' trial required by the contract.

The trial began at 1.30 P. M., and ended at 5.30. The weather conditions were not very favorable, for throughout the entire run the ship was steaming against a strong head wind and sea, which increased in force to the end of the trial. The ship was remarkably steady, and at the maximum speed of the engines very little vibration was noticeable.

The speed was very accurately obtained for a portion of the trial, while running over the official measured course laid down for the trial of the *Ericsson.* The average speed for this 25-mile course was 15.95 knots, and with a mean allowance of 1.5 knots for the strong head wind and tide, the average speed of the ship was 17.45 knots.

The performance of the machinery throughout the trial was excellent. The main engines ran smoothly and without any heating of the working parts and main bearings. The combined air and circulating pumps worked uniformly and steadily, requiring no particular attention or adjustment at any time.

The performance of the boilers was highly satisfactory; there were no evidences of priming, and at a moderate forced draft they fully demonstrated their capability of furnishing all the steam required by the main engines and all auxiliaries as required by the contract.

The coal was selected Pocahontas, of good quality. That used during the official trial had been previously weighed and bagged, in order that the amount used during the trial might be accurately known.

After the trial the main engines, boilers, surface condensers and auxiliaries were examined and found in excellent condition.

DATA OF OFFICIAL TRIAL, U. S. S. *MAINE*.

Draught of water at beginning, forward, feet and inches	18– 2
aft, feet and inches	19– 1
at end, forward, feet and inches	17–10
aft, feet and inches	18–11
mean, for trial, forward, feet and inches	18– 0
aft, feet and inches	19– 0
Displacement at mean draught on trial, tons	5,500
Area of midship section at 18 feet 6 inches mean draught, square feet.	906
Wetted surface, square feet	21,850
I.H.P. (total) per 100 square feet of wetted surface	42.53
I.H.P. per 100 square feet of wetted surface at 10 knots in ratio of 3.5 power	6.0142
Mean speed, knots	17.45
Slip of screws, mean, per cent., starboard	12.805
port	10.205
$Speed^3 \times$ area immersed midship section $\div$ I.H.P.	518.26
$Speed^3 \times displacement^{2/3} \div$ I.H.P.	165.21

Synopsis of Steam Log.

	Starboard.		*Port.*
Revolutions of main engines per minute, mean	125.96		122.313
Piston speed, feet per minute	755.76		733.878
Steam at boilers, gauge		144.9	
engines, gauge	136.27		134.63
first receiver, absolute	67.70		66.33
second receiver, absolute	28.84		34.34
Vacuum in condenser, inches of mercury	23.875		22.839
Opening of throttle, tenths		10.	
Steam cut off in fraction of stroke from beginning, H.P.	.8		.8
I.P.	.7		.7
L.P.	.7		.7
Double strokes of combined air and circulating pumps,	51.55		42.444

	Starboard.		*Port.*
Temperatures in degrees Fahrenheit, steam at H.P. cylinder	364.0		363.4
Temperatures in degrees Fahr., injection		63.	
discharge	114.		99.5
hot well	127.3		127.3
feed	127.3		127.3
engine rooms, upper		146.	
lower		99.	
fire rooms, forward		127.	
after		134.	
Revolutions of blower per minute, main boilers		450.	
Air pressure in inches of water, ash pits		1.074	
furnaces		.92	
H.P. cylinder, mean pressure	54.372		53.656
I.H.P.	1,216.89		1,165.56
I.P. cylinder, mean pressure	20.907		19.597
I.H.P	1,218.35		1,108.94
L.P. cylinder, mean pressure	16.236		16.267
I.H.P.	2,261.75		2,200 00
Aggregate equivalent mean pressure on L.P piston	33.7175		33.0855
I.H.P. collective of each main engine	4,696.95		4,474.50
of both main engines		9,171.45	
of combined air and circulating pumps	28.25		24.593
collective of air and circulating pumps (2)		52.843	
of all forced draft blowers, (4)		38.068	
of main feed pumps, (2)		15.429	
of other auxiliaries		14.856	
of all auxiliaries		121.1962	
each main engine, air and circulating pump	4,725.20		4,499.093
both main engines, air and circulating pumps		9,224.293	
total of all machinery in use		9,292.646	
Indicated thrust, (I.H.P. main engines)		57,354.40	
per square inch of surface of thrust bearings		59.31	
Cubic feet swept per minute by L.P. piston, per I.H.P. of main engines	6.73		6.87
Square feet of H.S. per I.H.P		2.0462	
of cooling surface per I.H.P		1.5087	
I.H.P. of all machinery in operation, per square foot of G.S		16.1938	
I.H.P. per ton of propelling machinery, boilers and water		14.18	

Coal Consumption.

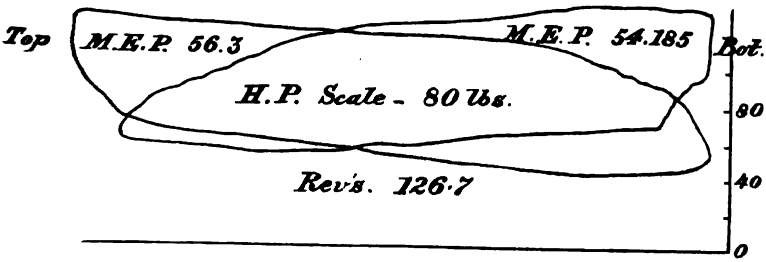
Square feet of G.S. in use	573.84
H.S. in use	19,015.36

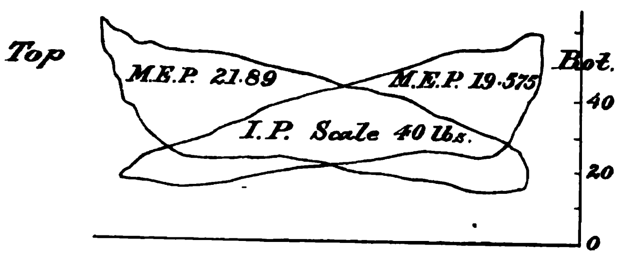
Kind and quality of coal used	Pocahontas, good quality.
Coal burned per hour, actual weight, pounds	20,272.
per square foot of G.S., pounds	35.327
H.S., pounds	1.066
per I.H.P. of all machinery, pounds	2.1815
per I.H.P. of main engines, air and circulating pumps, and feed pumps, pounds	2.194

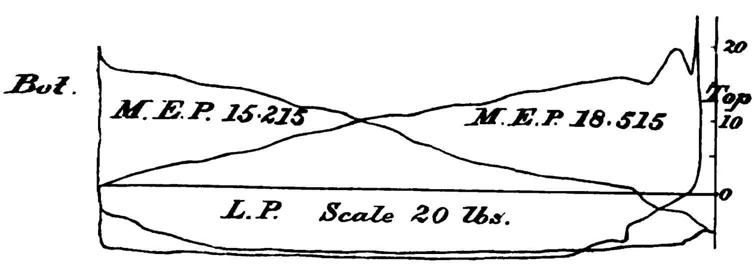
U. S. S. Maine.

Starboard Engine.

I. H. P. 4.823.3



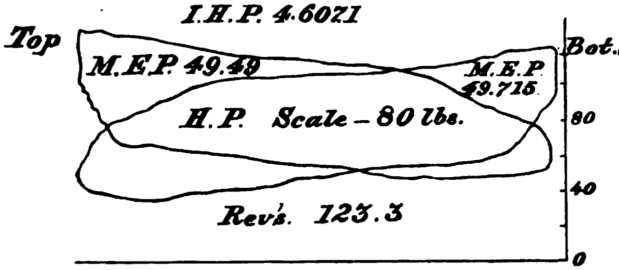


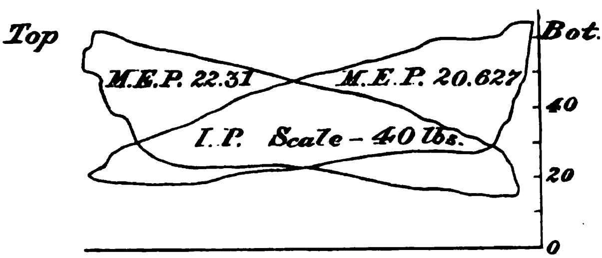


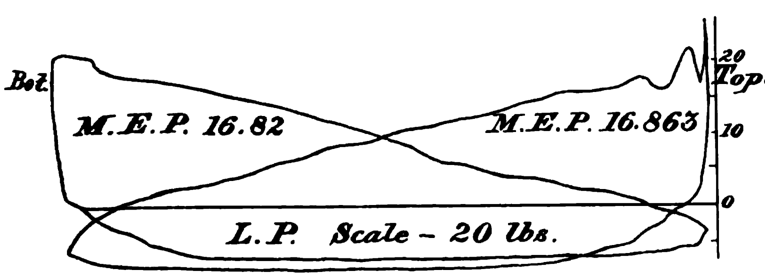
U. S. S. Maine.

Port Engine.

I.H.P. 4.6071



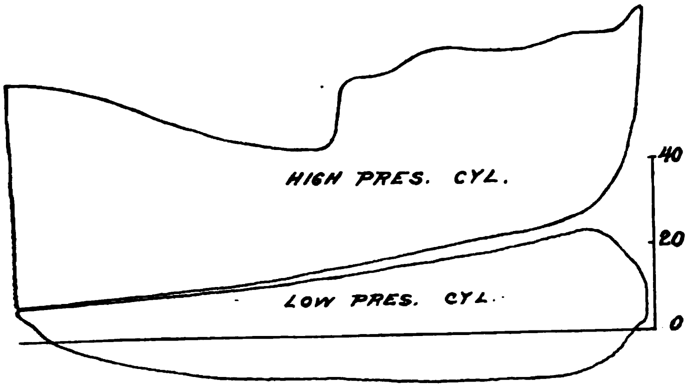




INDICATOR CARDS FROM BLAKE COMBINED AIR & CIRCULATING PUMP.

DOUBLE STROKES PER MINUTE 21

VACUUM IN INCHES $25\frac{3}{4}$



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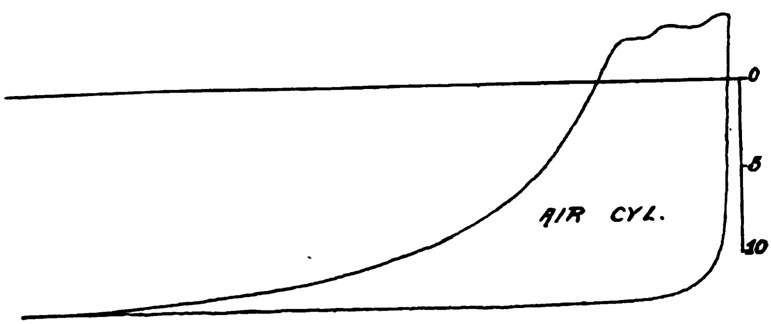
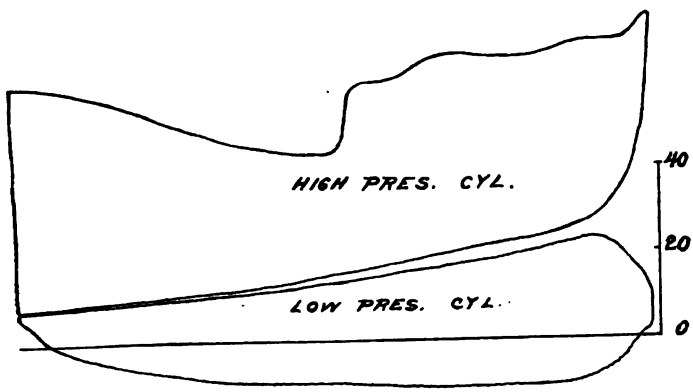


SCALE 10 LBS.

INDICATOR CARDS FROM BLAKE COMBINED AIR & CIRCULATING PUMP.

DOUBLE STROKES PER MINUTE 21

VACUUM IN INCHES $25\frac{3}{4}$



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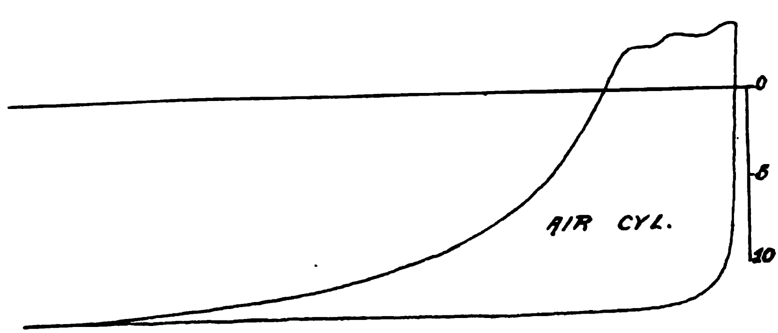


SCALE 10 LBS.

THE MODERN MARINE ENGINE, BOILERS, ETC.

A SERIES OF LECTURES DELIVERED AT THE NAVAL WAR COLLEGE, NEWPORT, R. I., SEPTEMBER, 1894.

BY PASSED ASSISTANT ENGINEER W. M. McFARLAND, U. S. NAVY.

LECTURE IV.—TRIAL TRIPS, ETC.

It is proposed in this lecture to say a few words with regard to the desirability of carrying out full power trials, and also with respect to the conditions that should govern a trial. It might seem at first sight, from the fact that trials are so universally enforced all over the world, that there could be no doubt of their value and importance; but a recent Congressional investigation based on the statements of a Washington lawyer attracted considerable attention to the point, and may have raised in the minds of many the question whether after all trial trips, as at present conducted, are of any great use, and whether they do not in fact subject the machinery to such severe stresses as to injure it and thereby reduce its usefulness for future service.

It is interesting to glance at some of the reasons which have led to the present contract requirements with regard to official trials. When the new Navy began, with the building of the Roach cruisers, the contracts specified the development of a certain horse power by the machinery, but fixed no penalty for failure to secure the stipulated amount, and provided also that if there was a failure to give the stipulated performance, and it was not due to defects of material or workmanship, the vessel should, nevertheless, be accepted. Most of you are probably familiar with the trouble in regard to the trials of the *Dolphin*, which failed by a small percentage to develop the required horse power. With our greater experience in running off trials at the present time, it is safe to say that a contractor at this day would never have let the question arise as to the success or failure of the vessel, because the amount which she fell short was so very small that, by a little more careful adjustment and more skill on the part of the men, the required amount could certainly have been reached. At all events, Secretary Whitney, who had just entered on his administration when the *Dolphin's* trials occurred, considered that the contracts had been rather loosely drawn, and when the first contracts were made during his administration the requirements were stated more carefully.

Mr. Charles H. Cramp, head of the well-known ship and engine building firm, has recently stated that, when these first contracts were to be drawn, Mr. Whitney called on a number of contractors, himself included, to see whether they were willing to submit proposals under the form of contract he had drawn. At first there was no provision for equitable settlement if the vessel failed to come up to the contract requirements, and the Secretary thought that, as the contract was worded, the ship would have to be rejected for even the slightest falling off. Of course, no contractor was willing to undertake to build a ship on any such proposition, and Mr. Cramp then proposed the same arrangement as had obtained in a contract between his firm and the Russian Government for building some vessels for that country, whereby, if the contract results were not entirely reached, there should be a certain penalty imposed for each degree of inferiority down to a certain point, when absolute rejection would ensue, and as a natural consequence of this penalty a premium was offered for results in excess of the contract requirements. This was so manifestly reasonable that it was at once adopted, and has since formed part of every contract made by the Navy Department for our new vessels.

When the first ships were contracted for during Secretary Whitney's term we had had no experience on this side in regard to the performance of very fast ships of modern type, and the contractors felt some hesitation in guaranteeing the high speeds which the vessels were expected to make, while they felt that with engines of given size and carrying a given steam pressure they could pretty safely guarantee the horse power. As a result, the contracts for the first seven or eight ships were drawn on the basis of horse power, with a penalty of $100 per horse power for falling below the contract requirements, and a premium of like amount for excess.

Two vessels, however, the *Philadelphia* and *San Francisco*, were contracted for on the basis of speed requirements not long after the first horse-power contracts, and after their trials had been completed all the later contracts were made on the basis of speed, the contractors feeling able to estimate pretty closely what vessels of given size and given power could do.

In the charges which were submitted by the Washington lawyer, and on which the Congressional investigation of the trial trips was based, it was alleged that the premium system was absolutely wrong, and that the speed of vessels could be predicted in advance within a very small margin. The testimony taken by the Naval Committee, however, showed that this was not the case, as such competent experts as the Engineer-in-Chief and the Chief Constructor of the Navy stated that it was absolutely impossible to predict the speed of a large fast vessel, unless very similar to another vessel which had already been tried, to within a knot. When a vessel was exactly similar in all respects to other vessels which had been tried, a very close approximation could, of course, be made to her probable speed. Attention was called also to the fact that in the case of the three sister ships, *Detroit*, *Montgomery* and *Marblehead*, there was a difference of as much as .6 of a knot between the highest and lowest, and no two came within .3 of a knot of each other. As these vessels were supposed to be identical in every respect, it shows, of course, how impossible it was to say in advance just what the speed would be.

Now, in regard to the plan of offering a premium, there is this to be said: The designers of a vessel might fix a speed which they believed to be just barely attainable without offering any premium, but necessarily providing a penalty for failure to reach it. The contractor in this case would see that he was very rigidly bound, and as a prudent business man, taking cognizance of all the chances in the case, would increase his bid correspondingly and allow for possible penalty for failure to reach the contract requirements. If, on the other hand, the contract fixes the speed at a figure which is known to be possible with good workmanship and reasonable skill in running off the trial, the contractor will lower his bid correspondingly. If, from his previous experience in building ships and machinery and running off trial trips, he has reason to think that he can pretty safely count on a higher speed than the contract requires, he will scale down his bid accordingly. That this is the case was shown conclusively in the experience of the Department with the building of the *Yorktown*, *Concord* and *Bennington*, and afterwards of the *Detroit*, *Marblehead* and *Montgomery*. When the *Yorktown* was contracted for, the horse power requirement was 3,000 with a premium, as already stated, of $100 per horse power. When the *Concord* and *Bennington* came to be contracted for with identical machinery, the horse power requirement was 3,400, it having been concluded in the meantime that the engines would readily give this amount. There was no doubt at all of securing 3,000 horse power, but the contractors all felt that 3,400 was very close to the limit, and, as a result, the contract price for these two later gunboats was $35,000 more than the contract price for the *Yorktown*. The *Yorktown* made nearly 3,400 horse power and got a premium of some $33,000, while the *Concord* and *Bennington* made just a little over 3,400 and got premiums of only about a thousand dollars. The net result to the Government in the total cost of the vessels was just about the same. In the case of the *Detroit*, *Montgomery* and *Marblehead*, when the vessels were first advertised the speed requirement was 18 knots, and the contractors all concluded that the vessels could not be built within the appropriation with this speed requirement. After careful consideration, the Navy Department re-advertised the vessels, simply reducing the speed requirements one knot. The speed premium in this case was $25,000 per quarter knot, or $100,000 per knot. The bids which came in under this second advertisement were just about $100,000 less than those which had been made the first time, because it was felt to be absolutely certain that the vessels would make over 18 knots, and consequently they were sure of $100,000 premium. The result to the Government was exactly the same as if the higher bids had been accepted the first time.

It may naturally be inquired, if the cost to the Government is about the same, whether the requirement is fixed at the maximum possible without any premium or at a lower figure with a premium, why is it not better to dispense with the premium system and simply fix the requirements at the highest attainable. To answer this requires an intimate acquaintance with all the conditions of ship and engine building and of running off trials, but it may be stated as a result of the experience of the ablest men who have looked into this matter that there is almost universal agreement that the premium system is the best.

It was remarked in an earlier lecture with regard to very high-speed machinery that in order to make a successful trial great care was necessary in the adjustment of the machinery. The same is true to a less degree with the trials of comparatively high-speed large machinery. To attain the maximum results there must be the greatest care used in workmanship and adjustment of all the parts, and great skill and ability displayed in running off the trial. We all know that at low speeds there is never any trouble from heated bearings or any other cause, because everything is running well within the capability of the machinery; but when it comes to pushing everything to the utmost to get the highest possible results, we are approaching the limit in all respects, and unless the greatest care and skill have been used the highest results cannot be obtained. Now all of these requirements involve the expenditure of considerable money, and unless the contractor has some prospective reward he is hardly likely to devote his time and money to securing high results.

As an example of the care required, it may be stated that one of our ships, not long since, went out on a preliminary trial and gave fairly good results. If there had been no premium involved, the trial would in all probability have been conducted within a short time; but it was evident to the skilled engineers who supervised the trial that the machinery was not absolutely perfect. Investigation showed that the main pistons were very slightly too large in diameter. This was not apparent when the engines were cold, as there was apparently sufficient clearance between the pistons and the cylinder, but under heat the expansion was not perfectly uniform and the pistons had come in actual contact with the cylinders. As a result of this, all the pistons were taken out and slightly reduced in diameter, which involved considerable expense, but the final results obtained fully justified this increased care.

The point has sometimes been raised that the full power forced-draft trials to which our vessels are subjected do not pay for themselves; that their results are not indicative of what the vessel can do under normal conditions, and that in fact the machinery is frequently overstrained. In the writer's belief, and this is confirmed by the most eminent engineers who have investigated the matter, this view is entirely erroneous. The machinery is designed to be perfectly safe under just these conditions of maximum stress, and although under the conditions of trial there is always more or less of a feeling of apprehension that something may go wrong, this is simply the feeling which is natural when the supreme test is put on any construction or upon any person. In all probability the repeated failures of English naval boilers under forced draft has had a great deal to do with this feeling that full-power trials bring undue stress upon the machinery; but the fact in this case seems to be that the design of the boilers was defective, in that too much was required of them. We have had no such experience with our boilers, although some have been subjected to very severe forcing; but, as has already been stated, when the machinery is properly designed there is absolute safety. What the trial does test most rigidly is the perfection of material and workmanship. Of course, if there are any defects in the machinery they are very thoroughly brought out, and we have had cases where some small part of the machinery happened to be defective, and this was clearly shown on the trial. It must be remembered, too, that as our contracts are drawn the contractors are responsible for the machinery until after the trial, and the trial must demonstrate that it is strong and well built. If any defects are developed by the trial the contractor has to make them good; consequently, when a trial has been run off and there has been no mishap of any sort, the Government has a right to conclude that the vessel can be relied upon when it is desired to repeat the performance through which she has gone. If no such trial were made, but the supreme effort was left for a time of emergency, there could be no assurance that when the emergency came the machinery could be relied upon to respond.

With regard to the remark sometimes made that the trial trip results cannot be duplicated in regular service, a complete denial can be made. The idea comes from the fact that full-power running is seldom employed because it is expensive, and that, in such cases as the *Charleston's* chase of the *Itata*, the conditions are not the same. It can be asserted with absolute certainty that, given the same conditions as obtained on the trial trip, the performance can be repeated at any time. In 1889 the *Chicago*, *Boston* and *Yorktown* gave better results with their regular crews than had been obtained on the trial trips.

In this connection, it may be remarked that we have cause to congratulate ourselves upon the fact that we have never had a trial trip which was a complete failure due to any accident to the machinery. Trials have been delayed in a few cases on account of some minor defect in some small part, but this was remedied almost immediately and the trial carried out to complete success.

Coming now to the question of the method of conducting trials, a good deal may be said. Where no question of premium is involved, and it is not necessary to determine the speed with great accuracy, it would be entirely unsatisfactory to determine the speed by the use of the patent log. Unfortunately, the patent log is entirely unreliable for accurate work. Instances could be multiplied without number to prove this, but it is hardly necessary to give specific cases because every officer knows the truth of this statement by experience. Runs over an accurately measured base naturally suggest themselves, but the question then arises as to what the length of this base should be. At one time English vessels were tried almost entirely on the measured mile, the speed being determined as the mean of a series of runs in opposite directions. When measured-mile trials are properly conducted the effect of the tidal current is practically eliminated, so that the speed thus determined is thoroughly accurate and reliable. The objection is that at high speeds the series of runs could all be made in less than an hour, and it would be perfectly possible to maintain a very much higher average speed for this short time than for a longer period. One way out of this difficulty is to increase the length of the course so that runs may be made over it in opposite directions, and the entire time occupied will be enough to insure results which can be considered average and not unduly high on account of the short duration. Unfortunately, when the course is lengthened the tidal current is not eliminated by runs in opposite directions, and it then becomes necessary to make elaborate tidal observations, which have to be applied to the observed speed to determine the true speed. This is the method which has been employed for all our ships except one, the Department taking the view that it is the most accurate method, although probably the most expensive. On the recent trial of the *Columbia* it required the services of eight vessels to determine the effect of the tide, and while in one sense it may be said that the expense was not great because these vessels were in commission anyhow, there would frequently be times when to get so many vessels together would require at least a considerable expenditure of coal, and might require their detention from more important service.

There are very serious objections to this method of determining the speed, however, because there is always some doubt as to whether the tidal corrections have been determined with absolute accuracy, and it is troublesome to lay off accurately as long a course as is required for two hours' run of a high-speed ship. But, even admitting the entire accuracy of the method, it is objectionable from the contractor's standpoint, for the reason that every variation which can possibly occur is against him. Nothing can possibly be in his favor. The ideal course would be one in which the tidal current is directly along the line of the course, but it is generally impossible to secure this absolutely, and, if the current is at an angle to the direction of the course, the rudder must be put over a certain amount, which increases the vessel's resistance and thereby diminishes the speed. If passing vessels get in the way, compelling a detour, the course is lengthened, but the contractor cannot get credit for this. Then, too, if fog should happen to set in when the trial was almost completed, so that the end of the course could not be accurately determined, the whole trial would have to be abandoned, notwithstanding the time, trouble and expense which had already been expended. This actually happened twice in the trials of the *Olympia*. The fog set in both times when the trial was within half an hour of completion.

Another method of conducting trials has been proposed, and was brought to the notice of the Navy Department by Engineer-in-Chief Melville, which is known as the standardized screw method, and sometimes called the *Bancroft* method, because it was used in determining the speed of the *Bancroft* of our own Navy. This is a combination of measured-mile trials with endurance trials. It consists in conducting a series of progressive trials over the measured mile at a series of speeds running from as high as the vessel will make down to any convenient moderate speed, and therefrom determining a curve showing the relation of speed and revolutions. The reason why it is necessary to determine this curve is because, as the speed increases the slip of the propeller increases, so that it requires rather more revolutions to make a knot at high speed than at lower ones. When this curve has been laid out the endurance trial can then take place anywhere, as no landmarks or buoys are necessary. The ship simply goes to sea in water sufficiently deep to insure no retardation due to shoal water, and the four hours' trial is run off. The total number of revolutions made in the four hours divided by 240 gives the average per minute, and from this the average speed for the four hours is at once determined.

There are a number of decided advantages inherent in this method. In the first place, the progressive trials on the measured mile enable data to be obtained which are of the greatest service to the designers of both hull and machinery, in securing the relation of speed and power through the entire range of the ship's performance. Then the endurance trial requires the services of no ship except the one which is actually being tried. The staff of observers which would be required for determining the engine room data on any other trial will be the same, and the deck observers will probably not be as numerous as in the trial over a longer course. From the contractors' standpoint there is the important advantage that it can be determined at any moment what the performance of the vessel is, as it is simply necessary to count the revolutions for a minute, when the speed is at once known. When the vessel is tried by the long-course method, the speed is not definitely known until after the trial has been completed and the tidal corrections worked out. There have been some cases where the contractors were subjected to great disappointment because the tidal correction proved much greater in amount than had been anticipated. From knowing at any moment what the performance of the vessel is, the contractors are enabled, if the performance improves steadily, to continue the trial beyond the four hours, and take any consecutive four hours for the vessel's performance. While this might enable them to earn a higher premium, the Government is also getting a ship which has been subjected to a more thorough trial than was required. There is still another great advantage to the contractors from the fact that if the trial takes place in a locality not in the line of passing vessels, fog need not interfere with the trial in the least. The speed can be maintained at the same point as was made before the fog set in, as the engine-room counters, on which the determination rests, can, of course, be seen just as readily as when the weather is clear. In case it became necessary to alter the course to avoid passing vessels or for other reasons, this would not operate to the disadvantage of the contractors, as the detour could be made to such a large circle that the helm need be scarcely put over at all, and the revolutions would be maintained the same as before.

It is probable that this method would have been adopted as the standard method for all our trials, were it not for the fact that some hesitation seems to be felt on the ground that the revolutions are not an absolute criterion of the vessel's speed. This is, of course, true under certain conditions, as, for example, the same number of revolutions, which in absolutely smooth water and without wind, would give a certain speed, would not give so high a speed in a rough sea with a strong head wind; but inasmuch as the measured-mile course can be laid off at sea, where the conditions would be practically identical with those under which the trial would be run, and as no contractor would ever run off a speed trial when the weather was bad, it is evident that this objection is imaginary rather than real.

Some years ago, when Chief Engineer Isherwood conducted an elaborate series of trials on the tug *Nina*, to test the Kunstadter steering propeller, he used a speed recorder, which consisted of a small propeller connected to a registering device by gearing, and rigidly connected to the ship's side amidships by struts. The propeller used was large enough to be more than the toy which the propeller of the patent log is, and by standardizing it at a moderate speed the indications would be the same for a knot at any speed. The only objection to this method would be the possible increase of resistance, at the high speeds of our modern ships, from the struts and the propeller when made of the size necessary to secure strength.

We may feel sure, in any case, that the speeds of our vessel which have been tried for speed, have been determined with very great accuracy, and we can depend upon the figures given. Recent trials in the English Navy have depended upon the patent log for the speed, so that no reliance could be placed upon the speed thereby indicated. In almost all our trials patents logs are used in addition to the other methods, and it is worth noting that in the recent trial of the *Columbia*, which was the fastest large vessel afloat at the time she was tried, the speed, as determined by accurate measurements over the course, was 22.8 knots, while the patent log reading gave her a speed of 24.34 knots. Of course, we claim only 22.8 knots, but when a comparison is made with fast vessels of the English Navy, the speed of 24.34 knots would be the one to use.

It is probable that the requirements of our full-power trials are sometimes regarded as very rigid, but it is interesting to compare with them the requirements of the French Navy. It has apparently been considered sufficient thus far in our trials to insist upon one thing at a time, and when the requirement was for speed nothing was said about horse power or the economy with which the horse power is obtained. In the French trials, however, not only is a particular speed insisted upon, but that under full power the horse power should be obtained with a certain coal expenditure. Their trials at more moderate speeds are also coupled with conditions for economy of coal still more rigid. As these trial requirements are quite interesting, I have had a copy made of a translation which appeared recently in the "Journal of the American Society of Naval Engineers," and which is as follows, being from the contract for machinery of 8,000 I.H.P.

TRIALS.

After the contractors are satisfied that the machinery is in readiness, it will be inspected and tested in their presence by a commission.

This commission will make all the tests that it deems necessary, with all or a part of the fires lighted, to determine that the boilers are well made, that the feed is abundant, and that the various parts of the engines work with the ordinary means of lubrication from oil and water, regularly and without heating of sufficient intensity to demand a continuous use of sea water even at the maximum speed.

The commission will ascertain that each of the main engines can be driven by the steam from any one of the boilers; that the stoppage of the air and circulating pumps of one of the main engines will not prevent the working of both of the main engines at a slow speed, and that the brakes are sufficient to hold the screws while the engines are being coupled and uncoupled.

It will also ascertain that each of the circulating pumps can, in less than sixty seconds after the order is given, take water directly from the bilge and discharge it into the sea in the quantity specified in the contract; that this manœuvre shall be made without any possible hesitation, by one man only, from the upper platform of the engines, and without there being any chance for connection between the sea and the bilge.

The commission will also ascertain that the tools and spare parts delivered conform in size, quality and quantity to the provisions of the contract, and that similar pieces are interchangeable. It will ascertain by repeated trial that, by means of the hand reversing gear, the engines can be started ahead in less than forty-five seconds, and that, upon the order to reverse, the engines can be backed in less than ninety seconds, although they might have been going at full speed ahead. The same thing must be true in going ahead from backing. With the steam-starting gear these manœuvres must be capable of execution without hesitation, by one man, in one-third of the time specified for the hand gear—that is, in fifteen or thirty seconds.

The commission will also ascertain that, with the valves sufficiently closed, and with the normal vacuum in the condensers, the engines are able to maintain a normal speed of less than thirty revolutions per minute.

After these examinations, the following trials will be conducted, for each of which the vessels shall be, as nearly as possible, at the designed load water line.

1st. Trial for coal consumption and good working at 8,000 I.H.P., under natural draft, with twenty-four boilers; duration, twelve hours. For this test the engine will work triple expansion, and all the boilers will be in use. The pressure at the boilers is not to exceed 17 kilos (242 pounds per square inch), and that at the reducing valve 12 kilos (171 pounds per square inch). The firing will be done with natural draft. The point of cut-off, which must be maintained at the same point during the whole of the trial, is to be regulated by the contractors so as to develop 8,000 I.H.P., the speed of the main engines not to exceed 125 revolutions per minute.

In case it should be necessary to change the screws, in order to obtain 8,000 horse power without exceeding the 125 revolutions, this change is to be made at the expense and risk of the contractors.

The consumption of coal measured for six hours at the beginning of the trial must not exceed one kilo (2.2046 pounds) per horse power per hour. If it exceeds $1\frac{1}{10}$ kilos (2.425 pounds), the machinery may be rejected. If the consumption is less than one kilo, there will be a premium of 400 francs for each gramme (0.0022 pound) below one kilo.

2d. Trial of power under forced draft with twenty-one boilers for four hours. The engines will be worked triple expansion, and twenty-one boilers will be in use. The pressure in the boilers is not to exceed 17 kilos (242 pounds per square inch), and that at the reducing valve 12 kilos (171 pounds per square inch). The combustion will be by forced draft obtained by jets of steam in the chimneys.. The cut-off in the cylinders must remain constant during the whole trial, and will be regulated by the contractors so as to develop 8,000 I.H.P. If, during this trial, which shall last during four consecutive hours, the total power of 8,000 I.H.P. is not obtained, there will be a penalty of 100 francs for each horse power lacking.

3d. Trial at maximum power, lasting four hours. For this trial the engines will work triple expansion, and all the boilers will be in use. The pressure in the boilers is not to exceed 17 kilos (242 pounds per square inch), and at the reducing valves 12 kilos (171 pounds per square inch). The stop valve shall be opened wide, and the cut-off will be at the latest point. Forced draft will be used, and the firing will be pushed as much as possible, so that the engines may develop all the power possible, without, however, the combustion exceeding 170 kilos per square meter (34.8 pounds per square foot), of grate surface.

During this trial, which is to last four consecutive hours, the working of the machinery is to be entirely satisfactory in every respect.

4th. Trial of good working and of coal consumption at 5,000 horse power, duration twenty-four hours. During this trial all the machinery will be in operation, and as triple expansion. The fires will be under natural draft.

Only eighteen boilers will be used. The pressure in the boilers and the point of cut-off at the engines will be regulated by the contractors, so as to develop a collective horse power of 5,000.

The cut-off must remain constant during the whole of the trial. The coal consumption during the entire trial must not exceed 850 grammes (1.874 pounds) per I.H.P. per hour.

If the consumption exceeds 850 grammes, there will be a penalty of 800 francs for each gramme in excess. If it exceeds 950 grammes (2.094 pounds), the machinery may be rejected.

If it be less than 850 grammes, the contractors are to receive a premium of 800 francs for each gramme below 850.

This trial of twenty-four hours shall include a period of six consecutive hours, taken either at the beginning or at any particular time during the trial selected by the contractors, during which there was no cleaning of the fires, and for these six hours the consumption of coal per horse power must not exceed 800 grammes (1.764 pounds). If the consumption during these six hours is in excess of 800 grammes, the contractors will be under a penalty of 400 francs for each gramme in excess.

If it is less than 800 grammes, there will be a premium of 400 francs for each gramme below. The premiums and penalties for these two trials of twenty-four and of six hours will be added.

5th. Consumption trial at 2,000 horse power, lasting six hours. For this trial all the machinery will be in operation, and at triple expansion. The number of boilers to be used and the pressure to be maintained will be determined by the contractors and notified to the commission at the beginning of the trial. The fires will be worked under natural draft. The cut-off will be determined by the contractors, but must remain constant during the whole trial. The coal consumption during this six-hour trial must not exceed 850 grammes (1.874 pounds per I.H.P. per hour. If it exceeds 850 grammes, the contractors will be under a penalty of 1,600 francs for each gramme in excess. If it exceeds 950 grammes the machinery may be rejected.

If it is less than 850 grammes there will be a premium of 1,600 francs for each gramme below.

6th. Various supplementary trials. Besides the trials above specified, the commission may make any supplementary trials they may deem desirable, with either forced or natural draft, and with the engines working together or separately, in order to determine the results which it is possible to obtain in the various cases, all of which trials shall be made without any additional compensation to the contractors.

During these trials the contractors will be responsible for the good working of the machinery, but whatever the results obtained, there shall be no penalty.

7th. Conditions applicable to all the trials. In the different trials the throttle valves will be wide open. The cut-off will be regulated to the degree necessary to obtain the desired power, and the boiler stop valves will not be partially closed unless this is found to be absolutely necessary to prevent foaming.

The mean revolutions during the trials will be deduced from the observations made at the counter and clock of each engine at the beginning and end of each trial, taking account, if necessary, of the errors in the clocks used.

During the trials the vessels must, as nearly as possible, be steered in a straight line, and the helm will be used as little as possible. When it is necessary to change the course, it will be done to a curve of a large radius.

In each of the trials for power and coal consumption, indicator cards will be taken every twenty minutes, from each of the cylinders of the main engines and air and circulating pumps, and at the same moment the number of revolutions of each engine will be noted.

The commission will not be required to take indicator cards from the other auxiliaries; it will determine previously the horse power of each of these engines for various speeds on the trial, and will take as the horse power developed the figure corresponding to the mean revolutions, as obtained from the counter attached to each engine during this trial.

To determine the total horse power developed during the trial, it will be calculated from the various observations obtained, based on the mean revolutions, throwing out such observations as are manifestly erroneous. In making this determination, the power will be assumed to vary according to the following exponent of the revolutions: For the main engines and the blowers, as the cubes of the revolutions; for the other auxiliaries, directly as the revolutions.

The horse power required by the contract will consist of the sum of the powers developed by the cylinders of the following machines: the two main engines, the two engines for the air and circulating pumps, the eight feed pumps in the fire rooms, and the two engine-room ventilators.

No account will be taken of the power developed by the steam jet in the chimney during the forced-draft trials.

In the trials for coal consumption the total amount of coal burned will be measured with the utmost care. In determining the premiums and penalties for excess or deficiency of power or coal consumption, no account will be taken of fractions of a horse power or of a gramme of coal.

In all trials, and until the vessel is received by the Government, the contractors are responsible for the machinery, and are to execute all the manœuvres and trials demanded by the commission and the officers on board.

During the trials the steam for the starting engines, bilge pumps, ash hoists, dynamos and other auxiliary engines, whose employment will be only what is absolutely necessary, will be furnished from the main boilers.

Account will be taken in the calculations for coal consumption of the amount of coal required for these small engines, but the horse power developed by these engines will not be taken into account in calculating the contract horse power of the motive machinery.

In discussing this matter of high speeds it is very natural that comparisons should be instituted between the performance of our war vessels and of the fast steamers in the merchant service, and at the very outset it is important to recognize that the vessels of the merchant service possess an inherent advantage over war vessels from their greater size. It has long been known that one of the important features for high speed was length, and for some years past the fastest vessels of the merchant service have all exceeded 500 feet in length, while it has been a rare thing for a war vessel to attain a length of even 400 feet, which is the length of the *Columbia*. Besides this, there is an absolute economy of propulsion due to mere size. This is expressed scientifically in what is known as Froude's law of comparison, which was also expressed somewhat differently, but to the same effect, earlier by a distinguished French naval architect named Reech. Some years ago the late Mr. William Denny, a most progressive and capable English naval architect, in lecturing on this point of the size of vessels, expressed this law in familiar language, as follows:

"What Mr. Froude discovers amounts to this: That for vessels of the same proportionate dimensions and of the same form, or, as we say, of the same lines, there are speeds appropriate to these vessels which vary as the square root of the ratio of their dimensions, and that at these appropriate speeds the resistance will vary as the cubes of these dimensions. This seems at first sight a very complex statement, but a simple illustration will show you better the meaning of it than any amount of exposition. Supposing we had two steamers of the same form, the one 100 feet in length, 10 feet in breadth and drawing 5 feet of water; the other 400 feet in length, 40 feet in breadth and drawing 20 feet of water. Then the ratio of the dimensions of the larger steamer to that of the smaller one would be as 4 to 1. This will be apparent when you notice that the length, the breadth and the draught of water of the smaller steamer is in each case one-fourth of the length, the breadth and the draught of water of the larger steamer. What Mr. Froude would have predicted of these two steamers is that if the speed of the smaller steamer were 10 knots, then the similar appropriate speed of the larger steamer would be 20 knots, because the square root of 4, which is the ratio of their dimensions, is 2, making the appropriate speed of the larger steamer twice that of the smaller one. At these speeds Mr. Froude proved that the resistance would be as the cube of the steamer's dimensions, which means practically that the resistance would vary as the displacement of the two steamers; therefore, by making the one steamer four times as long as the other, keeping the form and proportions otherwise the same, you could double the speed of the larger steamer without having any more resistance per ton of her weight than in the smaller steamer.

This law shows us further that the resistance of the large steamer at the same speed as the smaller one would be per ton of her displacement, or total weight, very much decreased. Thus in the same type of steamer, by simply increasing all the dimensions proportionately, the same speed can be obtained with much less resistance per ton of weight driven through the water; then, since the speed remains unchanged, much less expenditure of horse power, and consequently much less expenditure of coal per ton of weight driven. Judging from one case which I have taken, the resistance per ton of displacement at 10 knots of the 400-foot steamer, would be only one tenth of the resistance per ton of displacement of the 100-foot steamer. (That is, 10 tons of displacement of the larger steamer could be driven for the same power at the same speed as one ton of the smaller steamer.)"

The importance of this point will be noticed in comparing, for example, our *Columbia* with the fast Cunard steamers *Campania* and *Lucania*. Her displacement on trial was about 7,350 tons, while their displacement is 18,000. As already seen from the quotation is regard to Froude's law, the power required to drive a ton is less for the larger vessel, so that to secure the same speed there would be a smaller power in proportion to the size of the ship. It is to be noted, also, that in any vessel the structural requirements of the hull require a certain amount of weight, so that the proportion of the total displacement which can be given up to machinery and coal is limited. The *Columbia* made nearly 23 knots on about 18,000 horse power, while the *Campania* and *Lucania* are said to have made 22 knots on nearly 30,000 horse power. In the one case we have more than two horse power per ton of displacement, or, to be exact, 2.45, while in the other we have only 1.66. The space available in the war vessel being much less than in the merchantman, we are compelled to adopt types of machinery and boilers which are less economical than those which can be fitted to the merchant vessel, and the amount of coal which can be carried is enormously less in proportion. The coal bunkers of the *Campania* will carry 3,500 tons, and the coal expenditure at full power (25,000 I.H.P.) is about 500 tons per day, while in the *Columbia* at full power

21,000 I.H.P.) the coal expenditure would be about 520 tons per day. As the bunker capacity of the *Columbia*, even when she is loaded down to her deep draught and displaces 8,600 tons, is only 2,000 tons, it can be readily seen why long-distance steaming at full power is out of the question.

In connection with the comparison of speeds between war vessels and fast merchant steamers one very important fact is to be remembered. The speed for the war vessel is the actual speed through the water, the effect of current being eliminated. On the other hand, the speed of the merchant vessel is the distance made in a given time with no allowance made for current. Now, it is worth noting that the phenomenal speeds of the fast Atlantic steamers are always made on the western trips, and the big days' runs always in the same part of the trip. For about two days of the western trip, there is a favoring current which amounts, at times, to as much as a knot an hour, and it is for this portion that the big speeds are made. Had the *Columbia's* trial consisted of a run over this locality, her already remarkable speed would have been still more so.

It has already been stated that the type of engines and boilers in use in the merchant service give greater economy of fuel than those which we are compelled to use in war vessels. This matter was discussed very fully by the Engineer-in-Chief in one of his reports a few years ago, and was also touched upon by Professor Hollis, and as the matter is highly interesting and also tends to clear up a matter which is not always well understood by those who have not had time to investigate it carefully, I shall here quote from the Engineer-in-Chief's report. His remarks are as follows:

"While on this subject of coal economy, it may not be amiss to say a few words to clear up an impression, which seems to exist to some extent, that our vessels are decidedly uneconomical as compared with those of the merchant marine in ordinary cruising, and it is pointed out that our vessels need re-coaling after short runs, while the merchant steamers make long continuous voyages. It is frankly admitted that our machinery is not as economical, but from the nature of things it cannot be.

The circumstances of the two services are entirely dissimilar. The economical merchantman has small engines and boilers for a large hull, while our ships have powerful machinery for small hulls. This machinery must be built to develop the maximum power which will ever be required, while ordinary cruising is done at a fraction of this power, a circumstance which is inimical to economy.

"An interesting comparison of the conditions of the two cases is furnished by the *Baltimore* of our own Navy and a merchant steamer called the *Iona*, which have about the same displacement, 4,450 tons. The *Baltimore's* machinery develops 10,000 I.H.P.; that of the *Iona* 700 I.H.P. The *Baltimore* has room for only 17,000 square feet of heating surface in her boilers, with a ratio to grate surface of less than 30, while for the *Iona* the figures are 3,160 and 75. The *Iona* works always at full power and secures a speed of 8½ knots; for this same speed the *Baltimore* would require more power on account of the friction of the enormously larger engines. But the great economy is in the boilers. With the enormous amount of heating surface for the power developed, the *Iona* can evaporate 10.5 pounds of water per pound of coal, while the *Baltimore* probably does not exceed 8 pounds. The *Baltimore's* boilers weigh 490 tons for 10,000 I.H.P., and the *Iona's* 122 tons for 700 I.H.P. Were the *Baltimore's* boilers built for economy instead of power on the same ratio as the *Iona's*, they would weigh 1,743 tons, or nearly twice as much as the entire machinery of the *Baltimore* does. The comparison was made between these two ships purposely, because they are supposed to be of the best English design.

"In other words, economical machinery means heavy machinery taking up much room; but the power required in swift war vessels of moderate size is so great that to make the machinery both powerful and economical the whole ship would have to be given up to it. As the great requisite in our ships is powerful, but light machinery, economy must, of necessity, be sacrificed."

There has always been a tendency to underestimate the expenditure of coal per horse power, and the unfortunate mistake was made in this respect when compound engines were first introduced into our service. The old simple engines had been in use so long that their coal expenditure was pretty well known, and the bunker capacity was made proportionate to this expenditure. Published reports of the economy of compound engines were such as to lead to the anticipation of a degree of reduction in the coal consumption by the use of compound engines, which was not realized in practice; but the bunker capacity was cut down to this supposed economy, and the result was that there were very few of our ships fitted with compound engines which carried more than a week's steaming at full power. When the triple expansion engine was introduced this mistake was not made, because our engineers, from the experience in the case of the compound engine, were prepared to discount the claims of economy which were advanced for the triple expansion engine; but the amount of space which could be devoted to coal bunkers was in any case limited, and was made as great as it could be consistent with other requirements. Unfortunately, however, in the first estimates of radius of action, which were made by some of the officials of the Department, the figures for coal consumption were based on the statements of what had been done in the merchant service, and were very much lower than has been found to be the case in actual practice. Engineer-in-Chief Melville believed that the figures which were so often given were erroneous, and finally succeeded in having the coal accurately measured on several of our ships when tried at full power under forced draft, and it was found that so far from the coal expenditure being only from 1.6 to 2 pounds per horse power, it was actually from 2.4 to 2.8 pounds per horse power. This, of course, makes an enormous difference in the radius of action. A similar mistake was made in the estimates for low powers, so that, in the case of the *Columbia*, her radius of action at 10 knots, instead of being, as repeatedly published, 25,000 knots, is really only 11,000 to 12,000 knots. The quotation from the report of the Engineer-in-Chief shows very clearly why there is this great difference in coal consumption, and that it is thoroughly understood and recognized by our designers, although it is impossible to avoid under the conditions of the naval service. The comparison which he makes between the economical merchantman and the *Baltimore*, and the showing of the weight of machinery which would be required to secure the same economy, demonstrate conclusively why we must be content with less efficiency than obtains in the merchant service.

This leads to a suggestion by the Engineer-in-Chief, made in a paper which he read last fall before the Society of Naval Architects and Marine Engineers, for what he called an economical peace cruiser. It really seems as though naval designers all over the world have lost sight of the essential features in the design of unarmored vessels in the craze to secure high speed. A vessel of the Gunboat class, like the *Yorktown*, *Concord* or *Bennington*, or even our 2,000-tonners, the *Montgomery*, *Marblehead* and *Detroit*, cannot possibly be armored heavily enough to stand up and fight against a vessel with even a very small battery. The maximum speed which it is possible to give them will not enable them to capture any of the very fast and very valuable merchant vessels, added to which is the fact that these fast merchant vessels have just as strong scantlings as these unarmored gunboats, and are now, in almost every case, built with the view to conversion into armed cruisers in time of war. They could actually with safety mount a heavier battery than these gunboats, and, being very much faster, could choose their position in an action and speedily put the smaller vessels *hors de combat*. The speed which these small vessels do possess is very much more than is necessary to overtake and capture nine-tenths of all the steam vessels afloat, and, of course, much more than sufficient to capture every sailing vessel.

It would seem, therefore, that they are overpowered and overspeeded. When the Advisory Board was in existence and the four Roach cruisers were designed, they considered this matter very carefully, and in designing the *Boston* and *Atlanta* deliberately planned them as what would now be considered rather slow vessels.

What seems to be needed in time of peace for a cruising vessel is one which shall be economical in her coal consumption, and with large bunker capacity, so that she can keep the sea for a long time without the necessity of recoaling. Vessels of the

Concord class give up somewhere in the neighborhood of 400 tons to machinery of all kinds, and have a bunker capacity of about 400 tons. This is doing very well for vessels of only 1,700 or 1,800 tons displacement. The maximum speed is about 17 knots. It would seem that a more useful ship in time of peace, and this is the one proposed by the Engineer-in-Chief, would be a vessel of about 2,500 tons displacement, with machinery of about 1,400 or 1,500 horse power as a maximum under forced draft. When the machinery is so low in power in proportion to the size of the vessel, it would be possible to give proportionately greater weight per horse power than now obtains, and to design both engines and boilers for greater economy under ordinary service. The speed corresponding to full power would probably be about 12 knots, and when the machinery was working at its most economical rate, the speed would be between 9 and 10 knots, and the horse power about 800. With weight of machinery so much reduced, and taking the figures for weight of coal and machinery allowed in the 2,000-tonners, 875 tons, we would be able to allow for a bunker capacity of about 700 tons, which would give the vessel at the economical rate of steaming a radius of action of 10,500 miles, which is more than twice as great as the radius of action of any of the gunboats and smaller cruisers that we now have.

Although not properly coming under the engineering lectures, it may be added in connection with such a vessel that she should certainly be sheathed. If we had dry docks all over the world, as England has, it might not be a matter of so much importance, although it is to be noted that in all the recent English vessels a considerable portion of them are sheathed, so as to enable them to make long cruises on stations where dry docks are not readily accessible. It seems the height of absurdity to make calculations based on the performance of clean bottoms, when it is positively certain that a very short time out of dock will render the bottoms so foul that the power necessary to secure the same speed will be very materially increased. The Navy Department has taken hold of this matter, however, and the three small gunboats which are now building at Newport News would have been sheathed or composite, had it not been for an unfortunate circumstance that the bill which appropriated for them spoke of them as steel gunboats. The law officers of the Government construed this to be a rigid requirement, and although the Navy Department was anxious to secure the benefits of sheathing, the legal interpretation compelled the building of all steel boats. It is probably very safe to say that our next gunboats or small cruisers will certainly be sheathed.

Lecture V.—Practical Hints in Connection with the "Problem."

The scope of these lectures as mapped out by the President of the college includes a consideration of certain points connected with the "problem", which is the central idea in the whole work of the college this summer, and some attention will now be paid to these features.

The first point is the effect of ramming on the machinery of the vessel taking the offensive.

With regard to this, it may be said that there seems to be a prevalent idea that, when one vessel rams another, the attacking vessel is almost sure to damage her own machinery unless special precautions have been taken to prevent its displacement. Upon hasty inspection this view may seem reasonable, but careful study will show that it is extremely unlikely that any damage would be done. It is not the case of the irresistible force striking the immovable obstacle, because from the very nature of things the ramming vessel is expected to penetrate the hull of the other some distance, and the impact of so much energy would undoubtedly move the rammed vessel some distance. The result is that the effect is somewhat analogous to that of brakes on a railroad train in bringing the speed from a high figure down to a low one in a comparatively short time, but it is far from being the instantaneous annihilation of the stored up energy. Then, too, it must be remembered that in modern vessels, at least, the machinery is very carefully and firmly secured to its foundations, to withstand the stresses tending to cause movement which come about when a vessel is tossed about in a rough sea.

However, there are a great many instances on record to show definitely what will occur, and thus save us the trouble of dealing with the question entirely on theoretical grounds, and I may mention the case of the *Sassacus* ramming the *Albermarle*, which has recently been described by Passed Assistant Engineer Bennett in "The United Service." Here it is stated that the speed of the *Sassacus* was about 11 knots, and that her bronze stem was driven several feet into the timber belt of the *Albermarle*; all this without dislodging the machinery or injuring it in any way. In the harbor of Bahia, in 1864, when the *Wachusett* undertook to, and did capture the *Florida*, it was the intention of Captain Collins to ram the *Florida*. The engines were driven at full force, and the ramming attack would undoubtedly have been successful but for the fact that in some way one of the anchors got adrift and was dragged along for some time before it was noticed. Finally the anchor chains broke, and then, when the *Wachusett* struck, she was no longer dragging the anchor, but her speed had been checked so much that in the short distance remaining the speed probably did not get above four or five knots. Notwithstanding this, however, she cut into the side of the *Florida* from some 18 inches below the water line clear up to the spar deck, her bow cutting in at the level of the spar deck about four feet. There was no damage to the machinery here.

A notable instance of unintentional ramming is that which happened in 1879 to the fast merchant steamer *Arizona* when she ran into an iceberg in a fog off the banks of Newfoundland. The extent of the damage done to her bow and the force with which she struck is so well set out in an account given of the occurrence in "Engineering" that I quote from it as follows:

"After making the before mentioned fast passages, the *Arizona* had become quite a favorite with passengers, when her career was temporarily interrupted by an untoward accident which occurred in mid ocean through collision with an iceberg, on the evening of November 7, 1879.

"When the collision took place the vessel was steaming at about 14 knots an hour at night, and without the least warning, without even, so far as appears, the engines being stopped, ran full tilt against the iceberg, and so sustained the damage shown in the engraving. The bows were utterly crushed up for a length of about 26 feet at the upper part, the fracture extending to about 14 feet below the water line. We have no desire to discuss here the question who was to blame for so untoward an accident, but sufficient is known of the collision and its results to show that the vessel, with all on board, had one of the narrowest escapes on record from going to the bottom of the ocean.

"We have heard of small vessels ramming icebergs without suffering much injury, but is is no discredit to the *Arizona* that her bows gave way, for no ship ever built approaching her size could hope to ram an iceberg at 14 knots speed without crushing in the bows. It is, however, very much to her credit, and to the credit of her builders, that having met with such an accident she should still have kept afloat and have been capable of reaching a port of safety. There can be little doubt that had the vessel not been very strongly and faithfully built, with material and workmanship of the highest quality, she could never have kept water tight after such a fearful blow. It is often objected that merchant ships are very insufficiently subdivided into water tight compartments, and this is perhaps to some extent true, although there are strong practical reasons, as may be imagined, for the present wide prevailing practice in this respect. There is one bulkhead, however, that is fortunately never neglected, and that is one forward, termed ominously the collision bulkhead, generally situated from, say, 20 feet to 30 feet abaft the bow. Its integrity saved the *Arizona*, as it has saved hundreds of other iron vessels after less serious, or at any rate less heavy collisions. The proper position for this bulkhead is often a matter of discussion, and there can be no doubt the lesson taught by the *Arizona's* accident is in favor of keeping it well away from the stem so as to allow the whole force of the collision to expend itself on the fore side of this water tight bulkhead.

"In the case of which we have just been speaking the whole energy of the blow had to be absorded either by the bow of the vessel or the iceberg, or both. The softer the sides of the iceberg the more work it would absorb, and the less would fall upon the ship. Taking the *Arizona* at a displacement roughly of 9,000 tons, moving at a speed of 24 feet per second, the energy of the blow would amount to about 80,000 foot tons; or, supposing all the work to be absorbed by the ship, it would represent a resistance of something like 3,000 tons for every foot of the bow crushed up, a force sufficient to cause rupture in 150 square inches of iron if uniformly distributed. Of course, in cases of collision, the force of the blow cannot be uniformly distributed, and it is impossible to do more than judge of the nature of the blow by the results produced.

"An idea of the strength of the *Arizona's* bow may be gathered from the following facts: The stem is of solid wrought iron, 9 inches by $5\frac{1}{2}$ inches; the plating, which is $\frac{12}{16}$ inch and $\frac{13}{16}$ inch on alternate strakes, is at the bow $\frac{9}{16}$ inch and $\frac{10}{16}$ inch thick alternately. There are, as we have already said, two iron decks extending the whole length, besides other strengthening at the bow in the way of frames, stringers and breasthooks. The collision bulkhead is $\frac{7}{16}$ of an inch thick, and about its rigidity and water tightness there can be no doubt after the test it has been put to. An examination of the vessel and her machinery was made immediately after the accident, when it was found that she showed not the slightest trace of leakage in any part, *while the machinery was as perfect as before;* consequently she was quite seaworthy, notwithstanding the damage she had sustained. At the time of the accident the vessel was bound for Liverpool, but after a consultation with the passengers it was considered advisable to steer for St. John's, Newfoundland, where the passengers were transferred to another steamer. Before the *Arizona* left St. John's her bow was temporarily repaired, after which she steamed home to Liverpool with the whole of her cargo on board, meeting with rather heavy weather during the voyage."

Inasmuch as the *Arizona* was able to steam across to Europe after simply repairing the damage to her bows it is quite evident that no damage was done to the machinery.

An instance which will remain vivid in the minds of naval men for many years is the sad collision between the *Victoria* and the *Camperdown*, in which the latter was the ramming vessel.

A brief account of the disaster was published in the "Iron Age" of New York in its issue of August 17, 1893, written by Captain Cooper Kirton of Valetta, Malta. He says:

"The *Camperdown's* ram struck the *Victoria* nearly at right angles, say about 80 degrees, and cut nearly into her middle line just as if she had been made of cheese. So much for ramming. The feeling aboard the *Camperdown* was as if they were cutting into a soft sand bank. There was no jar felt, and *the engines worked afterward as if nothing had happened.* The damage to *Camperdown* was, stem 15 by 5 feet broken short off above the ram and turned to port 18 degrees; upper part of stem crushed in making an opening about 15 feet long by 10 or 11 feet wide; the plates on port side were crumpled up like paper. This side suffered most, a large hole, 9 by 10 feet, being ripped out, commencing at break of stem and running aft just above the protective deck. The frames showed the effects of the first blow and subsequent dragging clear, and were twisted out of recognition. The ram was practically uninjured and could have rammed another vessel. It was all wrought work, no casting, and admirably strengthened by heavy horizontal ram plates.

"The defect in bows and rams as at present constructed is that they are supposed to ram and rip up a vessel under water, the bow above not being affected, instead of which a vessel built for ramming cuts into another so easily that she never stops until choked off by the crushing up of her own top sides. Nothing, not even the strongest ironclad that was ever built, could withstand ramming. The thickest armor would be simply driven in."

Another interesting case is also an accidental collision where a Yarrow torpedo boat, while on a trial trip, ran into a barge loaded with wheat, owing to a defect in the steering gear which prevented the vessel's course being controlled. A description of this accident, together with a cut showing the damage to the torpedo boat, appeared in "Engineering" of January 20, 1893, from which the following extract is taken:

"A clutch had worked back without its being noticed, and the consequence was the steerman lost all control, and, before the engines could be got to fairly astern, we ran, stem on, at about 18 knots speed, into a large wooden sailing barge, loaded with over 100 tons of wheat, at anchor just above the Lower Hope Point beacon.

"Our stem cut deep into the fore part of the barge, just forward of the mast. The bargees got into their boat, and our engines were put full speed astern to disengage us, for the anchor of the barge held her so firmly that we could not push her on the shore, although this was only 80 yards distance. The sinking barge was so firmly fixed to our stem that she was pulling our bow into the water and lifting our stern so much that our propeller was only skimming the water, and we were helplessly gripped by the nose like a bull by a bulldog. To make matters worse, the strong ebb tide acting on our side, twisted our stem completely round to port, at right angles, tearing our plates open as far as the second bulkhead. For a short time it seemed as if nothing could save us, when the barge heeled suddenly right over to port, tore herself clear of the wreckage of our bows, and sunk in some 20 feet of water, still held by her anchor.

"As soon as we were released from the weight of the barge, our bows came up and our propeller gripped the water. We then steamed ahead to clear some vessels at anchor below us. We now found that the third bulkhead from forward was quite water tight, and by trimming all our ballast right aft we got the wreckage of our stem sufficiently out of the water to enable us to secure it by means of chains etc.; for, until we had done this, it would not have been safe to steam ahead; indeed our cutwater, being all twisted over to port, acted like a bow rudder and prevented us steering properly. An hour's work in hauling up the torn plates of our bow enabled us once more to obtain steering control. *Engines, boilers and steam pipes were not at all injured, and we steamed home without aid at the rate of quite ten or twelve knots per hour, arriving late, but all safe, at the works at Poplar.*

"*It might have been expected that such a collision would have shifted the machinery and broken some of the steam joints, but such, it will be seen, was not the case.* On account of the lightness of the scantling of the bow, no solid resistance was presented to cause the stoppage of the boat, the momentum being gradually taken up, as it were, by a buffer. The scantling of the hull was of the strength customary in Messrs. Yarrow's boats, and, although this may appear exceedingly light, it has been found sufficient in this case to withstand the stress of a voyage to Australia, the vessel in question arriving there some months ago without a rivet leaking."

These cases, it would seem, ought to satisfy us beyond doubt that with well built machinery properly secured for ordinary purposes no apprehension need be felt that the machinery will be dislodged, steam pipes disconnected, or anything of that sort in case of ramming, so that a commanding officer can undertake this manœuvre with perfect confidence as far as this aspect of the case is concerned.

Lest it may occur to some that the recent experience with the *Marion* in the typhoon off the China coast when on her way home may seem to cast doubt on what has just been said, inasmuch as her boilers shifted during the typhoon, it may be remarked that this was due simply to the fact that the vessel is very old, and the timbers to which the boilers are secured had become rotten, so that in the violent shaking up which they received the fastenings worked loose in the rotten wood. In our new vessels, built of steel, and with all precautions taken for securing the machinery properly, such a case could never occur.

Another point proposed for discussion is the effect of a shot penetrating one of the boilers or part of the steam pipe. With regard to this matter there is a good deal of uncertainty as to just how extensive the damage would be, as it would depend very largely upon the size of the rent made in the boiler. A clean hole that was not of very great size, would simply act as a safety valve and permit the steam to rush out without causing the explosion of the boilers; but if such a thing should occur as a shell exploding just against the side of the boiler so as to cause a large rent it would, in all probability, cause the explosion of the boiler itself, and in the confined space of the vessel's hold, the probability is that the explosion of a single large boiler would cause the explosion of all the others and the destruction of the vessel.

It may be well at this point to say a few words with regard to the rationale of boiler explosions. It is now generally admitted that the great destruction attendant upon a boiler explosion is due not so much to the steam in the boiler as to water. When from any cause a rupture in a boiler of sufficient size is produced to rapidly liberate a large quantity of steam, the water, which is already heated up to the same temperature as the steam, has sufficient heat stored in it to turn into steam of a lower pressure, and the result is that the whole mass of water becomes steam with great rapidity, devoloping a large amount of kinetic energy which completes the destruction already started, and where room exists frequently hurls portions of the boiler great distances. It will be seen, therefore, that the nature of the destruction will depend almost entirely upon the size of the initial rupture or perforation. When the hole made is not too large, the effect will be very much the same as if the safety valve had been entirely blown off, and the steam already formed, and that generated from the heated water, were discharged rapidly but without further injury to the boiler or machinery except as noticed further on; whereas, if a very large rupture is made, it will be sufficient to liberate the steam formed from the heated water with such rapidity as to permit of the generation of the kinetic energy necessary to cause intense destruction.

As showing the general explanation of boiler explosions it may be mentioned that in 1892 there was an accident on the *Dupuy de Lôme*, of the French navy, in which several men were scalded. The notices which appeared in the daily papers in this country with regard to this accident reported that the head of one of the boilers had been blown completely off. Commenting on this the "Journal of the American Society of Naval Engineers" says: "The first press reports received in this country were as wild as well could be. They stated that the head of one of the boilers had blown off, but engineers knew, of course, that this was absurd, as such a rupture would probably have caused the explosion of all the boilers and the complete wreck of the vessel."

It may also be stated that the mysterious disappearance of some vessels had been attributed to a disastrous boiler explosion. Within the last year the fine steamer *Naronic*, of the White Star line, left England on a trip to this country and was never heard of again. As she was not in the track of icebergs, it hardly seems possible that she could have been lost in that way, and as there were no survivors to give an explanation, it has been thought possible that in some way which is inexplicable the boilers exploded and caused the complete destruction of the ship.

One thing, however, is entirely certain with regard to the damage of a boiler when the perforation is of any size greater than a square inch in area, and that is that the outrush of steam would scald or suffocate everybody in the compartment. In old fashioned ships, where there were no protective decks nor water-tight bulkheads, a slight rupture on the upper part of a boiler might discharge the steam through the hatch and the persons in the immediate vicinity might escape; but with a boiler enclosed in a box not very much larger than itself there would be no escape for anybody. This will be very clear from a few quotations which will be made in considering the matter of the rupture of a steam pipe.

In this case the probability is that the damage would be confined to killing the people in the compartment, as even a complete severance of the pipe would hardly ever make an opening large enough to discharge the steam with sufficient rapidity to cause the explosions of the boilers.

We have, unfortunately, had one case of a ruptured steam pipe in our own Navy. Early in June, of 1891, while the *Concord* was at sea off the capes of the Chesapeake for a trial under the inspection board, her main steam pipe was burst for a length of about 28 inches by a water ram, while at the after end there was a circumferential rip about 7 inches long. This corner was thrown out so as to permit a very free discharge of the steam, and it entirely filled the compartment in which the two forward boilers were placed, scalding and instantly killing two firemen who were on duty there at the time. From an investigation of the circumstances of the case made by the Engineer-in-Chief, it appears that this rupture of the steam pipe was undoubtedly due to what is known as water hammer, in consequence of the pipe not having drains of sufficient size. The accident occurred just as the two forward boilers were being connected to the two after ones, under which the vessel had been steaming; and besides emphasizing the importance of proper drains it also calls attention to the fact that when changes of this sort are to be made there should always be ample time. The accident on the *Concord* was not caused by hurry, but in case it were necessary to connect additional boilers, if it were done in a hurry there might be danger of a similar accident, owing to lack of sufficient time to have the drainage properly attended to.

An accident similar to that on the *Concord* occurred in December, 1890, on board the English mail steamer *Jumna*, and caused the death of seven men.

The most disastrous accident of this kind, however, which has occurred for some time was that which took place on the 16th of February of this year on board the German battle ship *Brandenburg*. Here 45 men were killed. The "Journal of the American Society of Naval Engineers" gives the following brief account of the accident:

"The magnitude of the catastrophe can be better understood by a short statement of the arrangement of her steam pipes. In the main steam pipe in each engine room there is a separator, and between the separator and high pressure steam chest a length of copper piping of about 10 feet, one end of which is fastened to a stop valve on the separator and the other in a stuffing box slip joint attached to the stop valve on the steam chest. The stop valve on the separator broke short off close to the flange, thus giving a full opening to the escape of steam from the 12 boilers. The door between the two engine rooms was open so that the steam filled both, and of the men in them thirty-nine were killed outright, and nine so badly injured that six of them died subsequently."

It has been stated that a rupture to a steam pipe would probably not injure the boilers, but this was meant in the sense that there would be no explosion. In case the water in the boilers at the time of the rupture was not very high, and the boilers were working under strong forced draft with very heavy fires, the result of such an accident might be serious damage to the heating surfaces of the boiler, due to the rapid generation of steam leaving them uncovered and exposed to the intense heat of the fires under forced draft. With the ductile material now used for heating surfaces, it is probable that the damage would consist mainly in collapse of portions of the combustion chamber and of injury due to overheating, but probably with rupture. In the case of the *Concord*, it was impossible to get into the forward fire room for about two hours after the accident occurred, so that it is impossible to say just how rapidly the water fell. An examination made as soon as practicable showed that the water had fallen about 15 inches below the top of the combustion chamber leaving exposed five rows of tubes. The fire side of the upper furnace showed a red and rusty appearance, and there was no sign of overheating or bulging. The boilers were subsequently tested carefully at the New York Navy Yard, but showed no signs of injury. In this case, however, the boilers were not working under forced draft, and it seems likely that the steam, which entirely filled the fire room, entirely excluded the oxygen necessary for the combustion of the coal, so that the fires were deadened, and thus prevented from injuring the heated surfaces.

It is impossible, of course, to say just what should be done, because each case would probably require a different treatment, but in general the object should be to shut off the injured boiler or pipe from connection with the other parts under pressure, so that after the steam contained in the injured part is discharged no more will enter it. In all of our new vessels are fitted what are called self-closing stop valves specially designed to shut off the boiler in case of accident. They have to be lifted from their seats in order to give an opening, and when the pressure is normal throughout the steam system they will remain open, but when from any cause the pressure in the boiler falls below that in the rest of the system the valve will close of itself. Where these self-closing valves are not fitted, the valve stems should be fitted with spindles leading above the deck over the boilers, so that, in case of accident, the valves could be shut from there.

It goes without saying, of course, that, as soon as practicable, fires should be hauled from the injured boiler; or, if it is praticable to stay in the fire room, the fires can be deadened by a stream of water from the fire hose.

Attention has already been called to the advantages of coil boilers in their immunity from disastrous explosion, and this may be again mentioned. As far as the aspect of the case under consideration, where the explosion would be caused by a projectile, is concerned, one of these boilers would probably be very seriously damaged, as a shell would probably wreck a large number of the tubes; but, as has already been pointed out, the amount of water contained in a tubulous boiler is very small, and while there might be enough to scald the people in the immediate neighborhood, there could be no such disaster as has already been mentioned in the case of the *Concord* and *Brandenburg*.

The possibilities of liquid fuel are to be considered in this lecture according to the program, but little additional need be said, as the matter has already been discussed in a previous lecture. It was there mentioned that as far as the mechanical difficulties in the way of burning liquid fuel were concerned, there need be no doubt of its feasibility, and that the real obstacle in the way is cost. In case of war cost would naturally become a secondary consideration, and it seems probable that it would be advantageous to use it on torpedo boats, and to provide facilities for using liquid fuel in addition to coal on the larger vessels. The liquid fuel could be regarded on the large vessels as an emergency fuel, so that it would not be used up rapidly, and the torpedo boats would not use a very large amount, so that it would be practicable to have the tanks for its storage comparatively small, and simply to bring it up as needed.

Even with liquid fuel adopted for torpedo boats and used as an emergency fuel for the larger vessels, the main dependence would have to be placed on coal, and the question of its quick delivery to the fleet is important. This is a matter, of course, rather outside the scope of these lectures, for the purchase and transportation of the coal would have to be attended to by the

Bureau of Supplies, while other Bureaus might be involved in its storage and handling before being placed on board ship. In this, as in so many other things, much depends on how much time there would be after there was a prospect of war before its actual declaration. It would seem that if sufficient time was allowed, the best plan would be to erect a regular coaling trestle at New London, such as is used for coaling merchant steamers in many of our large ports. Provision could be made in this way for coaling a number of vessels at the same time, and certainly in the most expeditious way as far as getting the coal on board ship. As has been repeatedly pointed out, the speed of coaling ship in modern vessels depends a great deal more on the complexity of the bunkers and the manner of stowing it than on the question of getting it on board. It would probably be necessary, however, in addition to the coaling trestle to have colliers to supply such of the vessels as could not be spared to come to the trestle, and here the main point would be to have ample derrick capacity so that the speed with which the coal could be delivered would at least equal the speed with which it could be stowed.

With regard to the coaling of fires while in action, the course to be pursued would depend on circumstances. If the engagement were in the nature of a formal duel, where no long time elapsed from the readiness to go ahead at full speed until the action began, the best plan would be to have as much coal on the fire room floors as possible without interfering with the work of the men, and the lower bunkers well supplied. This latter, of course, could be done long before going into action, so that the coal would be as readily accessible as possible. If the action came at the end of a chase of long duration the probabilities are that it would be entirely a question of getting the coal out of the bunkers. Inasmuch as there are always bunkers which are more readily accessible from the fire rooms than others, it would be perfectly natural, and would occur to everybody, that these bunkers should be filled up before the chase began; in fact, it would seem that it would be an important part of keeping the ship in readiness for action to have the coal trimmed constantly, so that the bunkers nearest the fire room should always be kept full.

Economy of fuel may be an important question, not so much from its cost as from the loss of time involved in going to get fresh supplies. The proper course to be pursued will depend on the condition in which the Commander-in-Chief desires to keep the fleet. As telegraphic and other means of announcing the movement of the hostile fleet will undoubtedly exist, so that a complete surprise would be impossible, and as probably an hour could be allowed for getting steam up to full power, the best course would seem to be with cylindrical boilers to keep heavy banked fires in enough of the boilers so that the vessel could be got under way and making a speed of, say, 10 or 11 knots in 15 or 20 minutes. In the other boilers the water should be kept hot by the use of the hydrokineters, so that the only time required would be to get the fires burning brightly. As this would not take over an hour, fires need not be banked in these extra boilers, if that much time can be allowed.

If coil boilers are fitted, as the water in them is so small in amount that the time necessary to generate steam will not exceed the time required to get the fires into good condition, banked fires need only be kept in enough to make 10 knots at short notice, while in the others the water can be left cold and the fires laid, so that steam could be raised as soon as the fires were in good condition.

This would be one of the advantages of the use of oil fuel, because it would simply be necessary to keep steam in a few boilers so that the hydrokineters could be worked on all, and the liquid fuel could be started burning shortly after the coal had been started in the boilers whose fires were out, so that steam would be raised more quickly than where dependence was had on coal altogether, and not so many boilers would have to be kept under banked fires.

Where both liquid fuel and coil boilers were used, as in torpedo boats, it would be possible to raise steam in a very short time, so that if half an hour's notice could be given at any time before steam were wanted it would not be necessary to keep fires lighted at all.

As the boilers should be supplied with fresh water at all times, and as they are supposed, from the conditions of the problem, to be within easy touch of the base of supplies at all times, it would seem that the cheapest way of furnishing water necessary to replace losses would be simply to have a few tank steamers with powerful pumps, which could go around the fleet and supply the needs of the various vessels.

The outline of the course of study calls for a discussion of floating workshops or repair ships. Although the idea of building and equipping ships for this particular duty is very recent, the use of repair ships is by no means new. During our civil war there were repair ships at the headquarters of each blockading squadron. They were usually hulks or sailing vessels, which remained at anchor. They had an outfit of tools and mechanics which enabled any repairs, except those to very heavy parts of the machinery, to be made on the station. While these were very useful in the special case of blockade, they would be of comparatively little service under modern conditions. The need for such repair ships, however, especially for a fleet operating in foreign waters, is so evident that several countries have provided repair ships designed to accompany a fleet anywhere, and also do regular cruising duty. It is probably safe to say that wherever a fleet has to operate at more than a hundred miles from a repair yard a repair ship will be useful, while for service abroad it is essential.

It would seem that under the conditions of the problem, where our vessels are to be at home and not far from New London, the repair ships would not play so important a part as in a fleet operating in foreign waters. It would, in fact, not be much of a trip to New York to make extensive repairs, while it would not take long to fit out the station at New London, so that most repairs should be made there. A repair ship, however, would be very useful in supplying a large number of skilled workmen, who would have nothing to do except to repair work, while the mechanics on board the fighting ship would have a great deal of their time taken up in standing watch; and, moreover, the tools on board the repair ship would be vastly more numerous and of sizes appropriate to doing many kinds of work for which the small tools in the workshops of the regular ships would not be capable.

During the Chilian excitement in 1892 our own Government, realizing the importance of being prepared to make repairs to our vessels in case of war, made provision for fitting out several repair ships, and work was actually begun towards transforming the steamer *Ohio* of the Inman Line into a repair ship. The matter had been carefully considered, and the list of tools which were to be placed on board made out, together with all the fittings. As this will doubtless be of interest to all officers, I have copied the list for the *Ohio*, which is as follows:

MACHINIST'S.

1 lathe, gap, 40 inches swing, 20 feet centers.

2 lathes, 30 inches swing, 10 feet centers.

Each of the above to be fitted with boring bar with traveling head.

4 lathes, 18 inches swing, 6 feet centers.

1 lathe, 12 inches swing, 4 feet centers.

1 lathe, monitor, small.

1 planer, to take 4 feet square, 10 feet travel.

2 planers, to take 3 feet square, 5 feet travel.

1 shaper, 24 inches stroke.

1 shaper, 14 inches stroke.

1 shaper, 10 inches stroke.

1 radial drill, to drill at 48 inches from side of column.

2 drill presses, 3-inch spindle, to drill up to 1½-inch holes, 12 inches vertical movement.

2 drill presses, 2-inch spindle, to drill up to 1-inch holes, 12 inches vertical movement.

1 bolt-cutting machine, with standard taps and dies, to cut from ½ inch to 2 inches, varying by $\frac{1}{16}$ inch.

1 pipe-threading machine, to cut from ½ inch to 4 inches, with pipe taps and dies of standard sizes.

A complete set of cutting tools, dogs, chucks, angle plates, clamps, etc., for each power tool, together with all attachments and fitttings complete, including counter shafts, pulleys, etc.

200 feet 2½-inch shafting in 10-feet lengths, with universal couplings and short hangers for each length.

2 driving pulleys of each of the following sizes for power tool, to fit shafting and be ready to be slipped in place thereon: 20, 18, 14 and 12 inches diameter.

75 feet 12-inch double belting.
250 feet 6-inch single belting.
1,300 feet 4-inch single belting.
1,000 feet 3-inch single belting.
12 sides lace leather.

(All to be oak-tanned leather.)

1 emery wheel tool-grinder, 18 inches diameter and 2 inches face, fitted complete with all attachments, pulleys, etc.

2 grindstones, coarse, 50 inches diameter and 8 inches face, to run in cast-iron troughs, fitted complete with all attachments, pulleys, etc.

MOULDER'S.

1 36-inch cupola of most improved design, to melt 3,000 pounds metal at each tapping; to be set up on shore. A blower and engine to furnish blast; hoist, piping and fittings complete.

1 furnace, iron-lined, with fire brick, to take three 100-pound crucibles, funnel about 12 inches diameter.

3 sets crucible tongs, 1 set for each size of crucible.

50 crucibles of 50 pounds capacity.

50 crucibles of 100 pounds capacity.

3 crucible bearers for each size crucible.

3 complete sets of moulder's tools.

COPPERSMITH'S.

1 brazing forge, with two circular and one long fire, for blast to be built up in light iron and lined with fire brick.

1 set of tools, including shears, stakes, hammers, beck irons, blocks.

3 tinsmith's furnaces, with soldering irons, pots, etc.

BLACKSMITH'S.

1 open-hearth forge, 5 feet in diameter, with cowl and 12-inch funnel, to be built up of brick and iron, used for heavy forging or flange turning, to be fitted for power blast.

2 forges, with power blast, to weld 4 inches square (16 square inches).

2 forges, portable, with hand blowers to weld 2 inches square.

1 Sturtevant pressure blower, to be driven by engine attached; a quantity of 3-inch and 2-inch light iron pipe for leading blasts.

3 portable hand blowers, 14-inch fans, driven by levers.

6 Eagle anvils, with blocks, two of 150 pounds, two of 180 pounds, and two of 200 pounds.

1 complete set of forge tools with each forge.

1 surfacing plate.

6 swedge blocks, 200 pounds each.

1 welding block, about 6 inches square and 4 feet long, with three grooved sides, the grooves 2-inch, 3-inch and 4-inch die.

12 hand hammers.

6 flogging hammers.

6 sledges: two 6 pounds, two 8 pounds, two 12 pounds.

BOILERMAKER'S.

50 boilermaker's kits, to include hammers, chisels, caulking tools, drift pins, reamers, scrapers, etc.

12 sets riveting hammers: 8 sets straight pene, 4 sets ball pene.

12 sets roller expanders, from 1¼-inch to 3-inch, varying ¼ inch.

1 power punch and shears, single machines, 15-inch throat, to punch 1 inch in ⅞-inch plate and shear 15 inches by ⅞ inch.

1 set hand rolls, to be set on upper deck, rolls to be 6 inches diameter by 6 feet long.

6 rivet heating forges.

1 dozen boilersmaker's ratchets, short, with square shank-drills.

50 each of the following sizes of square shank drills: ½-inch, ⅝-inch, ¾-inch and ⅞-inch.

6 tube cutters, to cut from 1½-inch to 3-inch tubes.

1 dozen flogging hammers, 4 pounds.
1 dozen sledges, 8 pounds.
6 clubs and sledges, for holding on.
6 screw punches.
1 steam engine, vertical, double cylinder, of 50 horse-power.
4 6,000-gallon evaporators No. 5, Type B.
4 No. 6, distilling apparatus sufficient for above.
Feed pump, capacity 30 gallons per minute.
Circulating pump, capacity 600 gallons per minute.
1 blower No. 4, 32 by 25 by 33h.
3 exhausts No. 5, 38 by 30 by 37h.

If the problem had been the design of a repair ship to be built especially for that purpose, other tools would have been fitted. There was not sufficient time to make any important changes in the hull, so that tools whose use would have required special strengthening of the hull were omitted.

It is to be noted also that the list just given is of the tools and outfit required for repairing machinery only. Additional tools were to be fitted for hull work, although, of course, many of the tools mentioned would have been used for repair work of all kinds.

In the English navy the *Vulcan* has been fitted out as a repair ship for service with fleets in foreign waters. She is 350 feet between perpendiculars, 58 feet beam, and has a displacement of 6,630 tons at 23 feet mean draught. She has a bunker capacity of 1,000 tons, and machinery of 12,000 horse power, which is expected to give her a speed of about 20 knots, the idea being that she would not only serve as a repair ship, but could be used for scouting purposes, and also for offensive movements. In a description of her recently printed it is stated: "She is intended to accompany a fleet to sea, to form a depot for supplying mining and countermining stores, electrical gear, Whitehead torpedoes, etc., to assist in the work of laying out mines or fishing them up, as occasion may require, as well as forming a school of instruction for this kind of work in times of peace. She is also fitted with a factory for executing repairs to torpedo gear and boats, and to such ships of war as are not provided with the means of performing their own repairs.

"In the workshop there are five lathes of various sizes, from 15-feet bed and 9-inch centers down to 3 feet 6-inch beds and 6-inch centers; 2 drilling machines, planing, slotting, shaping and punching machines, and circular saw bench, a carpenter's bench, fitters' benches, and a Fletcher's air furnace capable of melting down two hundred weight of scrap steel in two hours. In the blacksmith shop, on the upper deck, is a powerful hydraulic forging press, a large forge fitted with Root's blower and steam blast, and also a coppersmith's forge and pipe-bending machine, together with a complete set of tools."

In the French navy, the *Foudre* is a torpedo boat and repair ship somewhat smaller than the *Vulcan*. She has a displacement of 5,970 tons, and with 11,400 I. H. P. is expected to make 19 knots. She has eight 3.9-inch, four 2.5-inch, and four 1.8-inch quick firing Canet guns, and five torpedo ejectors. She will carry ten second-class torpedo boats. No list of her tools is available.

The Austrians have also a repair ship in the *Pelican* of about 3,000 tons' displacemeut, which has made about 18 knots with 4,800 I.H.P. The machinery is by Schichau.

In 1887, the transatlantic liner *America* was purchased by Italy for a torpedo depot and repair ship. She has a displacement of 9,550 tons on 26 feet mean draught, and compound engines of 9,000 I.H.P. which are said to have given a speed of 18.5 knots. She has a bunker capacity of 1,550 tons. Her large size gives unusual facilities as a store ship. Late reports state that she had been found very useful.

As will be seen from the outfit for the *Ohio*, it would be possible to do any lathe work required except for large shafting, and any planer work that would be required by anything short of a complete smash up of some ship's machinery. Almost any castings which would be needed, short of such a disaster, could be made, and the thousand and one small repairs which are ordinarily made at a Navy Yard could be just as well made on board the repair ship.

There can be little doubt that, in future naval wars, every fleet which operates away from its own coast will have one or more of these repair ships as an important part.

It may not be amiss to add a few words in regard to a point which affects coal economy, and also the comfort and peace of mind of the people in the engineer's force, which is variation in speed. It must be remembered that steam boilers are not like a spirited horse, which can be held in hand ready for any effort up to the maximum, but that when everything is urged to the utmost the steam must be disposed of in some way. Of course, in time of action, it goes without saying that everything must be kept at the top notch, and everybody connected with the machinery prepared to execute instantaneously any order that comes. Besides the objection to blowing off steam through the safety valves, that it makes a great noise, it is also very wasteful of fresh water, and for this reason all our modern ships are provided with what are called bleeder valves, so that the steam can be sent directly from the main steam pipe to the condenser when the engines are not in use or are not being worked sufficiently fast to take care of all the steam. At the same time, this is rather hard service on the condensers, and it ought not to be done except when absolutely necessary, as is the case in action.

Now, in squadron manœuvres, or in time of peace when there is no emergency, if it is to be required that the engines shall be ready to respond to a call through a great range of speeds, it will be necessary to keep up steam on a considerable number of boilers, and when the machinery is working at moderate powers a great deal of coal will be wasted simply in generating steam which is thrown into the condensers. A given number of boilers will supply the power for some particular speed as a maximum, and, if the average speed is fixed somewhat below this, there is then a margin for some increase without giving any particular trouble, as it will take only a short time to build up the fires enough to give the full power required.

The point is, then, that the Commander-in-Chief in the case of squadron manœuvres, or the commanding officer in the case of a single ship, ought to inform himself as to the amount of power and the number of boilers required for various speeds, and then set the speed, which will be the normal, at such a figure as will obviate the necessity of keeping steam up on some boilers simply for reserve power.

In an earlier lecture it was remarked, in connection with the care of boilers, that the chief engineer should be notified in ample time before steam will no longer be needed; and it may be stated now that the highest efficiency in the use of machinery will follow when the commanding officer is perfectly frank with the chief engineer and tells him, as far as he can, just what will be required of the machinery, so that he can make the necessary arrangements. All this would undoubtedly occur to any commanding officer who would stop to think about it, but might not always occur to him that a speed which he would fix would be just beyond the capacity, say, of two boilers out of four, while very much within the capacity of three. A little consultation with the chief engineer would enable the best results to be obtained.

TESTS OF THE BOILERS OF THE STEAM YACHT *WILD DUCK*.

BY PROFESSOR IRA N. HOLLIS, HARVARD UNIVERSITY.

The accompanying statement of the results of four tests of Belleville boilers in use on this coast is given to the Society on account of its bearing upon the much discussed subject of Scotch and tubulous boilers. The tests were undertaken for the Atlantic Works of East Boston, at the suggestion of Mr. John M. Forbes, the owner of the Yacht *Wild Duck*, on which the tests were made.

The yacht was built by this firm in 1891, after the design of Mr. Edward Burgess. She was completed early in July of that year, and had her acceptance trial on July 13th. The main engine was designed and built by the Atlantic Works, upon specifications of Mr. Miers Coryell, and the boilers built at the Belleville Works, St. Denis, France, and imported complete for the vessel. There are two main boilers, and one auxiliary boiler, which had thus been in use four and one-half years. It is remarkable, as stated by the owner and the chief engineer, that they have required no special care, and have cost nothing for repairs during this time. An examination of the tubes and junction boxes discloses very little deterioration. There seems to be no reason why the boilers should not last as long again without repairs. It is this satisfactory record which calls attention to these, and renders a study of their economic features desirable.

The following brief description of the vessel, machinery and boilers may be of interest before going into the data of the trial.

DESCRIPTION OF THE YACHT.

The principal dimensions of the hull are as follows:

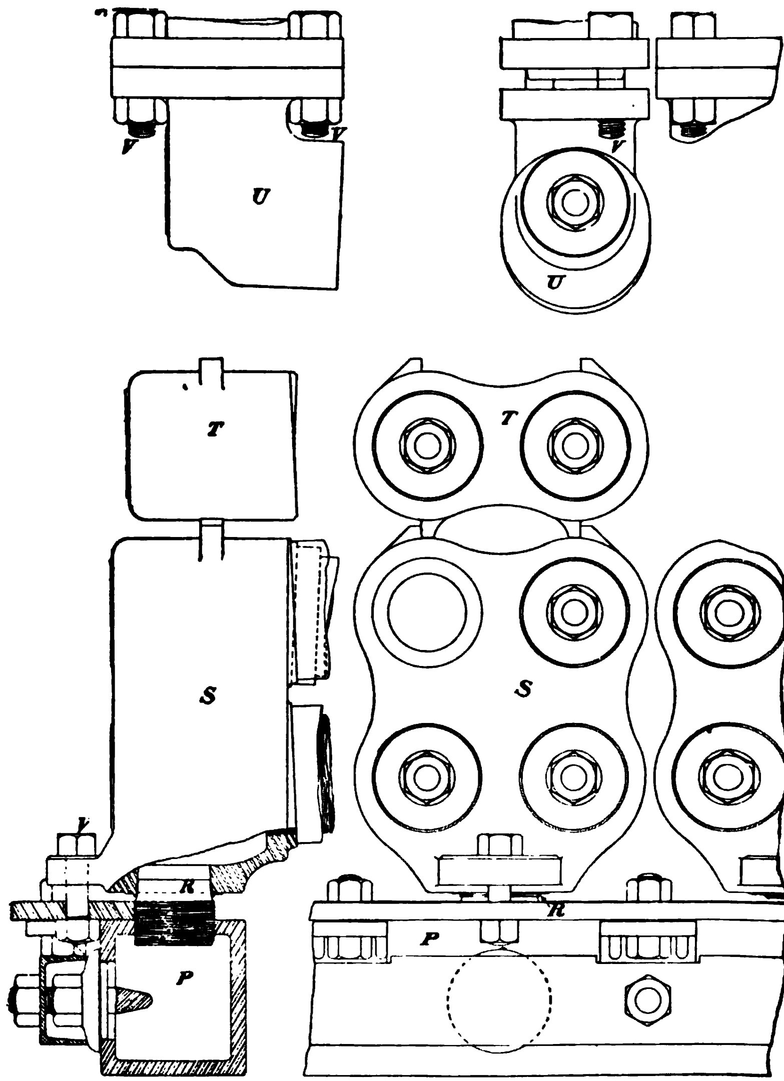
Length over all, feet	154
on L.W.L., feet	125

Beam, molded, feet and inches	23–6
Depth from top of keel to deck, feet and inches	12–6
Draught, forward, feet	7
aft, feet and inches	8–6
mean, feet and inches	7–9
Displacement, tons	350
Midship section, square feet	155
Contents of coal bunkers, tons	60
Number of water tight bulkheads	4

The yacht is schooner rigged, with two masts, 108 feet and 96 feet high respectively. During the winter of 1893, sponsons about 75 feet long, were added on each side to increase the width of the deck about 45 inches in its widest part.

MACHINERY.

The main engines were designed for about 400 I.H.P. when running at the highest speed with 200 pounds initial steam pressure. They are of the vertical inverted triple expansion type, with cylinders 10, 14½ and 28½ inches in diameter, and piston stroke of 18 inches. The piston rods are 2½ inches in diameter, and the shaft 5¾ inches. The H.P. and I.P. cylinders have piston valves, and the L.P. cylinder has a slide valve, all worked by eccentrics and the Stephenson link. There is no separate cut off. The throttle is an ordinary balanced poppet valve. The propeller is of the feathering type, with two blades that may be set fore-and-aft behind the stern post from the shaft alley. The diameter is 6 feet, the blade surface 7.78 square feet, and the pitch variable from 0 to 7 feet. There is a steam reversing engine on the starboard side of the bed plate. The condenser, located on the port side, forms part of the cylinder support, as is common with merchant ships. It is of the ordinary surface condensing type, with cooling surface of 605 square feet. The combined air and circulating pump is placed along side of the condenser. Both pumps are horizontal, driven by a steam cylinder placed forward, with the air pump aft, and the circulating pump in the middle, all three pistons being on a continuous piston rod. The steam cylinder is 8 inches in diameter; the circulating pump 10 inches, and the air pump 10 inches, with a



Details of Belleville Boiler.
Figure 2.

common piston stroke of 12 inches. The condensed steam is delivered into a filter tank 42 inches long by 24 inches broad and 36 inches deep. The engine room is 10 feet 6 inches by the entire breadth of the vessel.

BOILERS.

The details of the two main boilers are exactly like those of the *Shearwater's* boiler, with a few exceptions. The report of the Chief of Bureau of Steam Engineering for 1888 contains a description of this boiler, and a repetition, beyond what is required to understand the tests, does not seem necessary. There are seven elements instead of eight, and the grate surface is reduced in each boiler. Two figures, showing a later construction by the Atlantic Works, are added for the benefit of those who have not a clear idea of the Belleville boiler. Figure 1 represents the front and side views of the entire boiler, while figure 2 shows the method of making the joints at the top and bottom of the elements. The parts lettered are as follows:

A. Steam drum.
B. Circulation or feed return pipe.
C. Mud drum.
D. Feed water collector from end of steam drum.
E. Feed water collector from middle of steam drum.
F. Gauge glass column.
G. Attachment of gauge glass column to elements.
H. Regulating feed cock.
I. Steam stop valve.
J. Bottom blow cock.
K. Back end of furnace.
L. Roller supporting elements.
M. Boiler casing.
P. Feed collector for elements.
R. Chemise packing for securing elements.
S. Lower tube box.
T. Intermediate tube boxes.
U. Upper tube box, showing upper fastening.
V. Bolts securing elements.

The feed water is taken into the steam drum, where it is heated to the temperature of saturated steam at a very high pressure; thence it passes down the circulation pipe to the mud drum, where it is supposed to deposit a large percentage of its impurities; thence to the feed collector, and into the tubulous elements, from which it passes into the steam drum in the form of a mixture of steam and water. The circulation is not dependent upon convection, but is determined by the height of water in the circulation pipe above that in the tubes. A fuller statement of what probably takes place inside of the tubes is given later. A few of the dimensions are here repeated to save reference to the Bureau's report of 1888:

Number of main boilers	2
Number of elements in each boiler	7
Number of tubes in each element	16
Inside diameter of tubes, 1 lower row, inches	3.15
upper rows, inches	3.54
Thickness of tubes, 1 lower row, inch	0.394
upper rows, inch	0.197
Length of tubes and junction boxes over all, inches	73.
Breadth of nest of tubes, inches	70.
Height of nest of tubes, inches	50.
Dimensions of feed collector, outside, inches	5 by 5
Thickness of feed collector, inch	$\frac{5}{8}$
Diameter of steam drum, inches	19
Length of steam drum, inches	68
Diameter of circulation pipe, inside, inches	3.54
Thickness of circulation pipe, inch	0.197
Diameter of mud drum, outside, inches	10$\frac{1}{2}$
Length of mud drum, inches	35
grate bars, inches	59$\frac{3}{8}$
Grate bars of cast iron, 3$\frac{1}{4}$ inches wide at top, $\frac{5}{16}$ inch wide at bottom, by 4$\frac{5}{8}$ inches deep, spaced $\frac{5}{8}$ inch apart.	
Breadth of grate, inches	65$\frac{1}{2}$
Distance of grate below tubes, front end, inches	21$\frac{1}{2}$
back end, inches	28
ash pan below grate, front end, inches	16
back end, inches	13
Area of grate surface, 1 boiler, square feet	27
water heating surface, 1 boiler, square feet	451
steam heating surface, 1 boiler, square feet	270
heating surface, total, 1 boiler, square feet	721

Cross section of circulating pipe, square inches	9.84
mud drum, square inches	70.9
feed collector, square inches	19.14
tubes, lower row, square inches	54.53
upper rows, square inches	68.88
Diameter of smoke pipe, feet	4
Area of smoke pipe, square feet	12.57
Height of smoke pipe above grate, feet	32
Projected area between tubes, square feet	6.46
Height of upper end of circulation pipe above normal water level in boiler, inches	35
Ratio of H.S. to G.S.	26.7
G.S. to smoke pipe area	4.29
G.S to calorimeter between tubes	4.18

The outside dimensions of each boiler over casing and fire-brick, are 80 inches long by 92 inches wide, by 10 feet from the ash pan to the extreme top of the steam drum. The fire room runs athwartship between the engines and boilers. The whole floor space occupied by the two boilers and fire room is 16 feet 8 inches by 13 feet 11 inches, which includes a center board between the boilers. The volume of a rectangular box entirely covering one boiler, its casing and steam drum, would be 511 cubic feet, or 17.9 cubic feet per square foot of grate surface.

The boiler attachments are the same as those in the *Shearwater*, with the addition of a large separator common to both boilers. This separator has an inside diameter of 13¾ inches by a length of 78 inches. It is provided with an automatic drain into the condenser, designed to operate from a float inside the separator. The feed inlet is only 0.29 inch in diameter, requiring, therefore, a feed velocity of 27 feet per second. It is probable that the feed water enters the steam drum in the form of spray. The main steam pipe is 3 inches diameter at the engine, 3.35 inches diameter at the separator, and 2⅝ inches internal diameter from each drum, being only 1½ inches in the nipple forming the exit from the drum. The steam, therefore, leaves the boiler with a velocity of 130 feet per second.

It is to be regretted that the weight of the boilers could not be obtained.

AUXILIARIES.

A small auxiliary boiler of the Belleville type is placed in the fire room. It is used for distilling, and as a make up of fresh water for the main boilers. Salt water is freely used in it without serious or even troublesome consequences. Its principal dimensions are as follows:

Number of elements	5
Tubes in each element	6
Outside diameter of tubes, inches	3.23
Length of each element, inches	39.37
Grate surface, square feet	4.09
Heating surface, square feet	88.91
Height over all, inches	72½
Breadth over all, inches	49.4
Length over all, inches	51
Space occupied per square foot of grate surface, cubic feet	25.8

The following auxiliaries are fitted in the engine room:

Two feed pumps.
One bilge pump.
One Baird's evaporator.
One distiller.
One evaporator feed pump.
One distiller pump.
Two dynamo engines.

The feed pumps are of the Belleville type, 10¼ inches and 6¾ inches by 7 inches stroke.

There are two fresh water tanks forward of the boilers, holding 1,850 gallons.

As stated above, the steam trials here reported were made at the suggestion of Mr. Forbes, but the yacht could be spared for only a few days at the end of the season, and there was no time for any long trips at sea, or for any great preparation. The boilers were taken just as they would be found after two or three days' steaming, without cleaning the tubes either inside or outside. To exhibit the various qualities of the boilers as fully as possible in the short time at our disposal, four trials were run: 1st. An efficiency trial at the dock under natural draft; 2d.

An efficiency trial at sea under natural draft, with both boilers fired moderately; 3d. A forced draft trial at the dock, with one boiler fired to burn about 30 pounds of coal per square foot of grate surface; 4th. A trial at the dock under natural draft with one boiler, using salt feed.

In all these cases the engines were run to use all the steam made by the boilers. The firemen were instructed to carry 220 pounds pressure on the boilers (the safety valves being set at that pressure), and the reducing valve was set to reduce the steam to 175 pounds for the engine. It will be noticed that these pressures were not maintained throughout with regularity, as the firing was not good.

On the first three runs the coal and feed water were carefully weighed, and all data affecting the behavior of the boilers were kept half-hourly. While the engines were run to use up steam, indicator cards were taken only as a check on the results, and as a matter of general interest. Every precaution was followed to secure substantially accurate results. All joints in the suction of the feed pump were blanked, and a separate suction run to the filter tank. The feed delivery pipe led direct to the boilers, with a short branch connected with an auxiliary feed pump. Any leak through this branch would have gone back to the suction side of the pump, and joints were therefore not blanked. The joints of the bottom blows were broken and blanks put in. The separator drains were all closed, and the pipe leading to the condenser disconnected. The separator was blown from time to time into a barrel located in the port fire room, where the water was gauged. Before the forced draft trial took piace, the gauge glass of the separator was graduated by weighing the water out, so that the weight of water could be determined at once by differences of height in the glass.

The delivery of the air pump was led into a barrel placed behind the condenser, and a small steam pump carried the feed water up to two barrels placed on platform scales alongside of the main cylinders. These barrels were filled alternately, their weights recorded, and the water was run down into the filter box, from which it was pumped to the boilers. The suction of the small pump above referred to had also a make up connection with the ship's tanks. The only possible error of the record was either a mistake in entering the weights, or the running over of the filter tank. The tank was closely watched, and only once, in the second trial, did it run over, and the amount was insignificant compared with the total feed for the run.

The coal was weighed in buckets from spring balances placed in each fire room. A tally was kept as the coal was placed on the floor, and the time of weighing was recorded.

A separating calorimeter was fitted to the steam pipe above the separator, and a throttling calorimeter between the reducing valve and the engine stop valve. The records were taken from these instruments about once an hour, but the indications of moisture were too small to be reliable. It will be noticed that in all cases the thermometer at the engine stop valve indicated superheat, while the throttling calorimeter showed from 0 to 1.50 per cent. moisture. The small amount of water collected in the separator showed that the boiler gave nearly dry steam even when forced. Inasmuch as the thermometer and steam gauges had been tested before use, I am inclined to think that steam entering the engine was either superheated slightly, or perfectly dry.

Thermometer cups were placed in the main steam pipe next to the engine stop valve; between the reducing valve and the separator; between the separator and the boilers; in the pipes leading from the mud drums to the feed collectors; in the main feed pipe, and in the smoke pipe above the breeching. The last named projected about 18 inches into the pipe. The temperatures of steam in the steam pipe, excepting those next to the engine stop valve, are not recorded, as they were substantially those of saturated steam. The temperatures of gases in the smoke pipe were difficult to obtain. A graduated glass manometer was used during the first and second trials. The melting points of brass and antimony were used as approximations during the forced draft trial. The temperatures recorded are probably below those actually existing in the stack.

In working up the results, tables have been made out for the second and third trials, as the data were taken fully, and recorded. The first trial is reported in synopsis with the second and third, as its half-hourly record presents little variation.

The fourth trial was conducted for the specific purpose of determining the behavior of the boiler using sea water. It is therefore given at the end, by itself.

The following notes on the different trials are added by way of explanation:

First Trial.—This run was made on Friday night, November 23d, from 7·55 to 11·00, at the dock in New Bedford. Both boilers were in use and the engine was running. The trial was started by burning the fires down and leaving about 6 inches of hot coals on the grate. The water levels in the boilers, filter tank and separator were marked. The trial was ended with the fires burned down as at the start, and the water levels the same. The appended summary, No. 1, gives the results. The evaporation is fair for any boiler, but very good in this case, when the small ratio of heating surface to grate surface is considered. The dryness of the steam at the engine is to be remarked. The separating calorimeter connected with the pipe above the separator gave no indication of moisture. It is impossible to determine the moisture in this case, as the throttling calorimeter showed 1.53 per cent., while the thermometer near by gave 2 degrees superheat. The real value at the engines probably lies between them. The results recorded in the table for the moisture at the boiler are obtained by working back from the engine for both the above results. The drain from the separator amounted to 1.14 per cent. The steam pressure varied too much, as the firemen did not fire with regularity.

The results of this trial seem to me below the capacity of the boilers under good management. The shortness of the trial was due to some small joints to be made in preparation for a longer run at sea.

Second Trial.—This trial was conducted at sea in Long Island Sound. The yacht left New Bedford at 10 A. M., Saturday, November 24th, and returned to the dock at 6·30 A. M., Sunday, November 25th. The trial began at 10·44 A. M., off Sand Spit, and continued nineteen hours, while the yacht steamed to Stratford Point and back to Sand Spit, which she passed at 5·44 A. M. The distance run was 192 miles, and the average speed was 10.1 miles per hour.

At 10·44 the fires were hauled completely from the grates, and new fires were started with a weighed quantity of wood. The ash pans were cleaned, and all ashes and clinker were thrown overboard. The boilers responded quickly to the new fires, and the engines lost very little in speed. Within half an hour they were going ahead with throttle valve wide open. The supply of feed water was regular, but the firing was too irregular to get even the approximate amount of coal burnt per hour, except by taking the average for several consecutive hours. The steam pressure fluctuated considerably, but the engine ran constantly with the throttle wide open, and the boilers gave no trouble whatever. At times the men were excited about the feed supply, as the feed pumps did not behave well, but the water level did not vary so much from an actual variation in the supply, as from differences in the conditions of the fires. With green fires the water dropped down in the glass, and with hot fires it rose to the top of the glass very quickly. The tubes, however, did not suffer. The same dryness of steam was observed as in the first trial, with even a greater degree of superheat at the engine.

The evaporation per pound of coal was low on this run. This, I consider, largely due to the firing, although the flame was pouring out of the top of the stack during most of the run. To show what might have been accomplished by careful firing, I have divided the run into two parts with the evaporation set opposite each part. The improvement from 5.53 pounds of water per pound of coal to 7.40 pounds, was due to coaching the firemen.

The observations of temperature on the stack were discontinued at 6 P. M., as the glass manometer had melted down. A fatality struck the other thermometers, and several records had to be discontinued during the last four hours.

Other data for this run, not shown on the table, are as follows:

Indicated horse power	H.P. cylinder	79 75
	I.P. cylinder	86.27
	L.P. cylinder	105.45
Total		271.47
Feed water per I.H.P., pounds		20.62
Dry coal per I.H.P., pounds		3.17

These results do not take into consideration the steam used for the air and circulating pump, the feed pump, the dynamo engine and the heaters. The safety valve lifted occasionally, and some steam was lost. The trial was ended off Sand Spit with the fires very low, but about 200 pounds of coal had to be used to work into the dock, where the fires were hauled immediately, and the ashes weighed. This coal, with the proportion of ashes, was subtracted from the totals to give the amounts set down in the tables. The appended Table 1 gives the log of this run from hour to hour, and the synopsis, column 2, gives the average results.

Third Trial.—This run was made at the dock on Tuesday, November 27th, with one boiler, to determine the behavior under forced draft. The engines were run as in the other trials. A small Sturtevant blower was put into the starboard fire room with an air duct leading to the ash pan of the port boiler. Manometers were fitted to indicate air pressures in the duct, ash pan and smoke pipe. With a pressure of $\frac{7}{16}$ inch water in the ash pan, about 29 pounds of coal were consumed per square foot of grate per hour. This was exceeded during the first two hours, while the fires were clean. The boiler behaved admirably, and the steam was perfectly dry at the engine. Even the throttling calorimeter indicated superheating. There was nothing to distinguish this trial from the others excepting the amount of coal burnt. The limit of 30 pounds per square foot of grate was set on account of the risk of fire to the decks. The base of the smoke pipe was red hot part of the time.

It will be noted that the evaporation improved toward the end of the run, as the firemen learned to manage the fire under forced draft, and the steam ran up from 4.75 to 7.23 pounds per pound of coal. Two or three of the joints in the feed collector which had started small leaks were made tight by setting down slightly on the chemise packing. The log of the trial is shown in the appended Table, No. 2, and the synopsis is given in column 3 of Table 3.

Fourth Trial.—This run was made at the dock on Wednesday, November 28th, entirely with the sea water as feed. The boiler had been drained on the previous night, and a number of caps taken off the tubes for examination. The tubes and mud drum were found to be clean and free from scale. The trial, which began at 8·30 A. M. and ended at 5·30 P. M., was planned to continue at least twelve hours with saturation kept at 6 by blowing. The starboard boiler was used, and the engine was run as before. The steam was practically dry at the engine, and the separator showed very little water. The amount of coal burnt per hour was 490 pounds, and the amount of feed water per hour (based on the result of the second trial) was about 2,940 pounds. The feed water was not weighed in this case, as the boat had to be cleared of apparatus for Thanksgiving Day. The saturation was taken four or five times an hour, in a salinometer pot connected with the mud drum. It gradually increased to $4\frac{1}{4}$ at noon, when it dropped to $\frac{3}{4}$ within fifteen minutes, and from that hour until 4 o'clock fluctuated from $\frac{3}{4}$ up to 6, sometimes dropping down suddenly, at other times going up as quickly. With a green fire it seemed to be down; with a hot fire it rose again. At 4·30 P. M. a fusible plug blew out in the second element from inboard, but the trial was continued until it was discovered that all the tubes of this element, and many others in its neighborhood, were red hot. The fire was then hauled at 5·30 P. M. The saturation had gone up to 7 for a short time after 4 o'clock, and the boiler was blown twice before hauling the fire. As a check on the results above, the saturation of water drawn direct from the mud drum into a bucket was taken, and found to be the same as that in the salinometer pot. The saturation of the feed water, as taken from overboard, was found to be 1.

During the whole run, the boiler behaved well, and showed no sign of distress even with red hot tubes. After hauling the fire, the water was blown out, and a number of caps were taken

Table 1.

NATURAL DRAFT TRIAL OF BOILERS ON THE STEAM YACHT *WILD DUCK*.

10'44 A. M. Nov. 24 to 5'44 A. M. Nov. 25, 1894.

Hour.	Pounds steam pressure above atmosphere. Boiler.	H.P. cylinder.	I.P. cylinder.	L.P. cylinder.	Vacuum.	Barometer.	Temperatures. Air.	Engine room.	Fire room.	Feed.	Circulation feed.	Steam at engine.	Injection.	Discharge.	Stack.	Strokes of air pump.	Main eng. revolut'ns per min. Counter.	By count.	Per cent. moisture in steam. At separator.	At engine.	Weights, pounds. Coal.	Feed water.	Water from separator.	Coal per sq. ft. G. S.	Feed water per lb. coal.
A. M.																									
10'44	......	......	......	......	......	......	......	......	......	......	......	......	......	......	.....	.....	......	.....	.....	.....	*124				
11'44	200	170	71	8.5	24.3	30.85	55	60	90	80	369	379	50	90	944	96	151.7	161	.....	1.4	2,025	5,156	52		
P. M.																									
12'44	210	173	72	8.5	23.5	30.83	46	63	87	97	370	379	......	......	...	...	160.6	160	.....	1.4	739	6,164	53		
1'44	193	170	68	8.0	23.0	30.85	46	60	89	86	368	380	......	......	...	...	158.4	160	2.0	1.3	1,285	5,287	34		
2'44	198	171	72	9.0	23.0	30.82	47	64	89	86	371	378	50	92	850	89	157.5	159	.....	.6	872	3,634	34		
3'44	213	173	70	8.0	23.5	30.80	46	61	90	90	373	379	......	......	...	...	158.4	160	.....	1.5	349	5,269	59		
4'44	188	170	68	8.0	22.3	30.79	46	60	89	98	368	380	......	......	...	...	157.9	157	.....	1.4	906	4,671	55		
5'44	180	171	72	10.5	23.5	30.79	47	69	90	81	370	379	50	90	936	100	156.2	155	2.0	1.4	1,031	6,381	51		
6'44	195	173	71	10.0	24.5	30.78	46	71	92	80	368	378	......	......	...	...	156.4	156	.....	1.8	454	5,656	79		
7'44	203	169	69	10.0	23.5	30.78	46	70	90	82	370	380	51	92	...	90	155.3	154	.....	1.6	1,244	5,697	53	18.58	5.53
8'44	193	167	70	8.0	24.5	30.75	48	71	89	82	371	380	......	......	...	...	153.7	164	2.0	1.6	1,630	5,364	17		
9'44	207	171	72	9.0	25.0	30.73	52	76	92	82	374	379	......	......	...	...	160.9	161	.....	1.4	931	6,006	17		
10'44	216	174	70	9.0	25.0	30.71	47	74	89	81	377	378	50	90	...	114	161.7	162	3.0	1.4	1,270	6,088	146		
11'44	223	174	70	9.0	23.5	30.66	47	67	89	83	378	379	......	......	...	...	161.8	162	.....	1.4	835	5,704	36		
A. M.																									
12'44	220	170	67	8.0	24.3	30.63	44	69	92	93	364	380	......	......	...	...	162.2	161	.....	1.4	122	6,368	37		
1'44	205	168	68	8.0	24.3	30.62	42	68	96	84	.....	380	......	......	...	...	162.6	161	1.5	1.4	1,024	5,000	22		
2'44	196	172	71	8.5	24.3	30.58	40	67	92	82	.....	......	52	90	...	123	161.9	163	.....	1.4	259	5,306	11		
3'44	204	172	68	8.0	24.5	30.50	39	76	92	83	.....	......	......	......	...	...	162.6	162	.....	1.4	390	5.332	11		
4'44	198	166	68	8.0	25.0	30.54	40	72	91	80	.....	......	......	......	...	...	162.4	162	1.5	1.4	998	5,989	14		
5'44	180	165	53	5.0	24.0	30.52	37	62	92	80	.....	......	......	......	...	..	158.4	160	....	0	204	5,313	28	14.14	7.40
	201.2	170.5	69.	8.5	24.	30.72	45.3	67.4	90.5	84.7	370.8	379.2	50.5	90.6	910	102	159	160	2.0	1.4	16,662	106,385	809	16.24	6.39

*One-half the weight of wood.

off the tube boxes. The upper and lower tubes were found to be quite clean, but the tubes near the water line, especially those of the element which had blown out the fusible plug, were one-fourth full of salt. The mud drum was quite clean. The conclusion to be drawn from this test is, that the saturation varies in the mud drum with the condition of the fires and that the scale and salt tend to collect in the tubes near the water line. With light fires, probably the steam does not lift much water; consequently it leaves the salt behind in the tubes, and does not carry it into the steam drum, where it can find its way into the down cast or circulating pipe, and be blown out through the mud drum. A certain amount of steam condenses to heat the feed water, and thus freshens it. If no salt is lifted, this freshened sea water goes to the mud drum, and the saturation shows very low; but if the salt water is lifted from the tubes by forcing the fire, the mud drum shows a high saturation at once. The weight of salt pumped into the boiler was about 800 pounds, and as the boiler holds about 1200 pounds of water, it is certainly remarkable that the salinometer indicated only an average of about 3, and never got above 7. Subsequently the boiler was filled with fresh water, and the salt dissolved out. The boiler suffered no injury. During the test, the boiler pressure averaged about 190 pounds, and the steam at engine about 165 pounds.

In summing up the results of these trials, I would say that the Belleville boilers on the *Wild Duck* supply practically dry steam under all conditions of steaming; that they are easily managed, and that either salt or fresh water can be used in them. These particular boilers are efficient only when burning very little coal, say under 12 pounds. The flame from the fire passes direct to the smoke pipe over the tubes, and the heating surface does not get the benefit of it. Movable deflectors were originally placed among the elements, and the back half of the tubes was covered by a piece of sheet iron resting on the top row of tubes. Notwithstanding the presence of a few deflectors, and the deflecting plates, the coal burnt well up in the smoke pipe in all the trials. The cause of this seems to lie in the lowness

Table 2.

FORCED DRAFT TRIAL OF BOILER ON THE STEAM YACHT *WILD DUCK*.

3'55 P. M. to 10'08 P. M., Nov. 27, 1894.

Hour.	Pounds steam pressure above atm.		Barometer.	Temperatures.						Per cent. of moisture in steam		Inches air pressure.			Weights, pounds.			Coal per sq. ft. of G. S.	Feed water pr. lb. of coal.
	Boiler.	Engine.		Air.	Fire room.	Feed.	Circulation feed.	Steam at engine.	Stack.	At separator.	At engine.	Blower nozzle.	Ash pan.	Stack.	Coal.	Feed water.	Water from separator.		
3'55	....	......	......	...	......	......	......	......	....	....	.80	......	1/4						
4'55	210	175	30.56	...	110	70	......	385	....	....	.49	1/2	3/8	—1/8	908	4,210	11.	33 6	
5'55	185	170	30.56	47	110	69	......	378	From 800 to 1400	Calculated from water in separator, considering steam as dry at engine.	3° S .46	1/2	3/8	—1/8	1,089	4,532	11.	40.3	
6'55	189	171	30.56	...	111	70	377	376			.42	1/2	3/8	—1/8	888	4,517	10.4	32.9	4 75
7'55	195	170	30.57	...	111	71	......	391			4° S.	1/2	3/8	—1/8	672	4,575	16.1	24 9	
8 55	190	170	30.56	45	112	76	377	380			.10	1/2	3/8	—1/8	748	4,648	16.1	27.7	
9'55	198	170	30.56	...	116	73	......	382			.50	3/4	5/8	—1/8	628	5,147	1.0	23.3	7.23
10'08	....	......	......	...	......	......	......	......	....		....	3/4	5/8	......	....	881	.3		
	194.5	171	30.56	46	111.5	71 5	377	382	1100	.57	4° S. to .8 M.	9/16	7/16	—1/8	4,933	28,510	65.9	29.4	

S—Superheat. M—Moisture.

of the elements made necessary by the design of the boat. The tubes above the water line probably act as superheaters, and the steam carries very little water into the steam drum under ordinary circumstances. The circulation is increased materially by the column of water in the downcast, the height of which probably increases with the demand for feed water in the tubes. The temperature of the water entering the feed collector is quite remarkable, being nearly that of saturated steam of the same pressure. The fire, therefore, has to supply only the latent heat to the water on its way through the tubes. The mud drum becomes most efficient through heavy firing when using salt feed, as part of the salt water is then forced out of the tubes with the steam, and is carried through the downcast with the feed into the mud drum, whence it may be blown out. The saturation certainly ought to be taken from the elements near the water line.

The numerous attachments or accompaniments of the Belleville boiler show great ingenuity and careful study. The automatic feed of the *Wild Duck's* boilers did not seem to be reliable. The men were jockeying it all the time, and the feed was practically regulated by the feed checks near the bottom of the boilers. In the hands of a careful water tender, it might work well. However, the boilers gave no trouble even with a fluctuating water level. They would probably not suffer with the water two or three tubes below the gauge glass.

The separator did its work well, but the automatic drain was leaking, and it had to be shut off. The water was drained from time to time by hand. The drainage provided in this case seems to me wasteful, as all water is carried to the condenser, when it might just as well go to the feed tank where the heat would be utilized.

In conclusion, I will say that the boiler commends itself very highly for use in both land and marine service. A few changes, mainly in the line of detail rather than in principle, would no doubt improve its working. The lowness in evaporative efficiency shown in the tables, seems to me due to other causes than type. The firing was intermittent, and the firemen

Table 8.

RESULTS OF BOILER TRIALS ON THE STEAM YACHT *WILD DUCK*.

		1 Natural draft.	2 Natural draft.	3 Forced draft.
1. Date of trial		Nov. 23, 1894.	Nov. 24–25, 1894.	Nov. 27, 1894.
2. Duration of trial	Hours	3.25	19	6.217
3. Locality of trial		New Bedford.	Long Isl'd Sound.	New Bedford.
4. Type of boiler		Belleville.	Belleville.	Belleville.
5. Number of boilers		2	2	1
6. Number of furnaces		2	2	1
7. Grate surface—65½ inches wide, 59⅜ inches long—27 square feet area each	Square feet	54	54	27
8. Water-heating surface (1 boiler = 451 square feet)	Square feet	902	902	451
9. Steam-heating surface (1 boiler = 270 square feet)	Square feet	540	540	270
10. Total heating surface (1 boiler = 721 square feet)	Square feet	1,442	1,442	721
11. Total heating surface to grate surface		26.7	26.7	26.7
12. Grate surface to smoke pipe area		4.29	4.29	2.15
13. Mean steam pressure in boiler above atmosphere	Pounds	197	201.2	194.5
14. Mean steam pressure at engine stop valve above atmosphere	Pounds	172	170.5	171.
15. Atmospheric pressure, by barometer	Inches	......	30.72	30.56
16. Force of draft in inches of water	Inches	......	......	$\frac{7}{16}$
17. Temperature of external air	Degrees	46	45.3	46
18. Temperature of fire room	Degrees	90	90.5	111
19. Temperature of feed water	Degrees	86	84.7	71.5
20. Temperature of water in feed collector	Degrees	368	370.8	377
21. Temperature of steam at engine stop valve	Degrees	378	379.2	382
22. Temperature of saturated steam at engine stop valve	Degrees	375.8	375.2	375.4
23. Temperature of gases in smoke pipe	Degrees	900	910	1,100
24. Kind of coal		Pocahontas.	Pocahontas.	Pocahontas.
25. Total amount of coal consumed	Pounds	1,977	16,662	4,933
26. Moisture in coal	Per cent	2	2	2
27. Dry coal consumed	Pounds	1,937	16,329	4,834
28. Total refuse	Per cent	11.22	11.22	11.22
29. Total combustible	Pounds	1,715	14,472	4,281
30. Coal consumed per hour	Pounds	608	877	794
31. Dry coal consumed per hour	Pounds	596	859	778
32. Combustible consumed per hour	Pounds	528	762	689
33. Coal burned per square foot of grate surface per hour	Pounds	11.26	16.24	29.41
34. Coal burned per square foot of heating surface per hour	Pounds	.422	.608	1.101
35. Coal burned per square foot of smoke pipe area per hour	Pounds	48.37	69.77	63.17
36. Quality of steam [dry steam = unity]		.984–.969	.98	.9943
37. Percentage of moisture in steam at separator	Per cent	1.56–3.09	2	.57
38. Percentage of moisture in steam at engine stop valve, by throttling calorimeter	Per cent	1.53	1.4	4° sup.–.8 M.
39. Superheating of steam at engine stop valve, by thermometer	Degrees	2.2	4	6.6
40. Total weight of water pumped into boiler	Pounds	17,141	106,385	28,510
41. Water actually evaporated	Pounds	16,611	104,252	28,349
42. Equivalent water evaporated into dry steam from and at 212°	Pounds	19,884	124,790	34,098
43. Equivalent water evaporated into dry steam from and at 212° per hour	Pounds	6,118	6,568	5,484
44. Feed water per pound of dry coal	Pounds	8.85	6.52	5.89
45. Equivalent water per pound of dry coal from and at 212°	Pounds	10.26	7.64	7.05
46. Equivalent water per pound of combustible from and at 212°	Pounds	11.58	8.62	7.97

had been using hard coal up to the time of the trial, when they were suddenly shifted to soft coal. Attention has already been called to the lowness of the elements made necessary to get the boiler below the decks of a shallow vessel. A design, in which the breadth of the tube box and grate are much greater than the height through the tubes, is very unfavorable to economy. This is not a necessary part of the Belleville system, as the elements can be made six or eight tubes higher under ordinary circumstances. Few boilers would stand successfully the test of red hot tubes, and be ready for work immediately afterward.

WATER TUBE BOILERS.

By Nabor Soliani.

[Translated from the "Rivista Marittima" August and September, 1894, by Passed Assistant Engineer W. F. Worthington, U. S. Navy.]

DESCRIPTION AND CLASSIFICATION.

Take a tube bent back on itself to form a closed curve of any shape, fill it partly with water and expose it to a source of heat in such a manner that one branch of it is highly heated and the other not at all, or only slightly, attach a pump to keep it supplied with water and a valve at the upper part at the bend, to carry off the steam, and we have in this combination the embryo of a water tube boiler. Indeed a water tube boiler is nothing but a collection of such elements. When the boiler is in operation, the water evaporated in that branch of the tube exposed to heat rises to the upper part of it, which becomes the steam space, while in the cooler branch of the tube there is formed a descending current of water which replaces that drawn away. The elementary arrangement just outlined, and in which the circulation takes place naturally, may be said to be characteristic of all water tube boilers. There are, it is true, water tube boilers differently arranged, and in which the circulation is forced by mechanical means. But these are confined to a few types only and have been abandoned, forced circulation not being well adapted for use in boilers. The description which I have given of water tube boilers appears, then, correct, even if it is only applicable to those with natural circulation. We may, however, embrace all water tube boilers in one definition and say: "Water tube boilers are those in which the water to be evaporated is contained within the tubes which form the heating surface". Indeed, while in ordinary boilers the water is contained in a large receptacle, and the hot gases of combustion heat the water in contact with the walls of the receptacle, or that which passes between tubes, in water tube boilers, on the other hand, whether the circulation is natural or forced, the heating tubes themselves contain the water and constitute the essential part of the boiler; whence the name "water tube boilers".

Water tube boilers came into use both on land and at sea later than the other kind. They are, therefore, designed to fill requirements which the others were incapable of satisfying. What are these? On land, the principal one is to prevent or reduce the damage caused by explosions, and at sea to economize weight, or to be more precise, they are wanted on war vessels to stand continuously and without injury, and to utilize efficiently, the high rates of combustion which are attained with forced draft, and such as ordinary marine fire tube boilers, whether of the cylindrical or locomotive type, can not stand. There are other advantages in the use of water tube boilers in war vessels, which will be mentioned later, such as the rapidity with which steam can be raised and ease of repair on board; but, as before remarked, it is essentially their power compared with weight and space occupied which has pushed them on in their struggle with fire tube boilers, and which will cause them ultimately to triumph. These are not mere theoretical advantages but real and certain ones, known to be such by actual experiment.

We have seen that a water tube boiler, in its elementary form, is composed of a system of tubes forming a closed circuit, in one branch of which, that exposed to the fire, is formed an ascending current of water in a state of ebullition, in the other a descending current of cold, or at least cooler, water going to take the place of the other. But it is not necessary that, for every ascending tube, there shall be a corresponding descending one; indeed, it is, and should be, otherwise, a few descending tubes being sufficient, and even a single one may suffice, provided it is large enough to supply all the ascending tubes, which should generally be numerous and of small diameter, in order to have greater heating surface in proportion to volume and weight. Similarly, it is not necessary or desirable that there be as many steam drums as tubes, but just the other way, a single steam drum of suitable capacity being generally sufficient, and well adapted to serve the purpose.

This process of natural selection has led to the general adoption of two drums, a lower and an upper one, united by a nest of tubes of small diameter, which form the ascending branch of the boiler, and of one large tube, or a few tubes of lesser diameter, forming together the descending branch. The upper drum is the steam space and the lower the water space.

From the nature of the case, water tube boilers are susceptible of most varied forms, and at present there are almost as many forms in use or designed as there are possible combinations of the tubes and drums which form their elements. Naturally, all of these are not good, and some that are good for certain purposes are not so for others.

To examine all of these types would be a long and tiresome task, so I shall restrict myself to noticing typical boilers, about which may be grouped all the others, and give the preference to those which are used on shipboard. And, unless the contrary is expressly stated, all the boilers referred to must be understood to have a natural circulation.

First Group.—Water tube boilers with straight "sub-horizontal" tubes, that is, slightly inclined to the horizontal, arranged in series zig-zag.—For the sake of brevity I call "sub-horizontal" those tubes that are slightly inclined, that is, which lie almost horizontal; and "sub-vertical," those that are nearly vertical. I shall call those tubes "in series" when they are joined one to another in such a manner as to form a single tube which extends from the water space to the steam space, and "in multiple arc" when the tubes are each independent of the other between the water space and steam space.

The Belleville boiler may be considered the type of this group. In it, the water space situated at the bottom and in front, and the steam space, much larger, above and also at the front, are united; first, by a nest of "serpentines," each composed of straight tubes arranged zig-zag, one after the other, and forming the heating surface or ascending branch of the boiler; second by one tube of large diameter, which forms the descending branch and also acts as a separator.

It is well to note here that the tubes in this boiler, slightly inclined to the horizontal, have a rather large diameter (7 to 12 centimeters outside). Many of the water tube boilers used on land may be grouped about the Belleville boiler as a type. But the Belleville boiler is used extensively in France on shipboard also, especially on war vessels, and the English Admiralty has decided to use it on two large cruisers, the *Powerful* and *Terrible*, of 14,000 tons displacement and 25,000 I.H.P.

Second group.—Water tube boilers with straight "sub-horizontal" tubes, placed parallel (in "multiple arc").—The greater number of water tube boilers used on land belong to this group. While, in the Belleville boiler, the tubes, divided in groups, are united "in series" in each group, (that is to say, are arranged one after the other in such a way as to form a continuous zig-zag pipe running from the water to the steam space) in the type under discussion, for example the Babcock and Wilcox boiler, the tubes, also sub-horizontal, and arranged in groups, are all parallel to each other and connect in "multiple arc" a vertical pipe, which forms the descending branch on one side, with another vertical pipe situated on the opposite side of the boiler, and which forms the means of communication between all the tubes of one group and the steam space. In the Heine boiler, a single lamina of water, of a breadth equal to that of the boiler, forms the descending branch, and the tubes, all parallel and in a single nest, have their origin in the descending branch and terminate at their other extremity in another vertical lamina of water, which connects with the steam space, of which it forms, so to speak, an appendage.

The difference due to arranging the tubes "in series" and in "multiple arc" is a very important one practically, and more will be said on the subject later. The Heine boiler used on land, is found on ship board in the form of the Oriolle, Lagrafel-d'Allest, Yarrow with sub-horizontal tubes, and Seaton boiler, all of which have straight tubes, slightly inclined and parallel, placed in "multiple arc" between the water and steam space. The Towne boiler also belongs to this group. In it the tubes connect the lower part of one lamina of water on one side of the boiler, which acts in this part as a water space, with the upper part of an equal and symmetrical lamina of water situated on the other side and which acts in this part as an appendage to the steam space.

Third Group.—Water tube boilers with curved, submerged tubes.—In these the water drum or drums, if there are two, situated at the bottom, and generally at the sides of the furnace, are connected with the steam drum, or drums, situated above, by nests of heating tubes of small diameter, more or less curved, forming an ascending branch, and by one or more pipes of larger size forming the descending branch. The heating tubes connect with the lowest part of the steam drum, or drums, and therefore remain entirely below the level of the water. To this group belong the Normand boilers, the White boiler with spiral tubes, and the Fleming and Ferguson boilers.

The Belleville boiler has the straight tubes of each nest joined in such a way as to form return bends. If in place of the jointed tubes of each nest we substitute a single tube to run from the water to the steam, we have another boiler of the same type. This is the Du Temple boiler, used so successfully on ships and torpedo boats of the French Navy. In the case of the single tube, the bend at the turn, being an easy one instead of a sudden one as in the Belleville boiler, the resistance to the motion of the fluid is less, and therefore the circulation more active. The bends themselves serve to render it more active, as this part of the tube is nearly vertical. Indeed, in the Du Temple boiler, tubes of small diameter (20 to 30 mm.) can be used with much advantage in the way of reducing weight, which would not be possible with Belleville boilers.

Fourth Group.—Boilers with curved water tubes which partly emerge above the level of the water.—These boilers resemble the preceding ones, and differ from them only in that the tubes join the steam drum at its upper part, and therefore the tubes are partially above the water. The difference is important, since it influences the circulation and the action of the boiler. To this group belong the Thornycroft, the Mosher, (which is a Thornycroft boiler with two lateral steam drums instead of one central drum) the Cowles and the Ward boiler in shape of a parallelopiped, the tubes having return bends.

Fifth Group.—Water tube boilers with straight "sub-vertical" submerged tubes.—These are formed like the preceding ones with one or two water drums below and one or two steam drums above, connected by straight heating tubes, almost vertical, completely submerged; that is, the tubes join the steam drum at its lowest point. To this group belong the Yarrow and Blechynden, which latter differs from the former only in that the tubes are slightly curved in order to facilitate removing them by enabling them to pass through small openings made in the walls of the steam drum.

Sixth Group.—Circular water tube boilers.—These boilers have the form of a vertical cylinder, circular or elliptical; the heating surface is composed of tubes with circular or elliptical section "sub-horizontal," and united in such a way as to form a number of large spirals or segments of spirals, concentric and rising from the water to the steam drum. The water drum is sometimes annular and forms the exterior base of the boiler; sometimes it is central and in the form of a vertical, cylindrical pipe, placed in the center, the upper part of which serves as a steam drum; in other boilers the lower annular drum and the central one are found combined. The segmental tubes are attached at one end to the water drum and at the other to the steam drum, as in the Morin boiler, or they connect with vertical and horizontal tubes which place them in more direct communication with the steam space, as in the Ward boiler. The segments may be more or less inclined; that is to say, the spiral which they form may have a greater or less pitch. The Ward boiler has been found very successful on the American war vessel *Monterey.* The grate has a circular or elliptical form, to correspond with that of the boiler.

Seventh Group.—Boilers with Field tubes.—The Field boiler is well known. In it the circuit typical of the water tube boiler is completed in each element, composed as it is of two tubes, one inside the other. The descending current is formed in the inner tube, and the ascending in the outer one. In the Field boiler, the tubes are generally placed in a vertical position, hanging from the crown of a vertical cylindrical furnace. If the tubes are inclined and project from the lamina of water which forms the ascending branch of a Lagrafel-d'Allest boiler, the opposite lamina being omitted, we then have the Dürr boiler, much used on land, but which has also been used with good results on German war vessels. If then, in place of the lamina of water of the Dürr boilers, we substitute a number of vertical tubes of suitable form, we get the Niclausse boiler, used in France on shipboard, as well as on land. Both in the Dürr and in the Niclausse boilers a vertical diaphragm is placed at the upper end of the internal tubes to keep separate, in the lamina of water or in the vertical tubes, the descending current which enters the internal tubes from the ascending current which leaves the external tubes. The boilers are so constructed that all the tubes may be easily inspected and repaired.

Finally, if we take a locomotive boiler, remove the cylindrical part in which the tubes are situated, substitute in place of it a prolongation of the furnace so as to form a chamber as long as the boiler, then attach to the top of this gallery, beyond the furnace, a number of Field tubes, we thus get a Kingsley boiler, used in America, and which seems to me adapted for use on shipboard for auxiliary purposes.

Eighth Group.—Composite boilers with water and fire tubes.— These boilers, strictly speaking, do not belong to the general class of water tube boilers, insofar, that in them there is a departure from the principle that "all the heating surface is formed of tubes filled with water," but it seems proper to notice them here because they are primarily boilers composed entirely of tubes, and also because the idea of fire tubes combined with water tubes, applied to some of them, is original, and may prove to be a good one. The Bartlett boiler belongs to this class. In it the water tubes are placed in an inclined position between two vertical laminæ of water, as in a Lagrafel-d'Allest boiler, and are crossed by fire tubes which connect the exterior walls of the laminæ of water so as to serve as braces. The Anderson and Lyall boilers also belong to this mixed type.

ANALYSIS OF WATER TUBE BOILERS AND THEIR ACTION.

Having now reviewed all the various types of boilers insofar as relates to their general structure, we will undertake the examination of this structure more in detail, in order to learn how the parts should be made in order to produce the best form of boiler; that is to say, one which will satisfy in the best manner the requisites of great power, efficiency, durability, facility of repair, etc.

I shall begin at once by saying that, in my opinion, they are all good for use on land. It is only when they are required for use on shipboard, and particularly with forced draft, that difficulties arise. It is then that imperfections are discovered, arising either from insufficient circulation, or grate surface, or allowance for expansion under the influence of heat, or else arising from complication of parts, faulty construction, use of unsuitable material, etc.

Circulation of Water.—In water tube boilers when in use, there naturally arises an energetic circulation, due to an ascending current in the tubes highly heated by the furnace, and a descending current in the tubes which are heated in a less degree or not at all. What is the force which produces it? Many think it lies in the difference of weight of the columns of fluid in the ascending and the descending branches, the fluid in the former being lighter because warmer, and because it is composed of a mixture of water and steam. This explanation does not appear to be correct, at least in the generality of cases: in fact, neglecting for the moment the difference of weight due to the difference of temperature, and consequently the density of the water itself in the two branches, differences which, even though slight, certainly constitute a motive force in the sense referred to, I cannot understand why the presence of bubbles of steam in one branch can be a source of motive power in the mass of liquid; not at least while there is sufficient liquid in the tube to allow the bubbles to escape freely without breaking the continuity of the liquid column throughout its height; that is to say, without altering the static pressure which this column would exert on the other branch.

On the other hand, it will be admitted that the bubble of steam, while forcing its way into the liquid mass, tends to communicate to the latter its own motion, and thereby start a current in the same direction. This is not the case if the bubbles are so copious as to form with the liquid a kind of foam which almost completely fills the tubes. In this case, the continuity of the liquid column no longer exists, and it may then be true, and is so approximately, that the motive force of the current is due to the difference in weight of the two columns of fluid in the ascending and descending branches. In any case, the fact remains that the circulation becomes more active in proportion to the quantity of heat received by the tubes—that is, in proportion to the activity of the combustion. This correlation constitutes one of the greatest advantages of water tube boilers with natural circulation, since the circulation increases and decreases automatically as required, which is not the case where the circulation is forced, and where, consequently, it is almost impossible to maintain a constant relation between the circulation and the rate of combustion. This explains the lack of success of boilers with forced circulation, and their abandonment.

From what has been said, it may be argued that the existence of water tubes out of contact with the heat, is not strictly necessary to obtain a circulation, which latter may be started and be made amply sufficient without such tubes, since among the water tubes exposed to heat there will always be a sufficient number, situated at a sufficient distance from the furnace so that the heat of the products of combustion will not be able to evaporate the water in them, or at least not freely. This is the case, for example, in the Oriolle, Yarrow and Thornycroft boilers of most recent construction, in which the external descending tubes are omitted.

Besides by the rate of combustion, the circulation is influenced by the diameter, length, kind, form and arrangement of the tubes, the condition of their internal surface and the pressure of steam. By reducing the diameter of the tubes, the area of their inside cross section is diminished much more rapidly than their external surface, until a point is reached where the heat absorbed by the walls is sufficient to evaporate so large a part of the water in the tube as to render the latter incapable (because in the form of vapor) of taking any more heat from the tube, which is then liable to burn. This point is reached the sooner in proportion to the intensity of the heat, and therefore in boilers designed to be forced, the diameter of the tubes must not go below a certain limit. This limit varies, then, according to the form, arrangement, length, material and condition of the interior surface of the tube. If the tubes are dirty on the inside, not only is the resistance to circulation greater, but the absorbent power of the walls is also less and the tubes more liable to burn. If the tubes have many sharp bends which increase the resistance to the motion of the fluid, as for example in the case of the Belleville boiler, the limit is reached sooner, and it is necessary to use larger tubes. The same may be said if tubes of the same length have different inclinations, the circulation being all the more energetic in proportion as the tubes approach the vertical position, in which the bubbles of steam most easily escape.

If tubes of equal diameter have different lengths, the same inclination and the same total length, and consequently the same total heating surface, even admitting that in the two cases the resistance due to friction is simply proportional to the length, the total volume of the fluid current which will circulate in a given time, the density being the same, will be greater in the case of the short tubes, even if the velocity of the current in them be less, because this inferiority is more than compensated by the greater number of tubes. For this reason, short tubes are probably better adapted to intense combustion than long ones. This appears to me evident in the case of straight tubes in "multiple arc," especially straight tubes slightly inclined (that is, nearly horizontal), as are those of the Lagrafel-d'Allest and Oriolle boilers. Indeed, in this case the density of the mixture will be relatively more uniform in the shorter tubes, that is, in comparison with the mean density; in the larger tubes, the difference in density at the lower and upper ends will be greater, whence in the latter the water will be mixed with more steam than in the short tubes; and since the tubes in the lower rows are equally exposed to the full heat of the furnace, whether the tubes are short or long, the danger of burning will be greater in the latter case.

The matter is not so clear when we compare straight tubes arranged in "multiple arc" with the same kind arranged in "series." (For example, if we compare a Lagrafel-d'Allest boiler with a Belleville boiler, assuming that they both have tubes of the same diameter, same length and same number.) In the first place it should be observed that while in the case of a nest of tubes in "multiple arc" the specific volume of the mixture of water and steam is greater in the lowest tubes which are most exposed to the heat, on the other hand, with a nest of tubes "in series" the specific volume (vaporosita) is least in the lowest tubes and gradually becomes greater and greater in the tubes according to their proximity to the top. Therefore, in the case of tubes "in series" the specific volume of the contained steam and water may be made greater without danger, as the greatest specific volume occurs in the upper tubes which are not exposed to the greatest heat of the furnace. On the other hand, in case of a nest of tubes "in series" in order that the specific volume of the water in the upper tubes may not be dangerously high, it must be very moderate in the lower ones, while in case of tubes "in multiple arc" the specific volume in the lower tubes may be increased to the maximum compatible with safety, without fear that it may be excessive in the upper tubes. This being the case, the question to be settled before all others is the limit of temperature to be allowed in the lower tubes in both cases. These tubes are supposed to be alike in both cases and exposed to an equal source of heat. We may then assume that the quantity of heat they receive will also be equal under like conditions. The only difference in the lower tubes will be the density and velocity of the mixture of water and steam. In order that these tubes may be subjected to the same conditions with regard to the limit of temperature, it is necessary that the quantity of heat absorbed by the fluid which passes through them should be equal; that is, the quantity of steam generated must be the same in both cases. Therefore, calling Δ_a and V_a the density and velocity of the fluid in the lower tubes arranged in multiple arc, and Δ_s and V_s the density and velocity in the tubes in series, the following should be approximately true:

$$(1 - \Delta_a)\, V_a = (1 - \Delta_s)\, V_s \qquad (1)$$

that is, in the lower tubes the velocity of the fluid should vary inversely with the specific volume (*i. e.* should vary directly with the density.—Translator.). Now let there be two boilers, one with n rows of n parallel tubes each, arranged in multiple arc, and the other boiler with n groups of n tubes of the same size as the former and the same inclination, but arranged in series. In both cases the boilers will have n tubes in the lower row, but in one case these will be independent of those above, while in the other case they will be connected to them in series. Supposing for the time being that the resistance to the motion of the fluid is zero, the velocity will depend upon its density and the difference of level between the extremities of the tubes in both cases. What will be the minimum possible mean density? It seems to me rational to assume that the minimum possible density is that which gives the greatest circulation throughout, and it is easy to see that in this case the mean density will be about equal to half that of the water; that is, the mixture of steam and water should be about half steam and half water. This will be the density of the mixture in the lower tubes of the boiler with tubes in multiple arc, and will also be the density of the mixture in the tubes half way up in the nest of the boiler with tubes in series. The mean density being the same in both cases, the velocity of the mixture will depend solely on the difference in level, and since this is n times greater in the tubes in series, the mean velocity in these tubes will be $\sqrt{n}$ times greater; not in all the tubes (*i. e.* not in all the sections of a coil.—Translator.), but in those about half way up in the nest. In the lower tubes the velocity will be less (the quantity of fluid which will pass through each group of tubes in series should be equal), and it will be less in inverse ratio to the density of the fluid in that part.

Then if V_a is the velocity of the fluid in the lowest tube of the nest arranged in multiple arc, $V_s' = V_a\sqrt{n}$ will be the velocity in the tube half way up in the nest, in series; and if Δ_s' is the density in that part, using the preceding notation, we get:

$$\Delta_s' = \Delta_a \qquad (2)$$

$$\Delta_s' V_s' = \Delta_a V_a \sqrt{n} = \Delta_s' V_s \qquad (3)$$

Combining these equations with equation (1) we get:

$$V_s = V_a + \Delta_a V_a(\sqrt{n} - 1) \qquad (4)$$

$$\Delta_s = \frac{\Delta_a V_a \sqrt{n}}{V_a + \Delta_a V_a(\sqrt{n} - 1)} \qquad (5)$$

Assuming that the rate of combustion is urged to the point where $\Delta_a = \frac{1}{2}$, that is, until the mixture in the lowest tubes of the boiler in multiple arc will be half water and half steam, we get:

$$V_s = V_a + \tfrac{1}{2} V_a(\sqrt{n} - 1) \qquad (6)$$

$$\Delta_s = \frac{\frac{1}{2} V_a \sqrt{n}}{V_a + \frac{1}{2} V_a(\sqrt{n} - 1)} \qquad (7)$$

We may take a practical example and compare a Lagrafel d'Allest boiler with 16 rows of parallel tubes with 16 tubes in each row, with a Belleville boiler, having 16 groups of tubes in series with 16 tubes in each group.

$$n = 16;\ \sqrt{n} = 4;\ \text{we have } V_s = \tfrac{5}{2} V_a,$$

the velocity in the lowest tubes of the boiler (in series). Also $\Delta_s = \frac{4}{5}$ the density of the mixture in these tubes. In the highest tubes the density will be about $\frac{1}{8}$ and the velocity about twenty times that in the lowest tubes of the boiler in multiple arc.

If this were really the case, the advantage on the whole would appear to be with the boiler with the tubes in series, since in the lowest tubes most exposed to heat there would be a mixture of water and steam much more dense and having double the velocity of the fluid in the boiler with tubes in multiple arc, while half way up the nest of tubes, where the heat is not so intense, the mixture would have a mean density equal to that in the lowest tubes in multiple arc and a velocity four times as great; and finally in the upper tubes there would be very damp steam containing about 20 per cent. water. But this will not be the case if there is much resistance to the movement of the fluid, on account of friction of the walls of the tubes, change of direction at the bends, etc. In this case, the balance may be in favor of the tubes in multiple arc, in which the only resistance is the feeble one of friction of the walls of the tubes.

In the case in question of the Lagrafel-d'Allest and Belleville boilers, while in the former the velocity of the water in the lowest tubes (the density of the mixture being $\frac{1}{2}$) would be about $1\frac{1}{2}$ meters per second, in the latter, supposing (which is probable) that at each bend there would be a loss of heat equal to that corresponding to the mean velocity of the fluid, then the velocity in the tubes half way up the nest would be about 2.3 meters only, instead of 4 meters. And supposing (which seems plausible) that the density of the mixture in the lowest tubes is as before $\frac{8}{10}$, the velocity in these tubes would be about $1\frac{1}{2}$ meters, that is equal to that which exists in the lowest tubes of the Lagrafel-d'Allest boiler, instead of being more than twice as great, which we have seen to be necessary if the absorption of heat is to be the same in the two cases. This being so, in order that the lowest tubes in the Belleville boiler may be in as favorable condition (insofar as it relates to the heat which they can stand) as those of the Lagrafel-d'Allest boiler, the diameter of the former must be much greater, about double. Indeed, this is the case practically, the external diameter of the tubes in the Belleville boiler varying from $7\frac{1}{2}$ to 12 centimeters, while those in the Lagrafel-d'Allest boiler are a scant 5 centimeters.

The case is different if, instead of the Belleville boiler, we take the Du Temple. In the latter, although the tubes are bent back on themselves, as if made up of a number of straight tubes in series, the bends have an easy curve, so that the loss of head is little or nothing. And for this reason, or because in this boiler the tubes are of copper and placed at a greater angle to the horizontal, and the bends less numerous, they are able to stand very intense combustion when the tubes are very small (diameter 2 to 3 centimeters), smaller, indeed, than are used in boilers with tubes in multiple arc.

Influence of the material and condition of the tubes.—The material of the tube and the condition of the interior surface have obviously an influence on their capacity for receiving and transmitting heat, and it is easy to judge what the effect of these would be. As is well known, a thin layer of incrustation or deposit of grease is sufficient to perceptibly reduce the conductivity and to neutralize any superiority which might otherwise exist, on account of the nature of the material. Therefore, little reliance can be placed on the nature of the material of the tubes to increase their efficiency, and the choice of material is determined by other considerations, of which more will be said hereafter.

Influence of the steam pressure.—The pressure has a beneficial effect on the efficiency of the circulation in promoting the abstraction of heat from the heating surface, since, by increasing the pressure, the volume occupied by a given weight of steam is diminished, and there is, therefore, an increase in weight of steam which can pass through the tubes with a given density of the mixture of water and steam and given velocity of the current. The beneficial effect of the pressure in increasing the weight of steam circulating in a tube in a given time is reduced somewhat by the greater density of the steam itself, which has a tendency to reduce the propelling force actuating the circulation, and to increase the resistance to be overcome by the current of steam, but this reduction is relatively unimportant.

Mr. Thornycroft has made some important experiments which bear upon this question, and which were published in the Transactions of the Institution of Civil Engineers, London, 1890. These experiments showed that, with an increase in pressure, the weight of steam generated by a boiler increases proportionately, the volume of the mixture of water and steam remaining constant. That goes to show that the maximum rate of combustion, and consequently the maximum power, instead of being constant for a given boiler, as is the case with the ordinary fire tube boiler, increases in the case of water tube boilers with the increase of pressure at which the boiler is worked.

To increase the efficiency of water tube boilers it is, therefore, advantageous to work them at a higher pressure than that for which the engine is designed; this proceeding is perfectly practicable if the boiler can stand the pressure, which can be reduced afterwards to that required at the engine, and it is also convenient as a means of avoiding the bad effects on the engine, due to those fluctuations in pressure which are likely to occur in water tube boilers.

Submerged and partly submerged tubes.—There is a difference of opinion with regard to the advantages of submerged tubes over those that are partly submerged. The advocates of submerged tubes point out that these are not liable to be burned like the others by a sudden fall of the water level, due to the checking of combustion when the engines are stopped, which disadvantage of partly submerged tubes is increased necessarily by the fact that the latter are almost horizontal for a certain part of their length at the upper end, where consequently sediment is likely to be deposited, favoring burning. On the other hand, it is claimed that if the tubes are of proper diameter and are properly arranged, the defect before mentioned is not manifest, while the circulation is more energetic and more regular. That it is really more energetic does not appear to be yet well proven, nor does there appear to be any good reason for it; on the other hand, we readily admit that the circulation may be more regular; indeed, in the case of partly submerged tubes, when the circulation is once started, the mixture of steam and water always meets the same resistance as it emerges from the tube and is discharged into the steam drum; on the contrary, in the case of submerged tubes, debouching under water in the steam drum, the mixture, besides overcoming the constant resistance of the tubes, must overcome in the steam drum the weight of the column of superincumbent water, which varies in height and density.

The advocates of partly submerged tubes claim also that with them the surface of the water remains more tranquil, the water not being agitated by the irruption of the steam ascending from the tubes, wherefore the volume of the steam drum can be reduced considerably without disadvantage. Thus, while in boilers of the locomotive type the volume of the steam space should be at least almost sufficient to contain the amount of steam used by the engine in a space of six seconds, in boilers with partly submerged tubes, according to Thornycroft, the space may be reduced until it only contains the amount used in one-fourth of a second; that is to say, it may be reduced to one-twenty-fourth of the former size. Finally it should be observed that the danger of burning, in the case of partly submerged tubes, may vary greatly according to the arrangement of the tubes, and may be rendered in effect practically nil by placing the emerging parts so that they cannot be reached by the gases of combustion until the latter have been considerably cooled by passing over the submerged parts.

Straight and curved tubes, facilities for inspection, repair and renewal.—Straight tubes are generally easier than curved tubes to examine and clean on the outside as well as inside and also to remove and renew. Moreover, they may be arranged (as for example in the zig-zag series in the Belleville boiler) in such a manner as to be free to expand under the action of heat: but in this case, as they must be placed sub-horizontally and united with return bends, almost without any gradual curve at the bends, they must necessarily have a somewhat large diameter. Where the tubes are of small diameter (and this is the tendency in the great majority of marine water tube boilers) they must be arranged in multiple arc; that is to say, whether they are straight or curved they should lead directly from the water to the steam drum. In this case the curved tubes certainly adapt themselves to changes of form in the boiler produced by changes in temperature; but this is a question of degree, and, according to Yarrow, who prefers straight tubes, the difference of expansion of the tubes is so small that it may be neglected.

The question is altogether largely one of degree: a just appreciation of all the points involved depends upon conditions not yet fully ascertained, more experience being required, and also upon circumstances affecting special cases. For example, in cases where the tubes corrode very slowly, the question of facility of renewal would become one of minor importance, and it would be sufficient if the removal could be accomplished without great labor; especially when it is considered that even with straight tubes arranged in the best manner to facilitate inspection and renewal, these operations can not be performed without extinguishing the fire and emptying the boiler; that is to say, without putting the boiler out of service for a time. Moreover, the curved form is not altogether an impediment to ease of renewal, and indeed there are boilers with curved tubes which, in this respect, are not very different from those with straight tubes.

A really important feature would be the possibility of providing a temporary remedy in case of injury to a tube, while continuing the boiler in use, but this good quality for which the ordinary fire tube boilers are justly esteemed has not yet been secured in any form of water tube boiler, whether the tubes are straight or curved. Leaving that out of the question, and comparing water tube boilers simply from the point of view of accessibility of the tubes, facility for examination, cleaning and renewal, it may be said that water tube boilers with straight tubes are generally preferable. We should then place in the front rank the Belleville boilers, in which all the tubes are alike, and in which the operation of removing and replacing a tube can be performed without interfering with any other tube, and can be done in a few hours with the means in hand on board, by a couple of firemen who are moderately skilful. In the second rank are the boilers with sub-horizontal Field tubes, such as the Dürr and the Niclausse, in which the inspection and renewal of a tube is effected from the outside by simply removing a plug or cover on the boiler front without being obliged to enter the boiler at all; the operation of removing and renewing a tube is not much more trouble than in the case of the Belleville boiler, the tubes not being expanded in the tube sheet nor in the vertical pipes which connect them with the steam drum.

In my opinion, the next in order are the boilers with straight tubes in multiple arc, sub-horizontal, like the Oriolle, Lagrafel-d'Allest, Yarrow, Seaton, &c., in which the tubes are all alike and the operation of inspection or renewal can be conducted from the outside by removing a plug or cover in the front and on the back of the boiler; but, in all these, the operation of removing and renewing a tube is more laborious then in the case of the preceding boilers, the tubes being expanded in the tube sheets or in the vertical pipes, the sheets and pipes themselves also being fixed.

After these come the boilers with straight or curved tubes in multiple arc and sub-vertical arrangement (such as the Yarrow, Blechynden, Fleming and Ferguson), in which the straight or curved tubes can be removed and replaced from the inside of the steam drum, each being independent of the other.

Last of all are the boilers with curved tubes (Thornycroft, White, Normand, Du Temple), the curvature being different for different tubes, and in which to change one tube necessitates removing and replacing several.

The cleaning of the tubes of deposits of soot and ashes on the outside is accomplished by a jet of water or steam. It is naturally more difficult in the case of boilers with straight or curved sub-vertical tubes, since in this case the soot and ashes collect at the bottom on the water drums, where it is difficult to get at them, while with sub-horizontal tubes the ashes naturally fall into the furnace.

To facilitate cleaning the exterior of the sub-vertical tubes of his boiler, Mr. Yarrow has made the casing at the sides removable, giving up the advantage which would ensue from having the sides fixed and composed of a layer of water tubes, as in the Blechynden, Thornycroft and Mosher boilers. In connection with the subject of cleaning, due regard must be had to the space allowed between the tubes, which is made different in different parts, to regulate properly the course taken by the products of combustion. The same end can be accomplished by leaving such spaces sufficiently large in every part and making use of diaphragms to direct the course of the hot currents.

Corrosion.—Corrosion, which for the most part is manifested in the form of pitting in the interior of the tubes, is one of the points which requires much attention in water tube boilers, especially in the light ones, which have tubes of small diameter with thin walls. In such, the corrosion, however light, may be sufficient to produce a hole, and make it necessary to put the boiler out of use until repaired. The danger is also increased by imperfections, cracks, blisters, defects due to drawing, etc., which tubes generally have, whether they are seamless drawn or welded. Owing to the small diameter, such defects are not discovered when the tubes are inspected before being used.

Corrosion also affects the exterior, on account of the corrosive action of the moisture and the chemical constituents of the ashes and soot deposited in them; but this is less injurious than the internal corrosion, especially as the latter goes on even when the boiler is not in use, notwithstanding the care taken to prevent it. This disadvantage arising from the corrosion of the tubes is a very serious one for the boilers of war vessels, which lie out of use for long periods, since it may and does happen that boilers supposed to be in good condition and left out of use for some time show leaks the first time steam is raised. This difficulty is not peculiar to water tube boilers alone, but is common to all, even fire tube boilers, if the tubes are of iron or steel.

Experiments made in our Navy seem to show that of the two methods of preserving boilers, the dry method with quick lime and the wet method with alkaline water, the latter is the better. Where the latter is to be employed, care should be taken that, in the case of water tube boilers with tubes only partly submerged, the upper curve of the tube does not prevent the latter from being completely filled with water. The difficulties with regard to corrosion of the tubes would certainly be obviated by using tubes of copper or brass instead of steel or iron, but copper does not seem to be very suitable on account of the rapid reduction of its tensile strength when heated above a certain point, a thing that might occur in boilers with tubes partly submerged, and also in case of submerged tubes if deposits of grease form in the interior. This is the opinion of Mr. Thornycroft, a good authority, who has entirely given up the use of copper tubes in his boilers. He prefers brass tubes, especially in boilers with submerged tubes, but in his own, which have partly submerged tubes, he prefers steel.

Mr. Yarrow and M. DuTemple use copper tubes in their boilers, which have submerged tubes, and, it appears, with good results. It remains to be seen, however, whether the galvanic action likely to be set up between the copper tubes and the other parts of the boiler will not constitute an equally serious disadvantage.

Many other persons who are authorities on this subject advocate rejecting copper as well as brass. Mr. J. T. Milton, chief engineer of Lloyds, advocates the use of weldless steel tubes.

On the other hand, Mr. Ward, the well-known builder of circular water tube boilers, while admitting that copper is preferable to brass, advocates tubes of the softest iron, made with wood charcoal.

Mr. Yarrow suggests galvanizing the interior of iron or steel tubes to render them less liable to corrosion. He also prefers seamless drawn tubes to those with welds, since in the operation of welding, scoria is liable to get in the weld and assist corrosion.

The use of plates of zinc in the boiler, which has given good results in the ordinary boilers, is also recommended for water tube boilers, to assist in preserving them.

On the whole, the choice of the best material for tubes from the point of view of corrosion, is another doubtful point upon which we must look for experience to throw more light.

Methods of fastening the tubes, either to each other, or to other parts of the boiler.—Where tubes are joined together, or to other parts of the boiler, they should be arranged so that the joint shall be steam tight, and remain so, even when the boiler is worked at its maximum capacity. The attachment may be made in various ways, either by screwing the tubes into suitable holes, or simply by expanding or rolling them in these holes, or by fitting threaded couplings to the tubes. The threaded joint is only applicable in case of straight tubes, which have to be fixed only at one end, and even in this case the simple expanded joint is preferable, as it is easier to make and just as efficient. Couplings are used only in those boilers, or parts of a boiler, in which the expanded joint is not practicable. In the Ward boiler, all the joints are threaded couplings, even in those parts exposed to the fire, and the results are good. Notwithstanding the good results obtained in practice, there is a prevailing opinion that they form a more delicate joint than the expanded joint, and that they should be avoided, if possible. It is perhaps well to note that, with an expanded joint, the internal pressure always tends to keep it tight, which is not always the case where couplings are used.

But in whatever way joints are made, they are always weak points compared to the rest of the tube, and therefore the generally accepted opinion is that they should not be exposed to intense heat.

Efficiency of the heating surfaces.—In order that the heating surface may be efficient, two conditions are necessary. First, that the tubes be arranged in a direction normal, and preferably zig-zag (*à losanga*) to the direction of the products of combustion, in such a way that the gaseous current cannot take a straight course to the smoke pipe, but are caused by the tubes to deviate continually. Second, that by means of diaphragms, or by placing the tubes closer together in some places, the gases of combustion are caused to traverse the whole extent of the nest of tubes in such a manner that the whole length of every tube is effective as heating surface.

Having due regard to the requirements of cleaning, the spaces between the tubes are made smaller in proportion as their diameter is smaller, the limit being reached when there is only enough space left for the passage of the gases for combustion.

The heating surface of water tube boilers does not seem to be as efficient as that of fire tube boilers, perhaps because it is difficult to arrange it so that all will be utilized. There is a great difference in this respect between individual boilers.

Size of the furnace.—The space above the grate, between it and the tubes, should be large enough so that the combustion of the gases may be completed before they come in contact with the tubes. This is essential for perfect combustion, and for the preservation of the tubes, as has been well demonstrated by the accomplished Dr. Siemens, in his valuable memoir on "Combustion with free development of flame." Where this condition is not fulfilled, the combustion will be incomplete, with a corresponding loss of economy of combustible; besides, the boiler will smoke, and the tubes be covered with soot and soon burn. It may also happen that the unburned gases will ignite after passing the tubes, thus burning the plates of the uptake and smoke pipe, with all the attending evil consequences. The stream of fire, which, in such cases, will issue from the smoke pipe, is another disadvantage in the case of war vessels.

The importance of a large furnace, although generally admitted by all who have spoken or written about boilers, does not seem to me to have received much consideration by builders of boilers, as they often sacrifice it for the sake of gaining other advantages, and do not attach to it the importance which it deserves.

Arrangement of the tubes with regard to the grate and to the space occupied by the boiler.—In many water tube boilers, especially in those of the Thornycroft and Yarrow types, with sub-vertical tubes in multiple arc, the tubes are placed at the sides and reduce the space available, in the transverse direction, for the the grate. This is not a disadvantage in itself, and may prove to be just the contrary if there happens to be much space available in the direction of the breadth of the boiler. This would be the case, for example, on board a large ship, where the boilers are arranged in one or two rows in a fore-and-aft direction, with their fronts parallel to a fore and-aft plane. On the other hand, in the case of a small, narrow, long vessel, like a torpedo boat, torpedo boat catcher, or scout, where the boilers must necessarily be placed with their fronts in a transverse plane, the reduction of the breadth of the grate by the nests of tubes might be a disadvantage. Mr. Thornycroft has fully recognized this disadvantage and makes his latest boilers with a single large water drum of cylindrical form, and places it at the center of the nests of tubes, and with two other water drums, also cylindrical, but of small diameter, at the sides, to which latter are attached the ends of a single zig-zag row of tubes which form the envelope. Notwithstanding all this, the reduction of the breadth of the grate is still relatively large. It is true that in the case of water tube boilers the importance of ample grate surface is less than in the case of the ordinary boiler, as in the former the activity of combustion can be urged to a much greater degree; at the same time it should be considered that an ample grate surface is always advantageous, whether to get an abundance of power from the boiler with natural draft without using the blowers, or to have a furnace sufficiently large in proportion to the amount of combustible to be consumed in a given time.

In nearly all boilers then, the nest or nests of tubes are placed above the grate, or turn and pass over it, so that the boilers are very short but very high. In many cases, when it is a question of vessels of a certain size, or of torpedo boats, this arrangement is very good, because the boilers then require little space on the floor of the ship, and more in the vertical direction where there is plenty. (Indeed in torpedo boats the available space in the height is limited only by the conditions of stability and protection from shot.) But there are small protected cruisers, like our vessels of the *Tripoli* and *Partenope* type, in which the protective deck greatly limits the height available, and in such cases the most suitable form of water tube boilers is that in which the nest of tubes is situated wholly or partly back of the grate, such for example as the Cowles and the White boilers. Data with regard the the space occupied by boilers of different types is given in the table on the opposite page.

Radiation.—The radiation from water tube boilers used on shipboard may be great when their outer walls, composed of refractory materials, are exposed to intense heat, since it is impossible, on account of the weight involved, to make them thick enough to keep down the loss by radiation to moderate limits. This defect is common to many water tube boilers with sub-vertical tubes, in which the front and back of the furnace are composed of refractory materials and metal plates. In many of those with sub-horizontal tubes the refractory walls, besides being used

TABLE OF COMPARISON BETWEEN BOILERS OF DIFFERENT TYPES.

	Ratio of heating to grate surface.	Combustible in the coal burned. Per square foot of grate surface per hour.	Combustible in the coal burned. Per square foot heating surface per hour.	Draft in inches of water.	Steam produced, feed water being 212° F. Per pound of combustible burned.	Steam produced, feed water being 212° F. Per square foot heating surface per hour.	Steam produced, feed water being 212° F. Per cubic foot volume of boiler per hour.	Percentage of moisture in steam.	Heating surface per cubic foot of space occupied by the boiler.	Weight of boiler with water per cubic foot of space occupied by the boiler.	Power of the boiler. Per unit weight and volume of the boiler. $\frac{C.V.S.}{P.}$	Power of the boiler. Per unit volume of the boiler. $C.V.S.$	Indicated horse power. Per ton of boiler with water.	Indicated horse power. Per cubic foot of space occupied by the boiler.	Indicated horse power. Per square foot of heating surface.
		lbs.	(C)		(V)				(S)	(P)					
Marine cylindrical, double ended, Italian ship *Piemonte*	28	......	....	2.0	....	....	....	......	1.115	54.91	.266	14.60	33.3	29.3	8.
Marine cylindrical, single ended, Italian ship *Sardegna*	27.6	......	....	.5	....	....	....	......	.920	49.30	.173	8.55	21.5	17.5	5.67
Locomotive (Schichau), Italian ship *Urania*	41	51.2	1.25	1.6	....	....	....	......	1.776	46.80	.394	18.42	48.8	36.6	6.33
Locomotive (Orlando), Italian ship *Aretusa*	48	......	....	1.8	....	....	....	......	1.981	47.11	.391	18.43	48.8	36.8	5.68
Locomotive (Yarrow), H.M.S. *Havock*	......	......	....	3.0	....	....	....	......	1.667	36.69	.578	21.21	72.	42.35	7.77
Water tube boilers. Belleville cruiser *Milan*	29.4	......	....	Assisted	....	....	....	......	1.127	45.55	.170	7.76	21.3	15.54	4.20
Water tube boilers. Lagrafel-d'Allest	30	28.5	.95	Assisted	11.19	11.36	27.46	......	1.015	....	....	10.78	......	20.80	6.25
Water tube boilers. Ward	46.6	52.2	1.12	2.0	8.44	9.47	31.95	11.6	1.975	24.08	.776	18.67	77.6	38.05	4.64
Water tube boilers. Cowles	43.1	34.4	.80	2.0	8.42	6.96	25.15	......	1.828	22.46	.547	12.91	62.3	22.44	3.74
Water tube boilers. Thornycroft *Cushing*	64.5	61.8	.96	4.0	6.91	6.68	29.26	6.68	4.436	37.44	.784	29.35	87.3	52 42	3.60
Water tube boilers. Thornycroft *Daring*	42.3	......	....	....	....	....	....	......	1.219	14.97	.810	12.14	100.	24.2	6.08
Water tube boilers. Yarrow *Hornet*	50	......	....	1.5	....	....	....	......	2.267	24.96	.772	19.27	96.	38.5	5.18

(*a*.) The data of this table relating to the Cowles, Ward and Thornycroft (*Cushing*) boilers, is based on that published by S. H. Leonard, Passed Assistant Engineer, U. S. N., and Walter M. McFarland, Passed Assistant Engineer, U. S. N.

(*b*.) The data relative to the weight of the boilers, the space occupied and the power, should be understood as only approximate.

(*c*.) In the case of those boilers where the data with regard to the evaporation is wanting and only the I.H.P. is known, the value of the product *C. V. S.* has been calculated on the assumption that for every I.H.P. developed at the pistons of the engine there would be 17.63 pounds of steam per hour produced by the boiler (the temperature of the feed being 212 degrees Fahr.).

at the bottom around the furnace, are also used above at the sides of the nest of tubes, but even in these radiation is considerable.

Refractory materials are certainly useful and indeed necessary in the interior of the furnace, where they serve the double purpose of keeping up the temperature of the atmosphere in which the combustion goes on and of protecting the lower parts of the boiler from the destructive action of the flame; but they should form only an internal clothing for the furnace, the exterior walls of which should be formed of water tubes covered on the outside with a non-conducting substance. All other parts of the casing of the boiler subjected to great heat should also be composed of water tubes covered with non-conducting materials, wherever this can be arranged without interfering with the facility for cleaning the tubes. At the ends of the tubes, where the products of combustion are considerably cooled down, the casing should be composed simply of non-conducting material, which is light and incombustible, such as asbestos and cotton wool, and especially a mixture of asbestos and magnesia, which combines high nonconductive power with the greatest lightness. The arrangement just mentioned has been adopted for the Yarrow, Lagrafel d'Allest, and some other boilers.

Maximum power of water tube boilers.—The maximum power which it is possible to supply with a single water tube marine boiler, seems to me to have no other absolute limit than the conditions with regard to the space in which the boiler is to be located and worked. From the first boiler of a few hundred horse power we have already come to use boilers of 1,500 horse power each in the torpedo boat catcher *Daring* of the English Navy, which has Thornycroft boilers, and Mr. Ward, the well-known builder of water tube boilers, in his paper previously cited, after having mentioned that the boilers on his system, used on the *Monterey*, are of 1100 horse power each, does not hesitate to say that there is no difficulty in constructing and working water tube boilers of even much greater power; such is also the opinion of Messrs. Fleming and Ferguson, who have proposed to make water tube boilers of two thousand and more horse power.

That this should be so appears reasonable from the organic nature of the water tube boiler itself, thanks to which the difficulties in regard to increasing their dimensions beyond a certain limit do not exist, as they do in the case of the ordinary fire tube boilers. The question of the maximum power of a single water tube boiler is not without importance, since the power required affects the number required, their management, space occupied on board, number and complexity of the mountings and pipes, and the aggregate weight of the whole steam generating plant. The larger the boilers and the smaller their number, the easier they are to manage; and, other things being equal, the greater the saving in weight, space and accessories. On the other hand, the larger the boiler the greater the damage resulting from any casualty happening to one of them. The most suitable size of boiler depends, in particular cases, upon the total power of the machinery, the space available in the ship, and upon the conditions of the service upon which the vessel is to be used. Other things being equal, if water tube boilers are used, there should be a greater number than if there were fire tube boilers, because in the former case a simple leak of water from one tube would put the boiler out of use for at least several hours, while in the second case, it would be a defect which could be remedied in a few minutes. Therefore, on shipboard there should always be at least two water tube boilers, even when a single fire tube boiler would have answered. On the other hand, in large vessels which have necessarily a number of boilers, it seems to me that it would not be necessary that the number of water tube boilers should be much greater than it would be if fire tube boilers had been used.

An increased number of boilers serves, especially in war vessels, to limit the damage arising from accidents to one of them, whether from loss of material of the boiler itself, or loss of power of the motive apparatus; but if the number be sufficient for the requirements of the case, to exceed it would, in my opinion, be a mistake, because in addition to the disadvantages previously mentioned, it would increase the probability of accidents, which was the very thing attempted to be avoided.

In the mercantile marine, where the conditions of service are much more regular than in the Navy and the risks are less, a large number of boilers is less important, and for this reason it would be better to use boilers of greater power.

The specific power (capacità di potenza) of water tube boilers.— I call the specific power of a boiler the quantity of steam which it is capable of producing in practice, when urged to the utmost, per unit of space occupied and per unit of its weight, including the weight of the contained water. It seems to me that this quality is an important one for war vessels, since in most cases it is desired to have boilers which will furnish a maximum power for a minimum of weight and space.

Assuming the foregoing definition, and designating the said specific power by E, the weight of combustible burned per unit of heating surface by C, the weight of steam produced per unit weight of combustible burned by V, and the heating surface per unit volume of the boiler by S, and the weight of a unit volume by P, we get:

$$E = \frac{C\,V\,S}{P},$$

In order that this formula may have a value, and serve as a standard of comparison for the specific power of different boilers, the factors of which it is made up must be determined by laws which are rational, fixed and of easy application to practical cases. These laws, in my opinion, should be as follows:

1st. The combustible should be coal of good quality, such as is used on trials of vessels, and in getting the value of C, account should be taken of only that part of the combustible which is effectively burned on the grate.

2d. That the production of steam should be calculated "from and at" a given temperature of water, for example 100 degrees Centigrade.

3d. That the space occupied by the boiler should be measured by the parallelopiped having for its base the rectangle circumscribing the horizontal projection of the boiler, including the uptake, and for its height the height of the boiler from its lowest part, including the ash-pit, to the highest part, including the uptake.

4th. That the weight should include the bare boiler plus the weight of the fittings directly attached to it, plus the weight of the water at normal level.

Mr. Ward, in his paper previously cited, gives a formula similar to the preceding, and which, in his opinion, expresses the relative efficiency of boilers. The formula is as follows:

$$\text{Relative efficiency} = \frac{C\,V\,S}{P_1},$$

where C, V and S have the same signification as in the previous formula, but where P_1 expresses the weight per unit of heating surface instead of the weight per unit of volume. This formula does not seem to be well adapted to its purpose, nor sufficiently rational. Indeed it does not express the efficiency of the boiler with respect to the utilization of the combustible, because the same product $C \times V$ may be obtained when burning a small quantity of coal in an advantageous manner, in such a manner as to produce a large quantity of steam, and also when burning a large quantity in a disadvantageous manner, so that it produces a small quantity of steam, and rather than *efficiency*, which includes the idea of a return rendered, the Ward formula expresses the capacity of the boiler (that is its capability) to produce steam; it is probably in this sense that he uses the words "relative efficiency." But even taken in this sense, the formula appears to me defective in that it gives undue weight to the heating surface S. Indeed, if in this formula, instead of P_1 we substitute its value, $\frac{P}{S}$, from the preceding formula, we get,

$$\text{Relative efficiency} = \frac{C\,V\,S^2}{P},$$

from which it is seen that the efficiency of a boiler would vary directly with the square of the heating surface. This principle would be admissible if the hourly consumption of combustible in a boiler and the amount of steam produced were independent of the total amount of heating surface. Instead of this being so, the exact contrary is true. Increasing S increases the possible hourly consumption of combustible, or increases its production of steam; that augments the value of the product $C \times V$, so that the beneficial effect which the increase of the heating surface exercises in the efficiency of the boiler is already represented by the product CV, whence the factor S cannot appear in the formula except in its relation to C, inasmuch as the product CS gives the measure of the quantity of combustible burned.

For this reason I prefer to use the former formula $E = \frac{CVS}{P}$, to express the specific power, or relative efficiency of boilers, and it has been used in making the following table of comparison to express the specific power of boilers of different types, the data relative to which, under forced draft, has been determined.

If, from the second member of this equation, we remove the divisor P, we have the product CVS, which expresses the power of the boiler per unit volume occupied by it. This is an item for comparison, and I have thought advisable to note in the table its value for different boilers.

[That it is not an easy matter to originate a formula which will satisfactorily express the relative efficiency of different boilers will be apparent from an analysis of Col. Soliani's formula. If, instead of the letters, we substitute therein their values (using HS for heating surface), it becomes

$$E = \frac{\frac{combustible}{HS} \times V \times \frac{HS}{volume}}{\frac{weight}{volume}} = \frac{combustible \times V}{weight}.$$

In other words, it reduces itself to a statement that E is equal to the total evaporation divided by the weight of the boiler, regardless of the space occupied.

If the Ward formula be similarly expanded, it becomes

$$\text{Relative efficiency} = \frac{total\ evaporation \times HS}{weight \times volume},$$

or that it is equal to the total evaporation divided by the product of the weight per unit of heating surface and the space occupied.—EDITOR.]

Examining the figures in the table relative to the specific power of boilers, it will be observed that, even making due allowance for the fact that the figures showing the weight and space occupied are only approximate, still water tube boilers generally give more power per unit of space and weight than fire tube boilers. We must except the Belleville boiler, which, of all the water tube boilers given in the table, is the only one which furnishes less power than fire tube boilers. The second comparison of *power per unit of space occupied* is less favorable to water tube boilers; in this respect the water tube boilers are about on a par with fire tube boilers.

It is interesting to compare the results obtained from the Yarrow water tube boiler of the torpedo boat catcher *Hornet* with those of the locomotive boiler of the torpedo boat catcher *Havock*, made by the same builders, and which represents the extreme limit of power of locomotive boilers. If allowance is made for the difference in amount of forced draft used in the two cases, the comparison is decidedly in favor of the water tube boiler.

It is proper to observe that the space occupied by the boiler alone, as recorded in the table, does not give an exact idea of the space actually required for it on board ship. It will be necessary to add the space required for the fire room, passages behind the boiler, etc.; that is, it will be necessary to measure the space actually available for the boilers in the boiler compartments; but in doing this we would be liable to introduce greater discrepancies and uncertainties.

In the case of the *Hornet* and *Havock*, the former with eight water tube boilers and the latter with two of the locomotive type, the total useful space occupied in the boiler compartments per I.H.P. developed is about 2 per cent. greater in the case of the water tube boiler.

Management of water tube boilers.—The management of the fires requires less care in the case of water tube boilers than with fire tube boilers for the reason that the former are not sensibly injured like the latter by sudden changes in the rate of combustion, or by currents of cold air entering through the furnace doors, or by holes in the fire, due to improper firing.

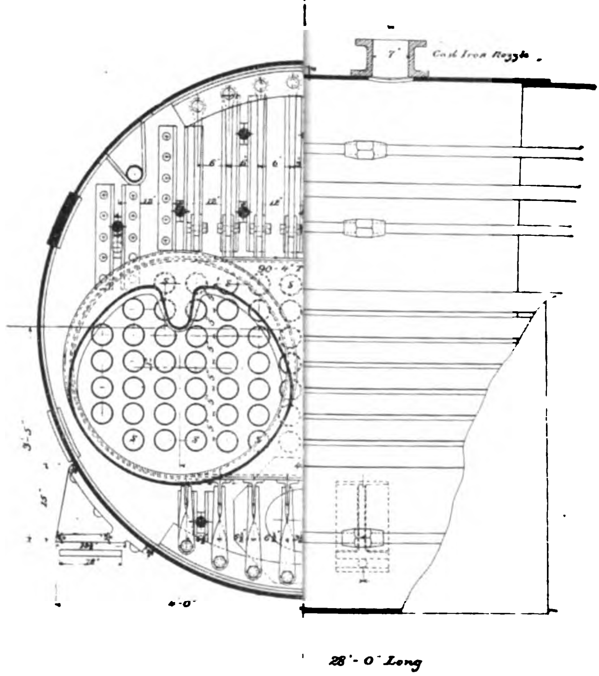
On the other hand, the regulation of the feed is more difficult, and requires more attention, especially if there are a number of boilers "in battery." This is another reason for reducing the number of boilers. In order to have a regular feed, where there are a number of water tube boilers used together on shipboard, it has been found necessary, or at least advantageous, to adopt special arrangements, such, for example, as automatic regulators, feed water accumulators, and separate pumps for each boiler, in order to render the feed of each boiler, as far as possible, independent of all the others. This sensitiveness in the action of the feed arises probably from the great changes in the pressure of the steam and of the level of the water in the boiler, due to the small quantity of water which these boilers contain, but it is also probably due to a certain extent to the want of experience hitherto had in the use of such boilers; and it is likely that in the course of time, when more simple means are discovered for regulating the feed, we shall be able to judge more correctly as to the importance of the irregularity of the action of the feed, which now appears to be a peculiarity of water tube boilers.

CONCLUSIONS.

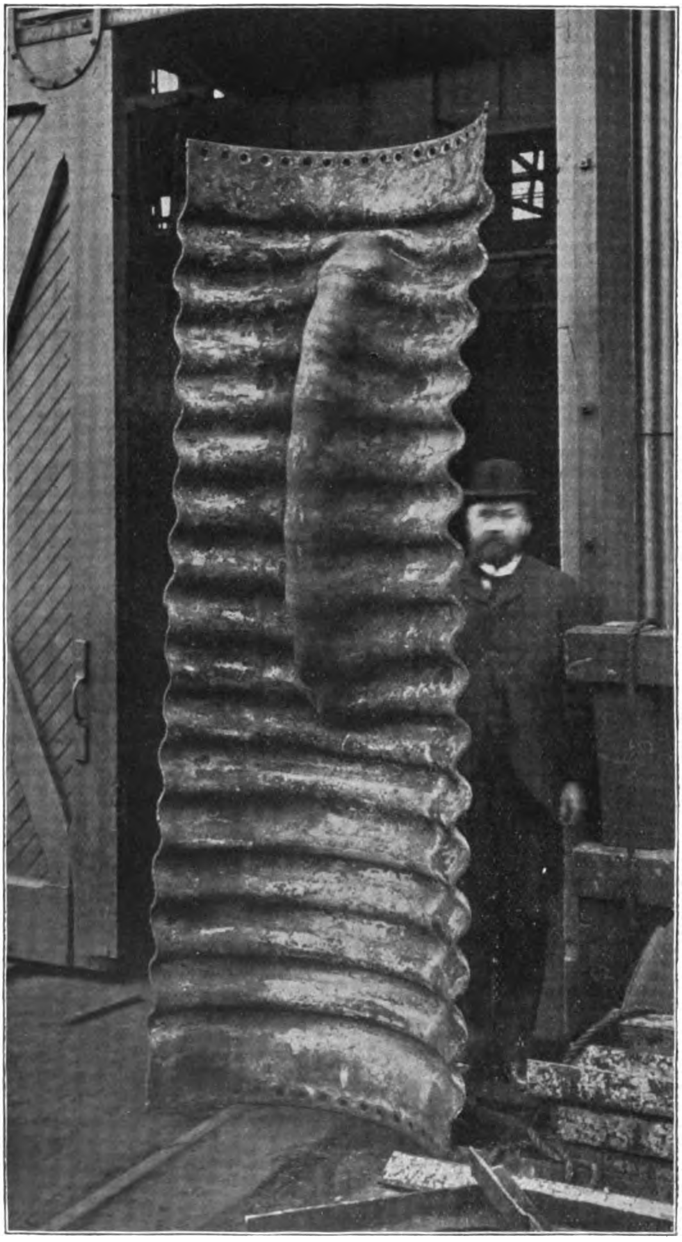
Water tube boilers are made on rational principles. Since it is necessary to use tubes in order to get a sufficient amount of heating surface, it is evidently advantageous to use such tubes also as receptacles for water. The outer shell, which in ordinary boilers surrounds the heating tubes, is a superfluity which has no *raison d'etre*, and its absence from water tube boilers is one of the reasons for the lightness of the latter compared with fire tube boilers. Another peculiarity which reduces their weight in a notable degree is the smaller quantity of water which they hold compared with their heating surface. The power of water tube boilers per unit weight is finally increased by the greater intensity of combustion which is admissible, compared with fire tube boilers, owing to the method of their construction. Composed as they are entirely of tubes, it is easy to arrange so that the latter can expand under the action of heat, and so that the flame will not strike the ends where they are attached to other parts of the boiler, but only the central part which can stand without injury a very intense heat when the circulation of water in the tubes is effective; and the construction of the boiler itself provides for this, since the circulation not only starts naturally but becomes more energetic in proportion as the action of the fire is more intense. From this peculiarity arises the great adaptability of water tube boilers to rapid changes, and without injurious consequences, from a very high rate of combustion to a low one and vice versa, which constitutes another important particular which, together with lightness, renders water tube boilers eminently suitable for war vessels. But that is not all; they have other advantages: they can be erected and taken down and renewed on board easily without removing a hatch coaming, without withdrawing the ship from service, while the same operations, in the case of fire tube boilers, would require the ship to be completely dismantled for no small period of time. Also the cost of construction and maintenance should, in the long run, be less. Indeed, if water tube boilers have only the tubes and not the shell, which forms such an important part of fire tube boilers, it is natural that they should be less expensive, both in construction and maintenance. In water tube boilers there are only the tubes to provide and keep in repair, and it is only reasonable to suppose that these will not cost more or require renewing oftener than fire tubes.

Another advantage not to be passed over, is the immunity from disastrous explosions. It may happen that from corrosion of a tube, a leak of water or steam may occur so that it will be necessary to throw the boiler out of use, but that will probably be the whole extent of the damage. In the case of fire tube boilers, the consequences would be very different if a leak should start in a furnace or combustion chamber. Fire tube boilers are better in one respect, that is, in the facility with which a leaky tube can be plugged without interfering with the use of the boiler; but this advantage will go on decreasing in proportion as means are found to overcome the effects of corrosion in water tube boilers, whether by galvanizing the tubes and having recourse to all the expedients which tend to lessen corrosion, or by using tubes made of some metal not subject to corrosion. In the same manner, the inherent difficulties with regard to the feeding of water tube boilers will disappear with the experience which will be acquired with regard to their peculiarities and also with the increase of size of single boilers, as when several boilers are required to be used together on a vessel, the number will be only great enough to provide a sufficient service in case an accident should happen to one. Some progress has already been made in this direction, and that is what, in my opinion, will facilitate the adoption of water tube boilers, even in the merchant marine, which requires an economical plant, and one that is easy to manage.

The future of water tube boilers seems henceforth assured. It is difficult to predict at this time what particular type will be preferred. The process of selection must be allowed to go on. The Belleville boilers have certainly given good results and are widely used, thanks to the state of perfection to which they have been advanced, both on merchant and war vessels. They have, too, many good points which render them desirable for use on shipboard, but they cannot be said to be perfect, nor superior to other types of water tube boilers now in use, and which certainly surpass them in power and other respects. It may even be said that from this time on the Belleville boilers will yield the palm to water tube boilers of other types in all cases where the first requisite is great specific power, in which cases they would not be suitable. So while it is likely that the Belleville boiler will be much used on large and medium vessels, it is, on the other hand, probable that the field of torpedo boats, torpedo boat catchers, fast cruisers, etc., will be reserved for lighter forms of water tube boilers, such as the Thornycroft, Yarrow, Normand, Blechynden, White, Lagrafel d'Allest, Du Temple, Ward, Cowles, etc.



7"
Cast Iron Nozzle
3'-5"
15"
4'-0"
28'-0" Long



PARTIAL COLLAPSE OF A CORRUGATED FURNACE FLUE.

By Assistant Engineer Charles H. Hayes, U. S. Navy.

The accompanying illustrations show the partial collapse, due to overheating and shortness of water, of a corrugated furnace flue, which occurred at 1·30 A. M., October 10, 1894, at the works of the Bergner & Engel Brewing Company, in Philadelphia.

This flue was made by the Continental Iron Works, Brooklyn, N. Y., and formed part of a two-furnace boiler of the gunboat type, which was built by the I. P. Morris Company, of Philadelphia. The boiler was connected with four other similar ones, each of which was fed separately, all working at a pressure of from 90 to 100 pounds per square inch. At the time of the collapse, the pressure was about 90 pounds, and the fires moderately heavy with a good quality of Atlantic bituminous coal. When the flue collapsed, the water had been out of sight in the glass for about thirty minutes, but the safety valve did not open at any time, either before or after the casualty.

An examination of the furnace showed the thickness of the metal at the top of the corrugations to be .376 inch, between the corrugations .383 inch, and at the bottom of the depression .353 inch, and gave indications of the water level having been about 10 inches below the crown. There were no rents, cracks or other defects visible on the depression, or on any other part of the furnace.

The other furnace began to go down in the same way, but there was only a depression about 2 inches deep on five of the corrugations.

There was no leaking, and no other injury or defect was discovered in the boiler while making repairs.

This collapse is chiefly noteworthy on account of the peculiar shape of the depression; showing the result of the pressure applied on the limited area about 8 inches wide and 4 feet 6 inches long on the overheated crown of the furnace, and also the excellent quality of the steel of which it was made as well as the integrity of the welding of the flue.

AIR PUMPS.

Conclusion of Discussion.

Chief Engineer G. W. Baird, U. S. Navy.—Mr. Bailey's paper so well covers the subject of air pumps that little is left to question; some observations and records may, however, be useful, if only to confirm.

The work of the air pump is diminished not only by more complete condensation of the vapor, but by the tightness of the joints, particularly in piston rod stuffing boxes and in drains, which have always demanded so much attention. The engines having two piston rods were particularly troublesome, as the distance between the rods at the piston when hot exceeded that between the center lines of the stuffing boxes, which wore the packing rapidly and created leaks.

The shop engine at Mare Island, which has a single piston rod, has a surface condenser but no air pump at all; the feed pump takes its water directly from the condenser; when new this condenser showed 21 inches of vacuum.

There has been some prejudice against horizontal air pumps, which has led to their condemnation without sufficient investigation. The *Vandalia's* condenser when new got from 22 to 25 inches of vacuum; the difference between the injection and the discharge water was small (about 20 degrees), but the feed water was very warm, from 40 to 50 degrees above the discharge water. It was a "two-part" condenser; *i. e.*, the sea water passed through half of the tubes and returned through the other half; the clearance spaces in the horizontal air pump were enormous; to diminish this the spaces were partly filled with wood, without, however, increasing the vacuum. The fault was found to be in the condenser, in that the exhaust steam entering the condenser was deflected by a rib directly into a space between the nests of tubes and thence to the air pump, without passing over the cold surfaces of the tubes; by filling this space, and by cutting away part of the obstructing rib, the condenser was so improved that the vacuum was increased to 26 and 26½ inches, when there appeared, if I remember correctly, a difference of about 25 degrees between the injection and the discharge water, and about the same between the discharge and the feed water; at this time the wooden filling having decayed, it was removed, leaving the original enormous clearance spaces, but neither the vacuum nor the condenser temperatures were altered by its removal. This pump was connected to the engine, having 42 inches stroke, and was double acting; its piston speed was 420 feet per minute; it ran quietly and never gave any trouble; the vacuum was "picked up" promptly, beginning with the first stroke of the engine.

The *Fish Hawk* has a single acting plunger horizontal air pump on each of her twin engines. The vacuum was satisfactory, but the temperature of the feed was not. She has a two-part condenser; the cold water entered at the bottom and was discharged at the top of the condenser; the pump connections were changed so as to put the cold water in at the top; the result was an increase of about 5 degrees in the temperature of the feed water, but without affecting the vacuum either way.

In each of these air pumps, the valves were circular, lifted vertically, and seated in water. I have always regarded this "water seal" as essential. No matter how shallow the depth of water on the valve seat, it seems to prevent the air leak back into the pump. This want of seal I have always believed to be the principal trouble with our air pumps having inclined seats; they may work well enough where a great quantity of water is handled, as with a jet condenser, but not so with a surface condenser.

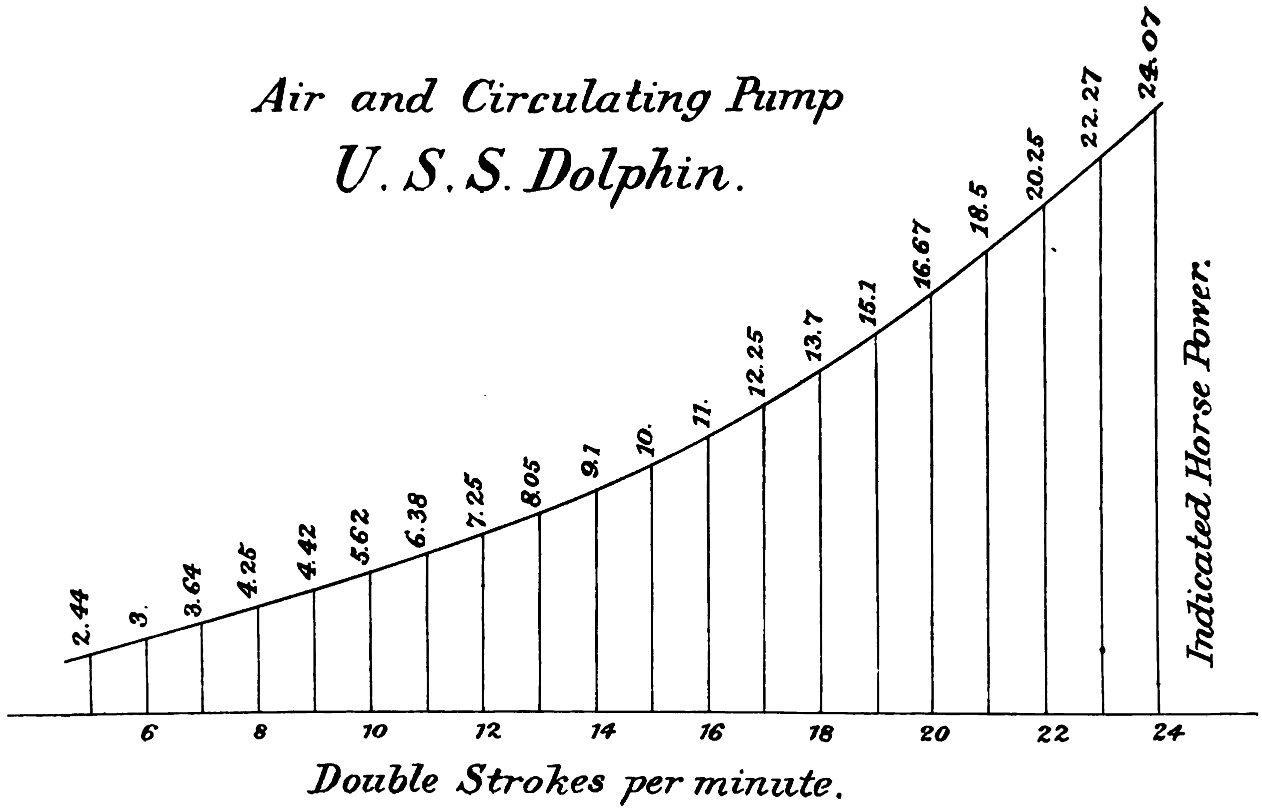
The best performance of the relatively small air pump in the steam cutter of the *Dolphin* is worthy of mention. The boat has a 3½ and 7 by 6-inch engine; the boiler has 6 square feet of grate, and the condenser 11 square feet of surface. At 315 revolutions the engine developed 13.8 I.H.P. The air pump is 2 inches in diameter and 1½ inches stroke, is vertical single acting. The air pump displacement, in cubic feet, per I.H.P., is .0622.

By tightening the joints on this keel condenser we got the vacuum up to 25, and for a short time 26 inches. The only difficulty is in insufficient joint surface, and the difficulty of access.

The multiple expansion engine, having a less number of rods working in a pressure below the atmosphere, has much less chance of air leaks than had the single expansion engines, and should, therefore, be able to work with less air pump. But as air leaks are liable to occur, and as the pump is liable to get an overload of water at any time (from a priming boiler for example), it would be unsafe to diminish the size of the air pump, and particularly of its valves, to a minimum.

The first thought of a careful engineer, when the engine begins to race, is the safety of his pumps; at such a moment the boiler is more apt to foam than at any other time, thus increasing the danger. This is what led to independent air pumps. The intermittent, jerky motion of the independent air pump so resembled "racing" that we were at once ready to testify against it; the circulating pump was then loaded upon it to regulate it, and with immediate success. The first of these was designed by Passed Assistant Engineer Newton, and installed in the *Wyandotte* and class (monitors); a single vertical steam cylinder, actuating two beams, the one carrying two vertical single-acting air pumps and the other two vertical circulating pumps. These were better than some that are used to-day, in that their steam valves afforded sufficient egress for the exhaust steam. Many "direct" pumps now in successful use are so cramped in the exhaust as to interpose a serious back pressure; this forcing the steam out of a cylinder, in addition to the legitimate work, increases the cost of the net power to a frightful amount; the horse power required to work the pumps should not be reckoned in comparison with the power to work the main engine; it should be figured in pounds of feed water per hour. Independent pumps, actuated by steam thrown valves, will not make the same stroke at different velocities of piston. I have in mind a combined pump having a nominal stroke of 24 inches on its steam end. It had been in successful operation for 12 years before it came to me. I found it making 21½ inches at its normal velocity; by moving the tap-

Air and Circulating Pump
U. S. S. Dolphin.



pets I lengthened the stroke to 22½ inches, when the pump would hesitate so long upon its centers that it was in danger of stopping. Then by speeding it up it would overrun this stroke. The enormous clearance spaces at each end of the cylinder, at each stroke of the piston, can readily be imagined. And yet it was unsafe to make further effort, for should the ship, in heavy rolling, throw the injection opening (which was well upon the turn of the bilge) out of water, this pump would have overrun its stroke, and probably knocked out a cylinder head.

The disabling of the air and circulating pump would disable the motive power of the ship. A record of the stroke may be of interest: At 10 double strokes per minute it made 21⅜; at 16, 21⅞; at 18, 22; at 20, 22¼, and at 24 double strokes, 22½ inches. The indicated horses required to run this independent air and circulating pump do not vary in any direct proportion.

The illustration shows the speed and power curve of the combined pump of the *Dolphin*, which has been reckoned as one of the very best of its kind. The normal speed of this pump is about 14 double strokes a minute, or about 56 feet velocity of piston; the steam follows the piston to the end of the stroke, and the throttle is necessarily kept nearly closed. At this speed, the indicated horse power amounts to about 9.1. To develop this power with a rotative engine, at a piston speed of 300 feet a minute, a compound engine with 4 and 8-inch cylinders would do the work with the pressure carried in the boilers of the *Dolphin*, instead of the single 22-inch diameter cylinder now employed. Connections are made in the *Dolphin*, and in other ships, for exhausting the steam from this pumping engine into the receiver, as a matter of economy, and it has been asked (more frequently by pump builders than by sea-going engineers) why this connection was so seldom used. The reason is plain; the pump is started before the engine, and must, therefore, be exhausted directly into the condenser; when the engine is running, the ship is in free route, the exhaust may be changed, but it requires at least three men, as one must attend to each of the two exhaust valves and one the main throttle. Now, let us suppose a signal comes to stop; the pump will stop automatically, as the receiver pressure will bank up from the pump exhaust and from the bleeder, and the result is a hot condenser. The time of stopping in a war vessel cannot be ascertained nor even guessed at. No sensible engineer would jeopardize the handling of the engine even for this saving. It would be better to compound these pumps, or at least to reduce the sizes of their steam cylinders.

The directly-connected air pump presents itself conspicuously as superior in saving weight, power and attendance. The pump Mr. Bailey has designed seems to admit of high speed, and the danger from racing is, therefore, eliminated. Practically, the pump valves which get out of order are, in nine cases out of ten, the suction valves; these also he has eliminated. Slow working engines profit by independent pumps, as the vacuum affords such assistance in starting; but with high pressure high speed engines the vacuum is "picked up" so quickly that I doubt if the difference, in practice, would be appreciable.

Passed Assistant Engineer F. H. Bailey, U. S. Navy.—It is certainly very gratifying to see the amount of interest which has been taken in this subject, as shown by the valuable discussion which it has brought forth.

Upon most points there seems to be a substantial agreement, but on one or two there is quite a difference of opinion. The greatest difference is the relative merits of the crank and fly wheel pumps compared with the direct acting ones. So far as the ratio of pump I.H.P. to that of the main engines, or the displacement of pump piston per I.H.P. of main engines is concerned, the tables do not show up at all well for the crank and fly wheel pump. It should, however, be borne in mind that these pumps were designed before their peculiarities had been well studied, and it was necessary to run them much faster than was desirable in order to keep them from stopping. It seems to me that the pump is entirely independent of its motive power, and that the same air pump piston displacement ought to give the same vacuum with a given engine whether the pump is attached to the main engine or driven from an independent engine directly or by means of a crank and fly wheel, provided, of course, that the piston speed is not too high for that particular pump. By adding up the capacities of the pump cylinders per minute, and dividing it by the sum of the I.H.P. of the pumps we get, for the crank and fly wheel pumps an average of 26.9 and for the direct acting pumps we get 22.3. From this we would conclude that for pump cylinders of equal capacities, or for pumps of suitable sizes for the main engines, the power required to drive them would be practically constant, whether the pump was driven directly or by means of a crank and fly wheel.

The *Olympia's* pump shows what can be done. The same thing can be done with two cylinders instead of three, but the pump would use a little more steam, as the valve setting would have to be different and not so good. This is shown by the *San Francisco's* pump. As originally built it was liable to stop at times, and it was considered necessary to run it at least 90 turns per minute to keep it going. Its valves were altered, and a heavier rim added to its fly wheels. Now it can be run from 3 revolutions per minute up, without danger of stopping.

The fly wheel gives a steadier motion to the pump the faster it runs, and that is what we want. Irregular motion is safe at low speeds, for the blow which the piston strikes upon the water is too light to do any harm, but without a fly wheel it would be unsafe to run a pump at the speeds given in the table for some of the fly wheel pumps therein shown. The gain in economy of the fly wheel pump is in its steadier motion. It does not stop at the end and "fill up" with steam. Whether this gain is of sufficient importance to merit its adoption, must be determined by the circumstances of that particular case.

The cheapest power is to be obtained from the main engines, and here it is often advisable to attach the pump, but in a man-of-war, where there is a good deal of manœuvring done, it will be necessary to attach another small air pump to the circulating pump (as was done in *Gunboat No. 7*) or resort to some other device to keep the condenser clear of water when the engines are standing still and the bleeder is being used.

One gentleman has spoken of the trouble which arises from letting the auxiliaries exhaust into the receiver instead of directly into the condenser. I think the gain is sufficient to warrant it in almost all cases. The arrangement for changing the exhaust into the condenser must have been very complex, or else so many men would not have been needed. The arrangement on the *Chicago* was very much better. There it was only necessary to open the valve admitting the exhaust directly into the condenser sufficiently to prevent the receiver pressure from rising too high. This valve was usually worked by the oiler, but it was near enough to the starting platform to permit of its being worked when necessary by the same man who worked the engine.

NOTES.

ACCIDENT TO THE MACHINERY OF *LA GASCOGNE.*

On her last voyage to New York, the French steamer *La Gascogne*, when three days out from Havre, sustained an accident to her engines which delayed her arrival upwards of a week and caused great anxiety for her safety. The accident happened on the 29th of January, and she reached Sandy Hook on the night of the 11th of February.

To fully understand the accident and the nature of the repairs made to enable the ship to make port, it is necessary to state that she has one six-cylinder quadruple expansion engine, with the cylinders placed tandem and operating three cranks. There is one high pressure, two first intermediate, one second intermediate, and two low pressure cylinders. The second intermediate is placed between the low pressure cylinders, and the high and the two first intermediate cylinders above them, the high pressure over the forward low pressure, and the first intermediates over the second intermediate and after low pressure cylinders. The piston of the second intermediate cylinder broke across, and as it would have been impossible to remove it from the cylinder, it was decided to throw out the center pair of cylinders, consisting of one of the first intermediate and the second intermediate cylinder, and to run with the remaining four cylinders on two cranks as a triple expansion engine. To do this it was necessary to disconnect the connecting rod and firmly secure the cross-head of the disabled engine so as to keep it from doing damage on account of the rolling of the ship. Then the steam valve of the second intermediate cylinder was taken out and a blank flange put on the exhaust pipe from the high pressure to the steam chest of the forward of the first intermediate cylinders, and one on its exhaust pipe to the second intermediate, so as to shut off the first intermediate cylinder. As thus arranged, the steam, after leaving the high pressure, went to the after first intermediate cylinder, and from there to the low pressure cylinders, passing through the second intermediate, which acted merely as an enlargement of the low pressure steam chests.

The repairs were completed in about eighteen hours, during heavy weather, and when the engine was again started the speed was reduced from 62, the revolutions before the accident occurred, to 35, with which she logged 66 miles up to noon of January 30, and 215, 255, 280 and 213 miles on January 31, February 1, 2 and 3, respectively. On the following day, a violent storm was encountered, and to add to the discomfort of everybody it became necessary to again stop the engines on account of the over heating of the after crank pin brasses and the consequent running of the white metal, remove the brasses, and put in the spare ones. This was a very trying task under the circumstances, as the spare brasses had to be refitted, but after working for forty-one hours it was accomplished and the engines once more started, but at a still lower speed than before, on account of the spare brasses not fitting well and the difficulty of keeping them cool. However, she managed to keep on under her own engine, and reached Sandy Hook on the night of February 11. After arrival, the work of fitting the new piston, and of putting the engine in good condition once more was taken in hand by the Morgan Iron Works and completed on the 16th of February.

Great credit is due Chief Engineer Eugene Martin, of *La Gascogne*, for the successful manner in which he and his force, working under such unfavorable conditions, completed the arrangements and thus enabled the ship to reach port. While this accident was not of so serious a character as the breaking of the thrust shaft of the *Umbria*, the extremely bad weather which prevailed at the time rendered the work of remedying the defect much more laborious and vexatious, and the engineer force is to be congratulated on its successful accomplishment.

TESTS OF THROTTLING CALORIMETERS.

Professor D. S. Jacobus of Stevens Institute, Hoboken, N. J., read a paper on this subject before the American Society of Mechanical Engineers, of which the following is an abstract.

The tests were preliminary to an investigation undertaken for the Babcock and Wilcox Co. by Professor Denton, to determine the conditions under which throttling calorimeters applied to a steam main are reliable means of determining the average amount of moisture in the total quantity of steam flowing through it.

The results of the experiments tend to confirm the opinion that the indication of these instruments may greatly exaggerate the amount of moisture, and that the degree of inaccuracy depends upon the local conditions.

If a nozzle closed at the inner end, and perforated with a number of small holes in its cylindrical surface, is employed, the calorimeter will ordinarily indicate too high a percentage of moisture, as shown in the table.

These results show that other devices than perforated nozzles should be employed to obtain an average sample of steam, and tests are in progress to determine the efficiency of an arrangement devised by Professor Denton, which consists of a tube passing through a stuffing-box, and so arranged that it may be moved to any position across the pipe under a full head of steam. The tube has an open end, and there are no side holes. This arrangement allows determinations to be made at all depths.

The nozzles were all of half-inch pipe, and were of the following forms:

Nozzle No. 1 contained twelve holes drilled along four equidistant lines parallel to the center line of the pipe. The centers of the four holes nearest to the outlet were about three-quarters of an inch from the inner surface of the three-inch pipe when the nozzle was screwed into place. The holes drilled along each line were about three-quarters of an inch apart.

Nozzle No. 2 was of the same form as No. 1, except that the holes were one-eighth inch in diameter, and the holes nearest the outlet were within three-eighths of an inch of the inner surface of the pipe when the nozzle was screwed into position.

Nozzle No. 3 contained six holes seven-thirty-seconds of an inch in diameter, drilled along two lines parallel to the center of the pipe and opposite each other. When in position the plane in which the holes were drilled was horizontal. The holes were three-quarters of an inch from each other, as in nozzles Nos. 1 and 2.

No. 4 is a special form of nozzle, in which a slot was cut about one-quarter of an inch wide and one inch long. This slot was placed so as to be at the center of the three-inch pipe. When the slot was turned so that the current of steam struck directly against it, the percentage of moisture indicated by the calorimeter was less than the true amount, and when turned so that it was away from the current the percentage of moisture was greater than the true amount. When placed at right angles to the current, an intermediate result was obtained, which was greater than the true amount of moisture. These experiments tend to show that the water which strikes a nozzle clings to it and passes around it so as to be drawn inward by the currents of steam entering the apertures. The nozzles were made with long threads, so that all the portion projecting into the three-inch steam pipe was threaded. All were closed at their inner ends.

To measure the amount of superheat in the steam the thermometer was placed in a special form of mercury well, having a bulb at its lower extremity, and provided with a very thin neck leading from this bulb to the outside of the pipe. The large bulb combined with the thin neck overcomes the error introduced by conduction of the pipe to the well, which in a well of a three-eighths-of-an-inch pipe, four inches long, amounts to about four degrees Fahr. This large error occurs only in the case of superheated steam.

To obtain the value of one degree of superheat measured in this way, including all radiation effects, the following method was employed: The entire amount of steam flowing through the three-inch pipe was throttled after passing by the calorimeter nozzle, and the temperature of the steam at low pressure was measured after it entered the twelve-inch drum. The temperature of the superheated steam was measured before and after throttling, no water being injected. The temperature before throttling was measured in a six-inch drum placed just before the point where the water was injected in the regular tests, so that the entire effect of radiation was included. All portions of the apparatus were well covered with hair felt. This method of allowing for the initial superheating of the steam was checked up to the limit of moisture that could be indicated by superheating in the twelve-inch drum, and was found to agree within one-fifth of one per cent.

Whenever the amount of moisture was low enough to cause the steam in the twelve-inch drum to be superheated, the percentages obtained by weighing, given in Table I, were checked by the percentages obtained by calculation from the superheat.

The basis of pressure was a plug device which was loaded with weights so as to correspond to the required pressures. The plug was one-half inch in diameter, and the hole in the bushing into which it was fitted was 0.5005 inch. Both the plug and the bushing were ground true, and were the work of the Pratt & Whitney Company. The readings obtained with this plug were checked by the square-inch knife-edge piece device of the Ashcroft Company and by a mercury column.

To standardize the thermometers they were placed in the mercury wells in which they were used, or in similar ones, and subjected to a known pressure of saturated steam. The corrections were made by employing Regnault's values for the temperature of saturated steam, so that the final readings correspond to the temperatures by an air thermometer. In general, if the entire column of mercury in the thermometer is heated, the reading indicated by the same will be too high; whereas, if a large portion of the column of mercury contained in the stem is not heated, the reading will be too low.

The radiation of the Barrus calorimeter was determined by passing superheated steam through it. The separator portion was filled with water to a given height in the glass, and the temperature of the superheated steam was adjusted so that the water level remained constant in the glass. If the water increased in height, the temperature of the entering steam was increased so as to re-evaporate some of the water; and if it fell too low, the temperature of the steam was decreased. The tests were extended over several hours. An average of the loss of superheat represents the losses by radiation. To determine the radiation of the heat gauge portion, the orifice was removed and superheated steam was passed through the apparatus at the same rate as if the orifice had been present. In this case the loss of superheat also represents the loss by radiation.

The true percentage of moisture was determined as follows: A known weight of water at a temperature of about 65° Fahr. was injected into a three-inch pipe, and traveled along with the steam for a distance of about eight feet into a three-inch Stratton separator. After leaving the separator the steam passed through a three-inch horizontal nipple six inches long into a twelve-inch drum four feet long. A valve between the nipple and twelve-inch drum was used to throttle the steam so as to obtain the desired rate of flow and maintain a pressure in the twelve-inch drum equal to about that of the atmosphere. The steam flowed from the twelve-inch drum through a system of piping into a surface condenser, and was finally weighed. The calorimeter nozzle was tapped into the three-inch nipple between the throttling valve and the separator at a distance of about three inches from the separator. The steam was turned at right angles in passing from the separator to the outlet pipe, so that the experiments correspond to placing calorimeters in a horizontal pipe near an elbow. The drip pipe of the separator was closed, and the water rose to such a height in the separator that it mingled with the steam passing from the same. This arrangement was adopted in order to obtain a thorough mixture of the steam and water.

A constant amount of moisture was maintained by taking weighings of the condensed steam and water every five minutes, and regulating the flow of water to a uniform rate. A continuous record was preserved, and only that portion where uniform conditions were maintained was employed in calculating the final results. The average length of such selected intervals was about twenty-five minutes, so that five readings of weights were used in calculating the results of each test. The readings of temperatures were made every two and one-half minutes.

COMPARISON OF ACTUAL PERCENTAGES OF MOISTURE WITH AMOUNTS INDICATED BY A THROTTLING CALORIMETER; STEAM PASSING THROUGH A THREE-INCH HORIZONTAL PIPE.

No. of test.	Character of nozzle.	Steam passing through pipe per hour, including moisture shown in column 6.	Pressure of steam in pounds per sq. inch above atmosphere.	Percentage of moisture by Barrus calorimeter.	Correct percentage of moisture determined by weighing water injected into steam pipe.	Remarks.
1	2	3	4	5	6	7
1	Vertical nozzle No. 1 with 12 holes $\frac{17}{32}$-in. diameter.....	1698	80	5.5	2.5	Separator of calorimeter and heat gauge both in use.
2		1877	80	9.3	3.3	
3		1768	80	11.1	4.7	
4		1788	80	20.9	10.9	
5		2003	80	31.8	19.1	
6		2381	80	47.9	36.5	
7	Vertical nozzle No. 2 with 12 holes $\frac{1}{8}$-in. diameter	1916	78 5	54.6*	21.0	
8		2044	78 9	50.8*	17.6	
9	Horizontal nozzle No. 3 with 6 holes $\frac{7}{32}$-in. diameter...	1538	80	6 3	2 3	
10		1586	80	8.4	3.2	
11		1525	80	14.6	8.8	
12		1637	80	17.8	10.1	
13		1745	80	37.4	23.0	
14		2187	80	46.9	37.2	
15	Nozzle No. 4. Slot away from current	1577	80	5 6	1.0	
16	Nozzle No. 4. Slot toward current............................	1576	80	0.1	1.4	
17	Nozzle No. 4. Slot at right angles to current	1578	80	2.5	1.2	

* In these tests the calorimeter was not attached to the same horizontal pipe as in the others, but to the pipe leading to the separator, and within about one foot of it, and the conditions were such that it is probable that moisture ran along the bottom of the pipe and entered the lower holes of the nozzle.

THE BRITISH SHIPBUILDING PROGRAMME.

The new shipbuilding programme provides for four first-class, four second-class and two third-class cruisers, twenty torpedo gunboats, and twenty torpedo boat destroyers. The first-class cruisers are to be improved *Blenheims*, and will be about 400 feet long, and have engines of 25,000 I.H.P., for a speed of 22 knots. The second-class cruisers will be improved *Talbots*, which latter are of 5,600 tons displacement, and they will have engines of 9,600 I.H.P., for a speed of 19½ knots. The torpedo gunboats will be larger than the *Dryad* class, and in all the new vessels a marked increase is made in the boiler power. The contract speed for the torpedo boat destroyers is to be 29 knots.

FRENCH WARSHIP BUILDING IN 1895.

From the "London Times."

In the years 1890 and 1891 the Superior Council of the French navy deliberated upon and laid down a tactical composition for the fleet, and, in accordance with the proposals then made, what was known as the "decennial programme" was adopted by the Naval Department at the close of 1891, but never expressly submitted for the sanction of Parliament. Within ten years eighty-two new vessels were to be laid down to take the place of as many which were deemed obsolescent, torpedo craft not being included. There were to be ten battleships, one "coast-defence" armor-clad, nine first-class cruisers, nineteen others of the second-class, and seventeen of the third-class, four torpedo transports, two torpedo depôt ships, five torpedo catchers, eight despatch vessels, and seven gunboats. The year 1895 should therefore have seen the thirty-third of the vessels of this programme in hand, but in practice and, according to the proposals of the committee and the Minister, twenty-six only will then have been laid down. Moreover, the tactical composition adopted appears to have been departed from in some particulars, and the "decennial programme" may be considered to have been definitely abandoned.

The financial proposals of 1895 were submitted by Admiral Lefebvre, then Minister of Marine, last March, and it was forecast that the list of ships to be laid down would be restricted, the loss falling chiefly upon the private yards. A change of ministry ensued, and M. Félix Faure found himself confronted by a difficult financial situation. He projected to defer until 1896 the payment of certain sums for new constructions which would probably have fallen upon 1895, but this proposal was not accepted by the committee, and the estimates were revised anew. The building programme as at first presented, described as the "État P," was a remarkable document—chiefly, indeed, for its negative character. It proposed to adjourn *à une époque indéterminée*, or, in other words, to the Greek Kalends, twenty-one vessels which had appeared in the estimates of 1894, and among them the battleship *Henri Quatre*, which has often been spoken of as actually in hand. The ships to be laid down were a new battleship, described as "*A7*," the first-class cruiser *Jeanne d'Arc*, which had long been deferred, a first-class despatch vessel, and certain torpedo boats. This restricted scheme was not to the mind of M. Faure, and still less to that of M. Brisson, who had been deputed to report upon the estimates. In 1891 M. Brisson discharged the same office in a remarkable manner. He made proposals of so drastic and withal so impracticable a nature that the Minister declined to accept his dictation, whereupon he resigned and was replaced by M. Cochery. As a member of the extra Parliamentary Commisson on naval affairs, M. Brisson has since learned much, and his report upon the estimates of 1895 is a volume of 600 pages, filled with instructive matter. In regard to the revised building program of the year, he is at length in accord with the Minister, and there is no reason to doubt that the proposals will receive the sanction of the Chamber. The cruiser *Jeanne d'Arc* now goes the way of the *Henri Quatre*, and none of the ships indefinitely postponed are reinserted; but, on the other hand, certain new vessels are placed in the list, which give the proposals an extension that would almost have satisfied the framers of the decennial scheme. The following, then, are the vessels of the shipbuilding program of 1895:

To be built in the State dockyards:

A battleship, "*A7*," at Brest, to be completed in 1899. No particulars are published concerning this ship, but she will probably be a sister of the *St. Louis* and *Charlemagne*, for the estimated cost is the same—27,513,366 francs. Displacement, 11,232 tons; I.H.P., 14,000; nominal speed, 18 knots; armament, four 11.8-inch guns, ten 5.5-inch quick-firers, six 3.9-inch quick-firers, and many smaller.

A station despatch vessel, "*S2*," to be completed in 1897, for foreign service, for which the plans have been approved. Displacement, 1,243 tons; length, 223 feet; beam, 34 feet; d'Allest boilers admitting of 2,200 horse power; speed, 15 knots; range, 4,000 miles at 10 knots; armament, thirteen quick-firers.

To be built in private yards:

Two first-class cruisers of a new type, described as *croiseurs* *corsaires*, which are inspired by the American "commerce destroyers." The plans are not decided upon, but the *avant-projet* discloses the principal features. Displacement, 8,500 to 8,800 tons; length, 426 feet; beam, 59 feet; vertical engines, supplied by multitubular boilers, developing 26,000 horse power and driving three screws, which are to give a *maximum* speed of 23 knots; coal supply, 1,450 tons, permitting a range of 7,500 miles at 12 knots; armament, 18 quick-firers; complement, 35 officers and 590 men. The cost of each cruiser is given as 18,369,130 francs.

Second-class crusier "*E4*," designed by M. Tissier, and to be completed in 1898. She is intended for colonial service, and will be of steel, planked and coppered. The displacement will be 4,065 tons, the length 321 feet 6 inches, and the beam 44 feet 6 inches. Vertical engines, supplied by Belleville boilers, will develop 9,000 horse power and give a maximum speed of 19 knots. A coal supply of 571 tons will permit a range of 6,000 miles at 10 knots, and of 1,000 miles at full speed. The armament will consist of thirty-two quick-firers, with two torpedo tubes. The total cost of the cruiser is estimated at 8,233,125 francs, and she will carry 14 officers and 370 men.

Two third-class cruisers "*K1*" and "*K2*," for colonial service, planked and coppered, and to be completed in 1896. The displacement of each will be 1,756 tons, the length 246 feet, and the beam 35 feet 6 inches. The engines, supplied by d'Allest boilers, will develop 3,150 horse power, and give a speed of 16 knots. The bunkers will contain 270 tons of coal, permitting a range of 5,000 miles at 10 knots, and of 1,350 miles at full speed. The armament will consist of seventeen quick-firers. The cost of each cruiser is estimated at 4,307,403 francs, and the complement of each will be 13 officers and 186 men.

Two seagoing torpedo boats *Mangini* and *Tenare*, of the Aquilon type, to be delivered in 1896. Each will displace 120 tons, and be 138 feet long by 14 feet 6 inches beam. Normand boilers and engines of 2,000 horse power will give a speed of 25 knots, and the range of action will be 1,800 miles at 10 knots, or 200 miles at extreme speed. Each boat will have two torpedo tubes, and will carry a couple of 1.85 inch guns. The cost of each will be 659,438 francs.

Five first-class torpedo boats, to be completed in 1896, 80 tons, 121 feet long, engines 1,450 horse power, speed 22½ knots, range 1,300 miles at 10 knots, two tubes and two 1.45-inch guns. Cost of each boat 415,014 francs.

Five 14-ton aluminum torpedo boats, 59 feet 5 inches long, for the torpedo transport *Foudre*, like the "*C*," which was built by Messrs. Yarrow, at Poplar. The cost of each will be 136,000 francs.

It deserves to be noted, moreover, as significant of national policy, that France is building many cruisers specially designed for service on foreign stations; and the laying down of a couple of *croiseurs corsaires* betrays her intention to betake herself once again to the *guerre de course*. It is a policy which, in the hands of a weaker power, has never given victory, but it has always resulted in the infliction of immense loss upon the adversary. The gross sum now proposed by the minister to be spent upon shipbuilding, guns and torpedoes in 1895, is 86,104,529 francs, or, in round figures, £3,444,200. The total number of vessels in hand will be eighty-four, viz., twelve battleships (including three described as for "coast defense"), twenty-five cruisers, four dispatch vessels, one gunboat, forty-one torpedo boats, and one submarine boat, of which twenty-three will be under construction in the state yards, and the rest (including the torpedo craft) in private establishments. But of this number of eighty-four it is expected that forty-nine will be completed or be under trial before the close of 1895, though about this there is some uncertainty. The trials of the *Jauréguiberry*, *Tréhouart*, *Bugeaud*, *Foudre*, *Bruix*, *Descartes*, *Cassini and Casabianca* are put down for that year. In 1896 the fleet is expected to receive the battleships *Charles Martel* and *Carnot*, the protected cruiser *Pothuau*, the second-class cruisers *D'Assas* and *Duchayla*, and three third-class cruisers; and in 1897 the battleships *Masséna* and *Bouvet*, the first-class cruiser *D'Entrecasteaux*, the second-class cruisers *Catinat*, *Pascal* and *Cassard*, and the third-class cruiser *Lavoisier*, besides smaller vessels.

RECENT TRIALS OF FRENCH CRUISERS.

From the "London Times."

Some French cruisers have lately been giving unsatisfactory results at their trials. The *Latouche-Tréville* (4,660 tons), an armored cruiser, sister of the *Bruix*, *Charner* and *Chanzy*, has so far greatly disappointed those who built much upon the type of a powerfully armed and protected vessel of small displacement. She has been built from plans prepared by the French Admiralty, but it was discovered that her boilers would not stand the forced draft pressure contemplated. Accordingly many modifications were introduced, and she was fitted for new trials at Cherbourg. In the preliminary trials, however, she failed to develop more than 6,400 horse power, instead of the 8,000 anticipated; and, at the same time, the heat in the stokeholds became unbearable. She has, therefore, been docked afresh for further alterations. There are unsatisfactory reports also of the *Chanzy*, at Rochefort; but the *Charner*, though the ventilation of her stokeholds was defective, promises better, and it is hoped that the *Bruix*, the last of the type, will gain by the experience of her sisters. These vessels resemble, in many particulars, the unfortunate *Dupuy de Lôme* (6,600 tons), from which such great things were expected. This remarkable cruiser, furnished with three screws, and what is practically a complete coating of armor, gave disastrous results at her first trials in 1892, and the whole of her boiler tubes were changed. She should have developed 14,000 horse power with 140 revolutions, and steamed at 20 knots. In effect a speed of 18.7 knots has been attained with 13,000 horse power and 134 revolutions, but the trials were interrupted by the fusion of an eccentric, and, during a later trial, the boilers so far gave way that a disaster was narrowly avoided. Extensive alterations then became necessary, and the cruiser is now undergoing further trial. Of smaller, unarmored cruisers, the *Fleurus*, which was expected to join the Northern (Channel) Squadron, has recently turned out so unfortunately that she has been placed in the second category of the reserve at Cherbourg. Small defects had appeared in her earlier trials, but it was hoped these had been made good. However, after a four hours' run at Cherbourg, during the present month, with 4,000 horse power, her aftermost boilers showed signs of giving way, and, when she reached the anchorage, her forward boilers were leaking so badly that the fires had to be withdrawn hastily in order to prevent a disaster. The boilers, which are of the French Admiralty type, are to be changed.

EVAPORATIVE TEST OF BOILERS OF THE *HERMIONE*.

Two of the boilers of the British cruiser *Hermione* were recently subjected to an evaporative test, with the following results:

Coal per square foot of grate	12	20	28
Water evaporated per pound of coal	8.44	8.09	7.86
Coal per I.H.P.	2.58	2.59	2.56
I.H.P.	641	1,066	1,505

These two boilers are of the single-ended return fire tube type, and contain 137.8 square feet of grate and 3,860 of heating surface; they are three-furnace boilers, with a separate combustion chamber for each furnace. There are eight of them in the vessel. The engines are of the triple expansion type, and on the official trial developed 9,264 I.H.P. under forced draft.

SHIPS.

UNITED STATES.

Torpedo Boats Nos. 3, 4 and 5.—The bids for the construction of these boats were opened February 19th, those received being as follows:

CLASS 1.—(Department's plan.)

Bath Iron Works	three at	$142,000 each.
Iowa Iron Works	three at	137,000 each.
	one at	148,000
Fulton Engineering & Shipbuilding Co	two at	145,000 each.
John H. Dialogue & Son	one at	139,000
	two at	137,000 each.
	three at	136,000 each.
Hugh Ramsay	three at	126,000 each.
	three at	115,900 each.
Union Iron Works	one at	135,000
	two at	129,000 each.
	three at	120,000 each.

CLASS 2.—(Contractor's plans.)

Columbian Iron Works and Dry Dock Company	one at	$107,000
	two at	103,000 each.
	three at	97,500 each.
Hugh Ramsay	three at	146,000 each.
	three at	126,000 each.
	three at	115,667 each.
Union Iron Works	one at	125,000
	two at	120,000 each.
	three at	116,000 each.
	Special, 240 tons, 28 knots,	243,000
Herreshoff Manufacturing Company	1, 2 or 3 at	113,850 each.
	1, 2 or 3 at	138,000 each.

It is understood that the bid of the Columbian Iron Works was intended to have been made under Class 1. The bids of the Herreshoff Manufacturing Company are one for a steel hull, and the other for a bronze and aluminum hull, tough bronze for the under water portions and aluminum for the upper works and bulkheads. Similarly, the highest bids of Hugh Ramsay are for bronze hulls, and the lowest for one of steel.

As it will take considerable time to examine all the plans submitted under Class 2, it is probable that the award will not be made for several weeks.

AUSTRIA.

Kaiserin und Königin Maria Theresia.—This armored cruiser was built at Trieste, and her trials completed during the latter part of 1894. She is a twin-screw vessel, with a double bottom and two military masts.

Her principal dimensions are—

Length between perpendiculars, feet	367.46
Breadth, extreme, at water line, feet	53.15
Draught, mean, feet	20
Draught, aft, feet	20.26
Displacement, tons	5,185

She has an armored citadel 207 feet long, with a turret at each end of it, and a conning tower near each turret; the armor on the citadel, turrets and redoubts being 4 inches, and that on the conning towers 2 inches thick. The protective deck is 1½ inches thick at the center and 2¼ on the slopes. The main battery consists of two 9.45-inch guns mounted in the turrets, and eight 6-inch guns, four of which are mounted in the redoubts of the battery deck, and the remainder on the upper deck; and the secondary battery of twenty-two rapid fire and machine guns. She has four fixed torpedo tubes. Her engines are horizontal, of the triple expansion type, with cylinders 35.4, 51.5 and 78.7 inches in diameter and 41.3 inches stroke, and were designed to develop 10,000 I.H.P. at 123 revolutions per minute, with a boiler pressure of 156 pounds. The valves are worked by Joy valve gear. There are four double-ended boilers, each with six furnaces, which contain 592 square feet of grate and 16,330 of heating surface; and two single-ended two-furnace auxiliary boilers containing 38.7 square feet of grate and 1,033 of heating surface. The screws are 15 feet in diameter, and the pitch of their blades adjustable from 17 to 20 feet.

Her trials consisted of a run under natural draft for six hours, and one under forced draft for four hours. On the former she averaged 17.13 knots with 104 revolutions of the engines and 5,880 I.H.P.; and on the latter 19.349 knots with 119 revolutions and 9,755 I.H.P., the air pressure varying from 1½ to 2 inches. The maximum speed on this trial was 19.9 knots, with 123 revolutions and 10,300 I.H.P.

BRAZIL.

The Brazilian government has entered into contract with the Forges et Chantiers de la Mediterranée for the construction of two armored vessels of the following dimensions:

Length on water line, feet	267.32
Breadth, extreme, feet	47.89
Depth, feet	22.63
Draught, aft, feet	13.12
Immersed midship section, square feet	605
Displacement, tons	3,112

They will each have two turrets with two 9.4-inch guns in each, besides four 4.7-inch, and eight smaller rapid fire guns and two 6-inch rifled mortars. They will have an armor belt and a protective deck.

The engines will be of the triple expansion type, designed to develop 2,650 I.H.P. with natural draft and 3,400 with forced draft, the corresponding speed being respectively 13 and 14 knots.

CHILI.

Blanco Encalada.—A short description of this cruiser was given on page 602 of the last volume of the JOURNAL, since which time a more extended description has appeared in "The Engineer," London, from which the following is taken:

The conditions named in the contract were that, with the armament and protection stated, a sheathed vessel not exceeding 5,000 tons displacement should be constructed capable of carrying 350 tons of coal on a mean draught of 18½ feet, and of making a speed of 22.5 knots with forced and 20.5 with natural draft. As built and tried, her principal characteristics are—

Length between perpendiculars, feet	370
Breadth, extreme, feet	46.5
Draught of water, forward, feet	17.5
aft, feet	19.5
mean, feet	18.5
Displacement, tons	4,420
Coal carried on above displacement, tons	350
Bunker capacity, tons	900
I.H.P., natural draft	11,000
I.H.P., forced draft	14,500
Speed, natural draft, knots	21.7
forced draft, knots	22 78

Her armament consists of two 8-inch, ten 6-inch rapid fire, twelve 3-pounders, ten 1-pounders, and five torpedo tubes. The 8-inch and 6-inch guns are protected by shields 3 inches thick, and are of 40 calibers length and of the latest Elswick pattern. The 8-inch guns are mounted one forward on the upper deck and one aft. The ten 6-inch guns are mounted in sponsons on the upper deck, two capable of firing right ahead and two right astern, so that one 8-inch and two 6-inch can be directed right ahead or astern, and two 8-inch and five 6-inch can fire through an arc of at least 100 degrees on either beam, not counting the 3-pounder and 1-pounder Hotchkiss guns. Owing to the simple and handy breech mechanism of the 8-inch guns, and the admirable arrangements for bringing the powder from the magazines to the guns, the 8-inch as well as the 6-inch may fairly claim to be called quick-firing, seeing that during the gunnery trials four rounds were fired from one of the 8-inch in just over one minute, a hitherto unequalled performance in a gun of this size. The 8-inch guns can penetrate 18 inches, and the 6-inch guns 15.6-inches of steel. The 3-pounder guns are placed, eight on the bulwarks and four between decks, two forward and two aft. The 1-pounders are six of them in the military tops, and four on the shelters.

The five torpedo tubes, which are for discharging 18-inch torpedoes, are all situated above water in three torpedo rooms; one being a fixed tube firing right forward through the stem, and four training through an angle of 60 degrees, firing two on each broadside, and placed in two torpedo rooms on the lower deck before and abaft the machinery spaces. Owing to the great length of the tubes necessary for firing these large 18-inch torpedoes, they are made with a joint and hinge a little abaft the middle of each tube, to facilitate training and loading. The tubes fitted, are of the new Elswick design, and are arranged to use cordite as the impulsive agent. The experiments made with this new arrangement have given most satisfactory results, and have proved that the velocities obtained with cordite impulse are even more uniform than those when compressed air is used. By an ingenious contrivance the pressure can be very carefully regulated, and it is found that the high velocity of over 50 feet per second is obtained with a pressure of 35 pounds in the tube. The cordite is burned in a chamber formed in the door of the torpedo tube, and it is so arranged that it cannot be fired unless the door is properly secured, a point which has hardly received sufficient attention in the service tubes. The whole contrivance is exceedingly simple, and can be worked by any blue jacket, and there is nothing to get out of order. Other great advantages in the use of cordite are that there is no smoke or noise, air accumulators, pipes and valves are all done away with, and there is practically no fouling of the tube. At the gunnery trials torpedoes were fired from each of the broadside tubes.

Her protection consists of a complete steel deck extending from stem to stern, having a thickness of 1¾ inches on the horizontal portion, which is 18 inches above the load water line, and the sloping portions at the side are from 3 inches to 4 inches in thickness, and are carried to a depth of 4 feet 3 inches below the load water line. At the ends of the ship this deck slopes downwards, ending below water at each extremity, furnishing aft admirable protection to the steering gear and rudder head, and forward being brought down to the ram casting and securely fastened to it, greatly adding to the strength of the ram, and tending to distribute the shock of ramming over the whole of this heavy deck, and thus throughout the entire structure of the ship. It is scarcely necessary to say that this armor deck completely covers and protects all the main engines, boilers, magazines and steering gear, as well as other spaces devoted to stores, &c., at the ends of the ship. Wherever the armor deck is cut to form a hatch or other necessary opening, armor bars or shutters are provided, which can be closed down in action; coffer-dams are also worked round all openings to a height of at least 4 feet above the water, greatly reducing the chance of water getting below, if the deck ever became flooded. In action the commander has the shelter of a conning tower built of steel armor 6 inches in thickness, from which an armored tube conveys the rods from the steering wheel situated in the conning tower, telegraphs, &c., to a position of safety below the protective deck.

The *Blanco Encalada* was commenced on September 30th, 1892, when the first keel plates were laid. The outside plating was completed in June, 1893, and the ship launched on the 9th of September, 1893, less than one year from the date of her commencement. She was finally completed in July, 1894.

Her framing is a combination of the transverse and longitudinal systems. She is built with a cellular double-bottom extending throughout the space occupied by the engines and boilers, and carried on to the ends in the form of magazine and other flats. The double bottom is divided into numerous water-tight compartments, which can be utilized for water ballast, or as reserve feed tanks; and the longitudinal bulkheads to the side coal bunkers carry the inner bottom right up to the protective deck, so that with the coal bunkers above this deck, which extend over about half the length of the ship amidships, she can be said to have a double side over her whole main portion from the keel to a height of 6 feet above water. This and the subdivision of the vessel throughout into a very large number of water-tight compartments by means of transverse and longitudinal bulkheads, greatly minimizes the chance of her being sunk in action. All the bulkheads below the protective deck are, where it is absolutely necessary to have communication, fitted with water-tight doors which can be closed from the main deck, and have automatic means of indicating whether they are open or shut.

The powerful ram alluded to above is a great feature of the *Blanco*, projecting 8 feet beyond the point where the stem cuts the water line and with its spur about 9 feet below the surface. It is made of a strong casting of phosphor bronze, as are also the stern post casting and the struts for supporting the ends of the twin propeller shafts. The rudder is hung upon a short but very strong stern post, which is its axis, and projects below this and also in front, so that it is really a balanced rudder. The great advantage claimed for this form of rudder is that it enables a large portion of the so-called dead wood to be cut away, thus greatly reducing the lateral resistance of the vessel to turning.

The keel stops some 60 feet before the rudder, and abaft this the lower boundary line of the vessel follows approximately the level of the propeller shafts. There are thus some 70 or 80 feet of the vessel overhanging when she is docked, and special care has been taken to provide for the strains brought upon her structure.

The wood used for sheathing is the best teak, of a minimum thickness of 3½ inches, and this is fastened to the shell with bolts of naval brass. In the region of the stem thicker plates of naval brass are substituted for the copper, where the chafe of the anchor is likely to cause great wear and tear.

She is fitted with a steering gear specially designed and made at Elswick, and which has worked very well in other cruisers of similar type. Owing to the fineness of the lines aft, and to the fact that the steering gear had to be kept entirely under the protective deck, which is here brought below the load water line, the space available for the rudder crosshead was very limited, and only just over 4 feet in width; and the rods connecting the crosshead to the tiller had to be very long, measuring 24 feet, before sufficient space was found for the movement of the tiller. These rods have to pass through a water-tight bulkhead, and to allow for the lateral motion of the rods, specially designed stuffing boxes had to be fitted which could slide on the bulkhead as the rods moved nearer or farther from the center line of the ship in the process of steering. The tiller is fitted with a modified form of the Rapson slide, and is worked by a chain passing over two sheaves, one at each side of the ship, and round a sprocket wheel situated below, and turned directly by the steam steering engine. This engine is of sufficient power to move the tiller from hard over on one side to hard over on the other—through an angle of 38 degrees each way—in thirty seconds when the ship is going at full speed. Arrangements are made, in case of emergency, for rapidly substituting hand gear for the steam gear, and *vice versa*. The hand steering wheel is under the after shelter on the upper deck, and there are wheels in connection with the steam gear on the forward bridge, in the conning tower, and in a compartment forward in a safe position below the protective deck.

Besides smaller anchors, the *Blanco Encalada* is provided with four of 50 cwt. each. These anchors are stockless, and of Hall's patent type, stowing in the mouth of the hawse pipes. The gear for working the anchors and chain cables, consists of a four-lifter windlass, which was placed in a box sunk below the level of the upper deck sufficiently to admit of the forward 8-inch gun being fired over it. The windlass is worked by a steam engine, and placed on the main deck, and the gearing is so contrived that at any time the windlass can be worked by hand if necessary. Warping drums are also fitted, which can be worked with the windlass or independently. An auxiliary boiler is fitted on board for the purpose of supplying steam to the auxiliary engines, winches, &c., when there is no steam up in the main boilers. This boiler is of the vertical type, and is placed in a separate compartment on the lower deck.

She carries a 60-foot second-class torpedo boat, built by White, of Cowes, fitted for a 14-inch torpedo and a 3-pounder rapid fire gun. A 25 ton derrick is fitted to the mainmast for hoisting this boat in and out. She also carries a steam launch.

The whole ship is lighted throughout by electricity, between 400 and 500 incandescent lamps being necessary for the purpose. These are supplied from two dynamos, situated in a space over the main engine room. The dynamos supply the current for the three search lights which are placed, two on the forward bridge, and one on the after shelter, and are each of 20,000 candle-power. The masthead and side lights are fitted to use oil or electric lights, and oil lamps are provided in the engine room and stokehold, in addition to the electric light.

The engineer's workshop is situated in a convenient position on the lower deck forward, and is fitted up with a screw-cutting lathe, planing and punching machines, grindstones, &c.

The ventilation of all compartments above the protective deck is obtained by natural means; but artificial ventilation is required for some of the compartments below, and fans are provided for the purpose. Wherever an aperture occurs in a bulkhead to admit of ventilation between two adjacent water tight compartments below the protective deck, automatic stop valves are fitted to prevent the flow of water in case one of the compartments becomes filled. The pumping arrangements and fire service are most complete, and besides the main steam pumps there are two 7-inch Downton's hand pumps and two 5½-inch Downton's. Altogether more than 2,000 tons of water could be pumped out of the ship in an hour.

Two strong steel masts are provided, each carrying two military tops, which carry 1-pounder and machine guns. A light fore-and-aft rig is provided, and on the foremast is a yard for signalling purposes.

The officers' quarters are arranged aft under the upper deck. The captain has a saloon, a dining room, and two sleeping cabins. The ward room is placed just aft of the engine hatch, on the starboard side, and is a very fine room, about 30 feet long by 24 feet wide. The crew, which numbers 250 men, are accommodated on the main deck forward, and some on the lower deck. Their quarters are provided with messing and sleeping arrangements for the whole number.

The engines, designed by Humphreys and Tennant, are of the four cylinder triple expansion type, and are similar to those of the *Yoshino* and *Nueve de Julio* by the same firm. The cylinders are 40, 60 and 66 inches in diameter, there being two of the latter, and have a stroke of piston of 30 inches. The main steam valves are treble ported slides, fitted with relief rings, and are worked by Stephenson link motion. The bed plates are of cast steel bolted direct to the engine keelsons. The cylinders are supported on steel pillars at the front and by Y frames at the back.

There are two condensers for each engine, one on each side of the low pressure cylinders, the four condensers for both engines containing 14,000 square feet of cooling surface. The tubes are 7 feet 1½ inches long and ⅝ inch in diameter, and are so arranged that the steam passes through them and the water around them. There is one centrifugal circulating pump for each pair of condensers; it is operated by a vertical engine with cylinder 13 inches diameter and 12 inches stroke, and both are so connected that either pump can be used on the condensers of one or both engines. The air pumps, one for each condenser, are 13½ inches in diameter and 30 inches stroke, and each pair is worked from the after low pressure piston.

There is an auxiliary condenser in each engine room.

For all the working parts forged steel is used, the top end pins of the connecting rods being case hardened. The crank shafts are made in two parts, the cranks on each shaft being opposite, so that when bolted together the four cranks are at angles of 90 degrees with each other. Owing to the vessel being sheathed, the whole of the shafting outside is encased in brass. Each propeller is fitted with three blades of manganese bronze; gun metal is used for the boss. The screws are 13 feet 9 inches in diameter and have a mean pitch of 15 feet 4 inches.

There are two boiler rooms, each containing two double ended boilers 14 feet 9½ inches in diameter and 19 feet 2 inches long, each fitted with four furnaces. They are worked on the closed stokehold system of forced draft, eight fans being fitted for the purpose.

On the forced draft trial, with a piston speed of 850 feet per minute, the I.H.P. developed by the engines was 14,500, and with natural draft 11,000.

ENGLAND.

Magnificent.—This first-class battle ship was floated out of dock at Chatham dockyard on the 19th of December, and is the first of a new type of which seven are now under construction. The principal particulars of the design are:

Length on water line, feet	390
Beam, feet	75
Draught of water forward, feet	27

Draught of water aft, feet	28
mean, feet	27.5
Displacement at above draught, tons	14,900
Indicated horse-power	12,000
Speed, knots	17.5
Coal carried on draught of 27.5 feet, tons	900
Bunker capacity, tons	1,800
Weight of hull, armor and backing, tons	10,180
armor, tons	2,980
Length of armor belt, feet	216
Freeboard, forward, feet	25
aft, feet	18.5
amidships, feet	17.75

The armament consists of four 12-inch guns mounted *en barbette;* twelve 6-inch rapid fire guns in armored casemates, four on the upper and eight on the main deck; sixteen 12-pounder, and twelve 3-pounder rapid fire guns, eight .45-inch Maxim guns, and two 12-pounder boat and field guns. In addition to this, there will be four submerged torpedo tubes and one above water tube at the stern, all for 18-inch Whitehead torpedoes.

The armor is 14 inches thick on the barbettes, 9 inches on the belt, and 6 inches on the casemates, while the protective deck varies in thickness from 2½ to 4 inches. The 14-inch and 9-inch plates are Harveyized.

A comparison of the armament and armor of the *Magnificent* with that of the *Royal Sovereign* class shows that 12-inch guns have been substituted for 13½ inch ones, and that they are carried about four feet higher, or about 27 feet above the water line; that there are twelve 6-inch guns instead of ten, and that the protection of them has been carried out more completely, and that 12-pounders have been substituted for 6-pounders.

It is in the disposition of the armor that the greatest difference exists. That of the *Royal Sovereign* is compound and that of the *Magnificent* Harveyized. The *Magnificent* shows a very large area of side protection; in fact, the ship may be described as side armored in contradistinction to the term belted. In the *Royal Sovereign* a belt of armor, having a maximum thickness of 18 inches, extended over two-thirds the length of the vessel, joining the two barbettes. This belt had a vertical extension of 8½ feet.

Above this belt, to a height of about 9½ feet above water, was placed 5-inch armor for a great part of the length, to afford protection to the secondary armament. In the *Magnificent* there are two pear-shaped barbettes as in the *Royal Sovereign*, and on the side of the ship there are two tiers of armor plates 9 inches thick. These form a protected side extending about 10 feet above the water-line and about 6 feet below, extending fore and aft, wrapping round the two pear-shaped barbettes and protecting their lower parts, thus forming a central citadel extending over a greater part of the ship's length. There is thus a vertical extension of about 16 feet of armor 9 inches thick in place of the 18-inch and 5-inch armor in the *Royal Sovereign* class. The change bears evidence to the growing appreciation of the value of rapid fire and high explosive shells, as well, perhaps, as advance in the manufacture of armor plates. Whereas a few years ago the warship designer devoted most of his capital in displacement to a thick armored belt of small area designed to prevent penetration by the few heavy projectiles, he now fears rather the rapid destruction of large areas of side by smaller shot and shell projected with immense rapidity.

Within the armored citadel, is the thickest portion of the armored deck, where it is 3 inches on the flat and 4 inches upon the curved sloping edges. Forward and aft, beyond the armored bulkheads, the armored deck is 2½ inches thick at its stoutest part. An important modification has, however, been made in the armored deck. In all earlier battle ships, the outer edge of this deck is at the summit of the thick armor belt. In the *Magnificent*, it curves downward behind the vertical armor, and the lower edges of the two harmonize, as well as the outer edges of the forward and after armored decks, thus bringing the whole to a uniform level of about 5 or 6 feet below the armored deck.

The triangular space above the deck where it dips below the water will be filled with some water-excluding substance, so that if the side is pierced and the deck remains uninjured water will not flow in. The usual armor shelf for supporting the side armor is not necessary with this arrangement, as the bottom edge of the vertical armor rests on the outer extremity of the deck. The support to the side armor is very efficient. It consists, firstly, of about 4 inches of teak, at the back of which are two thicknesses of skin plating. The framing at the back of the armor consists of web frames about 15 inches deep, strengthened by reverse angles and spaced two feet apart. These frames extend vertically from the main deck, past the middle deck, to the lower edge of the armored deck, being attached to the deck beams by large bracket plates, the whole forming a very strong structure. The side armor is secured in the usual way, being fastened to the structure of the ship by special bolts, the nuts on which are set up on a sleeve washer into which India rubber is introduced to give elasticity, and thus prevent the bolt being broken off at the thread under the impact of shot.

The barbettes are built upon the citadel ends of the armored deck, and are to be plated with 14-inch Harveyized steel. Upon their summits will be revolving armored decks, hoods of sufficient capacity to hold the gun detachments working the guns by manual power, and as the barbettes are pear shaped in plan, there will be room within the thin ends for the ordinary ammunition hoists and ramming gear required for fixed loading positions.

There are two conning towers, both on the shelter deck; the forward one protected by 14-inch and the after one with 3-inch armor.

There is an axial ammunition hoist coming up between the guns in the barbettes so that the charge can be brought up from the magazines with the guns in any position. This central hoist is in addition to the fixed position.

The guns are trained and elevated by hydraulic power, but hand gear is also fitted.

A notable feature is two long passages on each side of the ship, and passing over engine and boiler rooms so as to give access to the magazines. These passages are suspended under the armored deck. In the *Royal Sovereign* there is but one passage, which is central, for giving access from end to end inside the citadel, but below water. In the latter vessel, however, there is a central magazine between the boilers, which does not exist in the *Magnificent*, where separate magazines and shell rooms are built for each class of gun at each end of the ship.

Bilge keels have been fitted for about two-thirds the length of the ship. They are about 3 feet deep, and formed of double plating with wood between in the usual manner. The ordinary bracket frame system has been followed in the double bottom, and Z-bars are used for frames outside the citadel. The average thickness of plating is 25 pounds amidships, tapering to 20 pounds at the ends. The outer keel-plate is 30 pounds, and the inner 25 pounds. At the bow the plating is made up to about 3 inches thick from the attachment to the ram for about 15 feet to 20 feet aft.

There are seven decks, namely, the platform deck, the lower deck, middle deck, main deck, upper deck, boat deck, and shelter deck, and above these are the bridges, the latter being at a height of 75 feet from the keel. The middle deck amidships and the lower deck at the ends of the vessel are protected by an armored deck, the average thickness of which is 3 inches. Some of the plates are 17 feet in length and 6½ feet wide, weighing nearly 3 tons.

The stem weighs 30 tons, and the sternpost 8 tons. Both are steel castings. There are 48 separate compartments between the inner and outer bottoms, the total number of water-tight compartments in the ship being 180; they are put into communication with each other by 190 water-tight doors.

The ventilating arrangements are necessarily somewhat complex, but the system has been very carefully thought out, there being 10 fans with engines attached. Care has been taken to protect all openings in the armored deck with armor gratings.

The steering gear is of the Rapson slide pattern. The rudder is of the unbalanced type now usual in these vessels, and is of great area. There is a steel casting of 14 tons, which forms the frame. The tiller is 20 feet long, the rudder head having to be kept low in the run of the vessel so as to be below the protective deck. This tiller weighs 4½ tons.

The ground tackle comprises seven anchors, three of which weigh 5 tons 15 hundredweight each. The main cables are 500 fathoms in length.

For electric lighting there are three dynamos, each of 400 amperes, the pressure being 80 volts. These work the search lights and incandescent lamps, of which there are 700, for the general illumination of the ship. There are two military masts, each fitted with two fighting tops, in which are placed three search lights and eight 3-pounder quick firing guns.

The machinery of the *Magnificent* has been supplied by Messrs. John Penn & Sons, of Greenwich, and is very similar to that for the *Crescent.* The feature of novelty about the *Magnificent's* machinery is that induced draft is to be fitted, the fans being placed in the funnels. The trials of this vessel will be watched with interest on this account.

The engines have no other special features of novelty. They are designed for 12,000 indicated horse power, induced draft, and 10,000 indicated horse power for natural draft, and are of the triple expansion vertical twin screw type, having cylinders 40, 59 and 88 inches in diameter, respectively, all with 51 inches stroke. The high pressure cylinders are placed forward, and are fitted with piston valves, the intermediate and low pressure slide valve being of the double flat valve type. The cylinder covers, pistons and steam chest doors are of cast steel. The cylinders are carried on cast iron columns at the back and round forged steel columns at the front, the motion bars being attached to the back columns. The bed plates are of cast steel, strongly secured to bearers built in the ship. The piston and connecting rods are of Siemens-Martin steel, the piston rods being fitted with combination metallic packing. The crankshafts are hollow, of forged steel, in three separate pieces, the cranks being set at 120 degrees apart. The surface condensers are made entirely of brass, the total cooling surface being 13,500 square feet. The circulating water is supplied by four 16-inch centrifugal pumps, made by the engine contractors. The reversing gear is of the ordinary link motion type, with solid bar links and adjustable working parts. Both steam and hand reversing gear are fitted. The air pumps are entirely of brass, and are worked from the low pressure piston rod crossheads; they deliver into a feed tank which overflows into the ship's fresh water reserve tanks.

The propeller shafting is hollow, of forged steel 14¾ inches in diameter inboard and 16 inches in diameter outside the ship. The propellers are of gun metal, four bladed, and are 17 feet in diameter by 19 feet 9 inches pitch.

The boilers are eight in number, of the marine return-tube type, 16 feet 1 inch in mean diameter and 9 feet 3 inches long, each containing four of Fox's corrugated furnaces 3 feet 8 inches in mean diameter. They are of Siemens-Martin steel throughout, and are designed for a working pressure of 155 pounds per square inch, and a proof pressure of 245 pounds per square inch. The heating surface is 25,248 square feet, and the grate 855 square feet. The main steam pipes are 14 inches in diameter, and made of steel; while all copper pipes of 6 inches and over are wound with copper wire for greater security.

A Weir's evaporator and Kirkaldy's distiller is fitted to each engine room. They will make together 180 gallons of fresh water per hour, while the evaporators can supply 400 gallons per hour to the auxiliary condensers. The last named are two in number, and are made entirely of brass, and fitted to condense the exhaust steam from all the auxiliary engines on board. There is a Weir's feed engine in each engine room and a Weir's auxiliary feed engine in each boiler room. Air compressing machinery is fitted in duplicate at each end of the vessel. Powerful boat hoisting engines will be supplied and fitted on the upper deck.

Majestic.—A sister ship to the *Magnificent* was floated out of dock at Portsmouth on the 31st of January. She is practically a duplicate of the *Magnificent*. Her principal weights are:

	Tons.
Steel in hull	4,340
Protective material	1,410
Armor	2,850
Backing	160
Wooden decks, etc	570
Fittings	850
Hull, complete	10,180
Equipment	600

Armament	1,500
Machinery	1,300
Coal, normal	900
full bunkers	1,850

Her machinery is by the Naval Construction and Armaments Company, Barrow-in-Furness, and is similar to that of the *Magnificent.* The engines are of the same size, and the boilers 16 feet 4 inches diameter and 10 feet 3 inches long, each with four furnaces and two combustion chambers.

Ardent.—One of the torpedo boat destroyers built by Messrs. J. I. Thornycroft and Co., similar to the *Daring* and *Decoy*, built by the same firm and described in the last volume of the JOURNAL. Her principal dimensions are:

Length, feet and inches	201–6
Breadth, feet	19
Depth, feet	14
Draught, mean, feet and inches	7–2

In general arrangement and in construction she is similar to the *Daring*, and has the same kind of machinery. The high pressure cylinders are 19, the intermediate 27, and the two low pressure cylinders of each set 27 inches in diameter, and the stroke 16 inches. The boilers contain slightly more heating surface than those of the *Daring*, due to the introduction of another row of tubes on the sides. This row is fitted just inside the two rows which form the casing, and the tubes are so spaced

Number of run.	Steam.	Receiver pressure.		Vacuum.	Revolutions.		Time	Speed.	Mean Speed.
		I. P.	L. P.		Port.	Star-board.			
	lbs.	lbs.	lbs.	in.			m. s.	knots.	knots.
1	110	42	10	27	280	277	2 48	21.429	19.275
2	85	40	9	27	269	268	3 22	17.322	
3	90	39	8	27	272	269	2 51.2	21.028	
With ⅝-inch air pressure.									
1	160	80	24	26	355	351	2 11.8	27.314	26.7
2	167	84	27	26	370	368	2 19.6	25.789	
3	160	78	26	25	368	366	2 7.4	28.258	
With 2-inch air pressure.									
1	200	100	43	24	411	408	2 7.6	28.214	29.182
2	195	95	41	24	407	405	1 59 4	30.151	

as to permit the gases of combustion to pass between them to the outer rows.

A preliminary trial, consisting of measured mile runs, was made on the 9th of November, the vessel not being at her trial displacement, when the results given on the preceding page were obtained.

The I.H.P. in the last two runs is reported to have been nearly 5,000.

The official trial was run on the 15th of December under rather unfavorable weather conditions, the result of the runs on the mile being as follows:

Number of run.	Steam pressure.	Vacuum.	Revolutions.		Speed.			
			Starboard.	Port.	For run.	1st mean.	2d mean.	Mean.
1			393.8	397.1	25.352	27.802		
2			390.7	400.8	30.252	28.039	27.921	
3	196	26¾	404.6	406.7	25.825	27.764	27.901	27.844
4			390.1	391.1	29 703	27.764	27.764	
5			398.9	402.9	25.825	27.813	27.789	
6			390.3	398.8	29.801			

Following the runs on the mile came a run of three hours' duration, during which the speed averaged 27.971 knots, and the I.H.P. 4,350, with 2¾ inches air pressure. It is estimated that the rough sea caused a reduction of one-quarter of a knot in the speed.

Boxer.—A sister vessel to the *Ardent*, and constructed by Thornycroft and Co., was launched on the 28th of November. She had a preliminary trial on the 8th of January, the speed reported having been 29.314 knots on the measured mile. She had her contract load of 30 tons on board, and was down to her mean load draught of 7 feet 2 inches.

The official trial was run on the 25th of January with the following results for the six measured mile runs made during the first hour of the trial:

Number of run.	Revolutions.		Speed.	1st mean.	2d mean.	Mean.
	Starboard.	Port.				
1	425.7	400.3	29 364	29.152		
2	420.5	419.6	28.939	29.296	29.224	
3	415.1	407.7	29.654	28.781	29.038	29 076
4	408 3	406.0	27.907	29.130	28.956	
5	418.3	411.8	30.354	29.045	29.088	
6	411.4	410.0	27.735			

On the remaining portion of the three-hour trial the steam pressure was maintained so steadily that the speed gradually increased as the vessel lightened, and at the conclusion of the trial it was found from the number of revolutions made that 87.525 nautical miles had been covered, equivalent to a mean speed of 29.175 knots, which is more than a knot greater than has been made by any of the other vessels of this class.

Shark.—Another vessel of this class, built by Messrs. J. and G. Thomson, had a preliminary trial in December, during which some of the tubes in her Normand boilers split, and several men were seriously scalded.

Lynx.—After having completed her official trials she left Birkenhead for Plymouth. Owing to boisterous weather she put into Holyhead the same night for shelter. She resumed her voyage on the following morning, and, notwithstanding the heavy seas running, maintained a speed of about 20 knots during the day. At about 9 p. m., when she was off the Cornish coast, the lookout man reported "Breakers ahead." The engines were reversed, the watertight doors closed, and the vessel's course altered. Before the orders could be executed the heavy seas and the wind together swept the *Lynx* broadside on to the rocks of Sennen Cove, near Land's End. She was in deep water again in about a minute, but not before she had sustained considerable damage, her plates throughout being strained. In going astern she struck another rock and knocked a hole in her stern, through which water entered and flooded the after compartment. In response to signals of distress from the *Lynx*, the Sennen Cove lifeboat and a number of fishing boats put off to her assistance. Owing to the large quantity of water which was rushing in, it was decided to anchor in the cove for the night. The lifeboat and a fishing boat stood by until about 6 o'clock the following morning, when the *Lynx* again proceeded on her voyage.

On her arrival at Davenport an examination of her hull was made. The compartment which sustained the greatest damage was the ward room in which, notwithstanding the continuous working of the steam pumps, the water had risen to about 3 feet. A large quantity of water had also found its way into the fore stokehold and the after compartment. There was a hole in the bottom close to the keelson, under the ward room, about a foot long and from 1 to 3 inches in breadth. The propeller casing was twisted, and one of the shafts badly bent. It will be necessary to remove twelve plates and to put in a new shaft.

A somewhat similar accident subsequently happened to the sister vessel *Ferret.*

FRANCE.

Friant.—This second class cruiser, a brief mention of whose trial was made on page 807 of the last number of the JOURNAL, has since been making her preliminary and official trials. During one of her preliminary runs she made 15.312 knots on 3,500 I.H.P., and with forced draft 18.5 knots with 8,200 I.H.P. Her contract is for 19½ knots and 9,000 I.H.P.

Her first official trial was made on the 20th of December, with six of her twenty boilers in use. It lasted eight hours, the speed being 12 knots and the I.H.P. 1,600. A second one was made with all boilers under natural draft, and a third one under forced draft with about three-fourths boiler power, when she made upwards of 18 knots on something over 7,000 I.H.P. On the 9th of January she made another effort under full boiler power to reach the contract power, but failed on account of hot bearings and the intense heat in the smoke pipes, "La Marine Francaise" stating that flame rose to a height of six feet above the top of the pipe; that the pipe was so burned that it fell over to an angle of 15 degrees, and would have fallen over altogether had the sea not been perfectly smooth, and that on account of this inclined position, and the intense heat, the top of the pipe was burnt off.

In appearance, the *Friant* resembles the *Jean Bart*, though she is smaller. She has three smoke pipes and two military masts, the latter being much shorter than those of the *Jean Bart*. Her battery comprises six 16-cm., and four 10-cm., besides twenty smaller caliber rapid fire guns.

Interest in the *Friant*, from an engineering point of view, centers in her boilers, which are twenty in number and of the Niclausse type, designed to work at a pressure of 213 pounds. They are divided into three groups, one containing four and the others eight boilers each, each group being in a separate water tight compartment. The boilers of each group are placed back to back, with a fire room at each end.

The principal data are:

Grate surface, square feet	782 8
Heating surface, square feet	23,248
Furnaces, number	20
Grates, length, feet	6.56
Tubes, total number	3,536
diameter, outside, inches	3.23
inside, inches	2.95
circulation, diameter, inches	1.57
length of vaporizing, feet	7.38
circulation, feet	7.22
Smoke pipe, forward one, diameter, feet	6 20
middle and after, diameter, feet	7.55
height of all, feet	60
Weight of boilers without uptakes, smoke pipes or water, tons	199 42
with uptakes, tons	210
with uptakes and water, tons	255 46
duplicate parts of boilers, tons	7.15

Her engines have cylinders 35.4, 53.5 and 77 inches diameter by 31.5 inches stroke. The condensing surface is 11,453 square feet.

Latouche-Tréville.—This first-class cruiser has been undergoing trials for some time, but with rather unsatisfactory results, the last one being on the 21st of January, when for six hours she maintained 7,400 I.H.P., and made 18 knots, after which her condensers leaked so badly that she had to go to dockyard for repairs before undertaking the final trial under forced draft.

She is 347.7 feet long, 45.9 feet beam, and on a mean draught of 19.15 feet has a displacement of 4,669 tons. She has horizontal triple-expansion engines, designed for 9,000 I.H.P., steam for which is supplied by 16 Belleville boilers working at a pressure of 241 pounds.

Fleurus.—After two unsuccessful trials, on the last of which three furnaces in her after boilers came down and the forward boilers leaked badly, it has been decided to remove the boilers and put in new ones.

She is a torpedo cruiser of 1,285 tons, 229.6 feet long, 26.9 feet beam and 13.9 feet mean draught. She has four locomotive boilers and triple expansion engines designed for 4,000 I.H.P.

Espiegle.—One of eight stern wheel gunboats for service in Madagascar, built by the Forges et Chantiers de la Seyne. She has a flat bottom, and is built in six detachable sections, the purpose being to transport her by steamer and to bolt the several sections together afloat, which can be done in three days.

She is 82 feet long, 18 feet beam, draws 16 inches of water, and has a displacement of 40 tons Her engines are of 50 I.H.P., and on trial gave her a speed of 6½ knots with 46 revolutions of the wheel. She mounts two 37-mm. rapid fire guns.

The other boats of this type are named *Precieuse*, *Zélie*, *Rusée*, *Poursuivante*, *Eclatante*, *Impetueuse* and *Insolente*.

ITALY.

Sardegna.—Though classed as a battleship, this vessel comes properly in the class of armored cruisers. She combines a light armor belt, great displacement, high speed, and a heavy battery, and is of the following dimensions:

Length between perpendiculars, feet	410.55
Breadth, extreme, feet	76.77
Draught, mean, feet	28.68
Displacement, tons	13,982

Her belt, which extends about 280 feet in length, is 4 inches thick, and runs to the upper deck. Above this deck, for the length of the belt, is an unarmored citadel, at each end of which is a turret protected by 13.8 inches of armor, and in which are two 34-cm. guns. Forward and abaft the belt the protective deck is 3 inches thick. In addition to the heavy guns, she carries eight 6-inch and sixteen 4.7-inch, besides twenty-seven smaller caliber rapid fire guns, and five torpedo tubes.

Her engines are of the vertical triple expansion type, built by Hawthorne, Guppy and Co., Naples. There are four of them, two on each shaft, the cranks of each set being at 120 degrees with each other, and all the steam valves worked by Marshall valve gear. The cylinders are 39, 59 and 88 inches in diameter by 51 inches stroke (the same size as the two engines in the English first-class cruisers and battleships), and the four engines were designed to develop 15,000 I.H.P. with natural and 22,500 with forced draft. The air pumps are vertical single acting, and are worked by independent vertical compound engines. The condensing surface of the four condensers is 32,000 square feet. The boilers, eighteen in number, are placed in three watertight compartments, two forward and one abaft the engines; they are 15 feet 6 inches diameter and 10 feet long, with four furnaces each, and contain 1,340 square feet of grate and 36,717 of heating surface. There are two smoke pipes, one for the two forward sets of boilers and one for the after one. The screw propellers are 20 feet in diameter and 21.5 feet pitch.

On her preliminary trial she made 18.97 knots with natural draft, on 92.5 revolutions of the engines and 12,985 I.H.P.; and on the official trial, under like conditions, 19.06 knots, 94.8 revolutions and 13,956 I.H.P., the displacement being 13,726 tons. On a preliminary forced draft trial, with 1 inch air pressure, she is reported to have made 20 knots for two hours on 17,260 I.H.P., but her official trial was a failure owing to the breaking down of the forced draft fans, and to trouble with the boilers. (From "Le Yacht.")

RUSSIA.

Petropavlovsk.—This battleship was launched from the Neva dockyard on the 9th of November, and is a sister ship to the *Poltava*, launched three days earlier. Her dimensions are:

Length on water line, feet	375
Breadth at water line, feet	70
Draught, mean, feet	26
Displacement, tons	10,960

The I.H.P. of her engines is 10,600 with natural draft, and with forced draft 13,500 is expected with very light air pressure. The machinery is by Hawthorne, Leslie and Co., Newcastle, England, and consists of twin screw triple expansion engines, having cylinders 44, 65 and 98 inches diameter by 51 inches stroke, to which steam is supplied by fourteen single ended boilers containing about 1,050 square feet of grate and 30,200 of heating surface. There are also two auxiliary boilers, containing about 44 square feet of grate and 1,100 of heating surface.

She has a belt of armor 16 inches thick at the center and 8 inches at the ends, and a protective deck from 3 to 3.6 inches thick. Her battery comprises four 11.8-inch and eight 9.2-inch, besides sixteen rapid fire guns and six torpedo tubes. The 11.8-inch guns are mounted in two central turrets, one forward and the other aft, protected by 10 inches of armor, and the 9.2-inch guns in four broadside turrets protected by 5 inches of armor.

Admiral Oushakoff.—The general dimensions of this coast defense vessel were given on page 210 of the last volume, and the following additional particulars are now available.

The machinery is by Messrs. Maudslay and Sons, London, and is of 5,000 I.H.P. with natural draft. The engines are twin screw triple expansion, with cylinders 31, 46 and 68 inches in diameter and 33 inches stroke. The framing and bed plates are of cast iron. The condensers have ¾-inch tubes, and contain 7,500 square feet of cooling surface. The air pumps are worked from the low pressure crossheads, and are 28 inches in diameter and 15 inches stroke. The screw propellers are three bladed, 13 feet in diameter, and with pitch adjustable from 13.25 to 15.25 feet The boilers are four in number, double ended, 13 feet in diameter and 18 feet long, and contain 24 corrugated furnaces 37½ inches diameter and 6.5 feet long. The tubes are 3 inches diameter and 6.83 feet long, the total tube surface being 11,300, the total heating surface 13,700, and the grate surface 490 square feet. There are two smoke pipes 6.5 feet diameter and 80 feet high. The battery comprises four 10-inch and four 4.7-inch and twenty-four other rapid fire guns.

MERCHANT STEAMERS.

The Harlan and Hollingsworth company, of Wilmington, Delaware, is building a single screw steamer for the Merchants' and Miners' Transportation Company, intended to run between Baltimore and Norfolk and Boston. She is in every way a duplicate of the *Fairfax*, built by the same firm in 1891 for this company. Her dimensions are:

Length on water line, feet	270
over all, feet	293.5
Beam, molded, feet	42
Depth to third deck, feet	26
fourth deck, feet	34

She will have accommodation for 110 first class and a few second class passengers, and will be handsomely fitted and furnished.

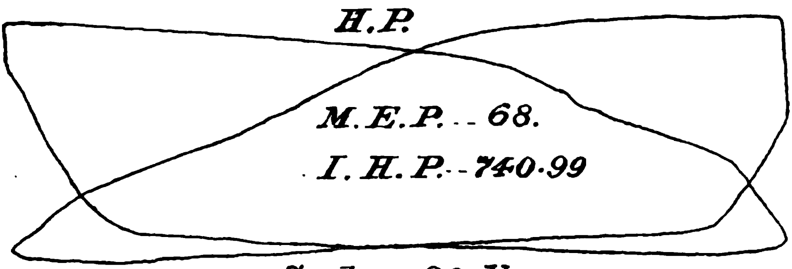
The fourth deck is a light hurricane deck, but has steel beams. On it are three house erections containing the social hall, rooms for first-class passengers, smoking room, ladies' toilet rooms, and rooms for the engineers. On top of the forward house is the pilot house and captain's room, all of which are finished in hard wood. The main saloon, which is finished in mahogany, is located aft of the engine space on the third deck, with a large stairway leading to the social hall above. On this deck are also located the galley and rooms for the cooks, oilers, and second-class passengers, with the crew in the extreme forward end.

She is rigged as a schooner, having two pole masts with wire standing rigging, and is provided with the usual steam capstan steam steering gear, and electric light.

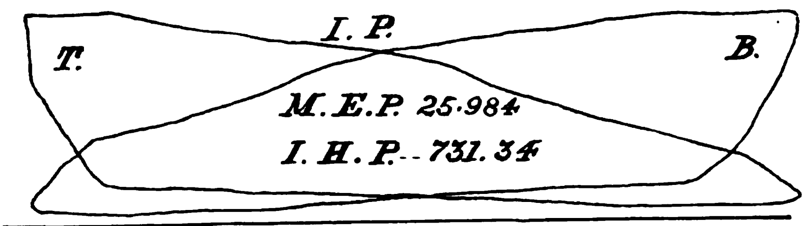
The motive power consists of one vertical triple expansion engine with cylinders 28, 45 and 72 inches diameter by 48 inches stroke, operating three cranks. The air, feed and bilge pumps are worked from the low pressure crosshead; the circulating

S. S. Fairfax.

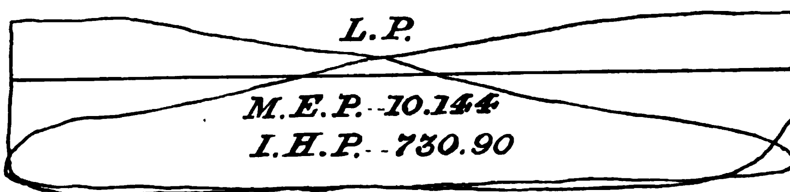
Engine $\frac{28 - 45 - 72}{48}$



Scale = 80 lbs.



Scale = 40 lbs.



Scale = 16 lbs.

Boiler pressure	155
1st Receiver	48
2d "	9
Vacuum	24½
Revolutions	73
I.H.P. of engine	2203·23

pump is of the centrifugal type and is run by an independent engine. The high and intermediate pressure cylinders are fitted with piston valves, and the low pressure with a slide valve, all worked by Stephenson link motion, and reversed by direct steam gear.

The boilers are four in number, each with three corrugated furnaces, and built for working under natural draft at a pressure of 160 pounds per square inch. They are 13 feet 6 inches diameter and 11 feet 6 inches long, and contain 272 square feet of grate and 7,780 of heating surface. There is also an auxiliary boiler 7 feet diameter and 10 feet long, built also for a working pressure of 160 pounds per square inch.

The vessel is intended for a speed of 15 knots at sea loaded.

The accompanying cards were taken from the engines of the *Fairfax* on the 21st of May, 1892, on her regular trip from Baltimore to Boston. On trial over the measured mile, with two-thirds power, she made a speed of 16 statute miles per hour with 1,680 I.H.P., the displacement being 2,590 tons.

New Lake Steamers.—The Chicago Shipbuilding Company has closed a contract for the construction of two cargo steamers of the following dimensions:

Length over all, feet	402
of keel, feet	380
Beam molded, feet	48
Depth, molded, feet	28
Carrying capacity on 14½ feet draught, tons	4,200
18 feet draught, tons	6,000

Although for different owners, the vessels will be built from exactly the same model and molds, at the same time, and in outside form will be as much alike as it is possible to make two ships. With the exception that one vessel will have two masts and a water bottom 66 inches deep and the other three masts and a 60-inch water bottom, the internal arrangements, including position of engines and boilers, will also be precisely similar. One vessel will have two Scotch boilers with about 5,600 square feet of heating surface carrying a steam pressure of 180 pounds, and the other two Babcock and Wilcox marine boilers with about 6,000 square feet of heating surface, carrying a pressure of 200 pounds. The engines of both ships will be built by the Cleveland Ship Building Co., and will be of the ordinary direct-acting inverted triple expansion type, with three cranks, jet condenser and connected air pump, and will be practically duplicates from the same patterns, except in the diameter of the high pressure cylinder, which for the ship with Scotch boilers will be 23 and for the Babcock and Wilcox boilers 22 inches, the other cylinders being 38 and 63 inches diameter in each engine, all with 40 inches stroke. The screw propellers will be duplicates.

The power of these steamers is considered sufficient for a speed of 14 statute miles per hour.

Through the courtesy of the Chicago Ship Building Co. it has been arranged that, as soon as these vessels are completed, they will be placed at the disposal of the Bureau of Steam Engineering of the Navy Department for a test to determine the relative efficiency of the two types of boilers in use.

Another similar steamer is under construction by the Cleveland Ship Building Company. She is of the following dimensions:

Length over all, feet	400
of keel, feet	375
Beam, molded, feet	45
Depth, molded, feet	28

Her engine has cylinders 23, 38 and 63 inches in diameter by 40 inches stroke. Steam is supplied by two Scotch boilers 14 feet in diameter and 13 feet long, each fitted with three 46-inch furnaces, and working at a pressure of 160 pounds.

Northland.—A sister vessel to the *Northwest*, described on page 212 of Volume VI, was launched from the works of the Globe Iron Works, Cleveland, Ohio, on the 5th of January.

Norman.—This steamer, built by Harland and Wolff, Belfast, for the Union Company, and engaged in the trade between England and the Cape of Good Hope, a brief description of which was given given on page 834 of the last volume of the JOURNAL, has recently been minutely described and illustrated in "Engineering," and the following is taken from that publication.

The *Norman* is a single screw vessel of the following dimensions:

Length over all, feet	502
on water line, feet	490
Beam, feet	53
Depth, molded, feet	37.5
Tonnage, gross	7,390
net	4,197
Board of Trade freeboard, summer, feet	10
winter, feet	10.58
North Atlantic, feet	11.17
in fresh water, inches less	7
Draught, load, feet	27.75
Displacement load, tons	13,420
Dead weight capacity, tons	6,513
Coal, included in above, tons	2,543
Draught, light, approximate, feet	16.13
Displacement, light, tons	6,907

She made several speed trials before her departure for the Cape, a mean of the results at two different speeds being:

Speed in knots	17.48	
Displacement, tons	11,400	
Mean draught, feet	24.25	
Steam pressure in boilers, pounds	176	
Vacuum, inches	28	
	Starboard.	*Port.*
Revolutions of engines	82	80
Steam pressure at engines, pounds	175	175
in first receiver, pounds	60	58
in second receiver, pounds	9	10
I.H.P., H.P. cylinder	1,287	1,486
I.P. cylinder	1,422	1,551
L.P. cylinder	1,375	1,466
total for each engine	4,085	4,503
total for both engines	8,588	

On her first voyage she made the run to the Cape in 15 days 19 hours net steaming time, which is equivalent to a mean speed of about 16.5 knots per hour.

The *Norman* is typical of the Harland design. She has a straight stem, the forefoot is cut away as in the *Teutonic* and other vessels built recently at Belfast, the bar form of keel has been used, the frames are of channel section, the shell plates are scarfed, the bulkheads have 'thwartship stiffeners, the propellers overlap, and there is a rise of keel towards the stern to allow a freer flow of water to the propellers, while the deadwood of the ship is bossed out for the propeller tubes. The frames are at 30 inch intervals, and in the region of the machinery double channels are used, 7 inches by $3\frac{5}{8}$ inches by $\frac{10}{16}$ inches, while throughout there are longitudinal stringers 3 feet 9 inches apart. These are composed of two angles, with a stiffening plate, forming intercostals between the channel frames. The angles are $6\frac{1}{2}$ inches by $4\frac{1}{2}$ inches by $\frac{1}{2}$ inch. Web frames about 3 feet deep are introduced at intervals between the bulkheads. The shell plating is for the most part $\frac{3}{4}$ inches, the vertical joints being triple riveted and the longitudinals double riveted. At the extreme ends the frames are of reverse angle section. There is a double bottom right fore and aft. The space being 4 feet deep, except under the machinery, where it is 5 feet. This provides capacity for 1,067 tons of water ballast.

There are nine water tight bulkheads, the first two compartments being given over to water ballast or trimming tanks, the next two to cargo, the fifth to cargo or for the stowage of reserve fuel. This compartment will hold 1,611 tons, so that in all 4,154 tons of fuel may be carried, equal to steaming at full speed to the Cape and home. The next two compartments are taken up with two separate installations of boilers, and 'thwartship bunkers for each of the four stokeholds, these bunkers having capacity for 2,543 tons. The twin engines are in one compartment. In the fore end of the shaft tunnel, and thus immediately under control of the engineer, are the electric light and refrigerating machinery, the latter running in connection with chambers immediately above for 124 tons of perishable cargo. The after compartment, again, is given over to cargo.

The *Norman* has five decks, the orlop, main or middle, upper, bridge and boat decks. The accommodation provided is for 250 passengers in the first class, 100 in the second class, and 160 in the third class; but should there be a greater number offering at any time, equally good quarters could be provided for them, and as a troop ship the *Norman's* capacity will be enormous. The first-class passengers are accommodated in the center of the ship, in the bridge deck house, where are the drawing and smoking saloons; on the upper deck house, where the dining room occupies the center of the ship; and on the middle deck, which is given over entirely to state rooms. The second-class passengers are accomodated immediately abaft the machinery, and the third-class passengers forward on the middle deck. The officers have their rooms on the boat deck, the engineers on the upper deck beside the machinery, the seamen in the forecastle, and the stewards, &c., in the poop. The rooms of the commander are immediately under the bridge.

A novel method has been adopted of cooling the air sent into some of the public rooms, notably the drawing room. On the top of the chart house, which is immediately above the drawing room, there is a casing containing a number of pipes filled with cold brine sent direct in piping from the refrigerating machine. A Sturtevant fan, driven by a steam engine, draws fresh air from the atmosphere and forces it amongst the brine pipes, thence into the drawing room, so that the air is kept at a moderate temperature even in the tropics. Many of the passages, again, are laid with India rubber tiles, ½ inch thick, which give the cool effect of mosaic tiles, and are free from that slipperiness which is a source of danger when the ship is swaying in a sea.

The dining saloon is situated on the upper deck, between the funnels, and exactly in the center of the ship. It seats about 250 passengers. Light and ventilation are secured not only by square portholes on either side, but by a large dome 20 feet by 10 feet, and about 18 feet high from the floor level.

The drawing room and library is an unusually large apartment, 36 feet long by 24 feet broad, the roof being 10 feet high, with a stained glass cupola.

The promenade on the bridge deck for first class passengers extends for just over 250 feet, and it is protected by the boat deck above. There is a long well forward and a short well aft, principally for the hatches to the two cargo compartments forward and to the one aft. There is a large poop for the second class passengers' promenade. They likewise have access to the extensive area of the upper deck, where also third class passengers may promenade.

Although the ship has been subdivided by water tight compartments in accordance with the recommendation of the Parliamentary Bulkhead Committee, boats in excess of the Board of Trade demands have been provided, ten 28-foot boats and two 26-foot boats, carried on the boat deck.

The main engines are of the triple expansion type, inverted and direct acting, and work with steam at 176 pounds pressure. The cylinders are separate castings of cast iron. Liners are fitted, with flanges for bolting to the cylinders, but they are not used as steam jackets. The cylinder covers are of box section, the stuffing boxes being bushed with brass, but the upper ends of only the low pressure rods pass through the covers. Loose cast iron valve faces, secured with Muntz's metal screws, are fitted to the low pressure cylinders, which have the ordinary double ported slide valves, while the high pressure and intermediate cylinders have loose liners and piston valves. The cylinder pistons are of cast steel, open and of conical section, with Ramsbottom rings, the high pressure piston rods having United States metallic packing, while the other rods have Beldam's packing, which is also used for the valves. The valve rods are $4\frac{3}{4}$ inches in diameter. The valves are of cast iron, worked by link motion and double eccentrics. These are of substantial construction, the quadrants having large bearing surfaces. The eccentric straps are of cast steel, fitted with white metal; the top ends of the rods are fitted with brasses, while the pulleys are of cast iron. The go-ahead rod is straight, all the set being on the astern rod. The valve spindles are of steel, and balance pistons are fitted to the low pressure slide rod. The high pressure and intermediate pressure rods pass through a brass dome. The reversing gear is of the ordinary Brown combined steam and hydraulic type. The engines are fitted with Aspinwall's governor, which is so set that with an abnormal speed it would operate the throttle valve.

The piston and connecting rods are of forged steel, and the crosshead gibs of cast iron lined with white metal, the guide being fitted for water circulation. The bed plates are of box section, having half-round recesses for shaft bushes and raised seats for cylinder columns. The main bearing bushes, are of cast iron filled with white metal, the keeps being of hollow cast steel fitted with brass lubricating boxes. The floor of the engine room is about 2 feet 6 inches below the top of the bed plate. The columns for supporting the cylinders are of cast iron connected at the top by a fore-and-aft piece of box section. This is in addition to the flanging together of the cylinders, and adds to the rigidity of the engine. The framing is hollow, and each affords capacity for the storage of 270 gallons of oil. A tap is provided at the bottom.

The condenser is of cast iron, and is part of the back framing, as in usual practice. There are ½-inch plates inside supporting the middle of the tubes. The tubes are of solid drawn brass, packed at each end with cotton cord and brass screwed glands. The tube plates are of solid rolled brass 1⅛ inches thick, and the tube holes bored from the solid. All stays and fittings are of brass, with brass baffle plate under the exhaust to protect the tubes. The air pumps are worked by a lever from the crosshead of the intermediate engine, while the circulating pumps are of the centrifugal type run by a single cylinder engine working at a reduced steam pressure, but strong enough to stand the full boiler pressure. The disc is of gun metal and the spindle of manganese bronze.

The propellers have bosses of cast steel, and three portable blades of manganese bronze. The thread of the screw on the shafts is on the opposite hand to the propellers, which both work outwards.

The propellers overlap each other, the starboard shaft extending fully 5 feet 6 inches further than the port shaft. Aft the ship is bossed out to the extent of 5 feet, so that the shaft is entirely within the ship. While the ordinary reverse angle frames take the ordinary curve to the keel, there are fitted to them short angle frames curved to a bulb shape to suit the diameter of the shaft, and on these latter frames the shell plating is riveted.

Moreover, the form of the stern framing is novel. It consists of a steel casting curved so that there will be a free flow of water to the propellers.

All the shafting is of steel, the crank shafts in three interchangeable sections, and a short section of line shafting fitted immediately forward of the propeller shaft so that the latter may be withdrawn inboard.

The thrust is fitted with white metal in horseshoe collars, The screws are of manganese bronze and 3½ inches in diameter, with brass nuts for adjustment, and the bosses are used for water service. Separate supporting bearings have been fitted on the brackets at each end of the thrust block, so arranged as to be readily removed and relined without lifting or disconnecting the shaft.

The propeller shaft is covered with brass ⅞ inch thick at the outer and inner bearings, and ⅝ inch thick at the center. The stern tube is of cast iron, fixed into the sternpost by a nut outside, and inside by a flange bolted to the bulkhead at the after peak, with cock and pipe leading to the gland. The outer and inner bearings are of brass, fitted with strips of lignum vitæ, with the end grain on the lower half, and with the grain on the upper half.

Diameter of H.P. cylinder, inches	31½
I.P. cylinder, inches	52
L.P. cylinder, inches	85
Stroke of pistons, inches	57
Piston rods, diameter, inches	8¾
Connecting rod, diameter, inches, top end	8⅛
bottom end	9⅝
length, center to center, feet and inches	9–10
Crosshead guides (26x23½ inches), area, square inches	611
Condenser tubes, number in each condenser	1,719
diameter, inch	⅞
thickness, No. 17 I. W. G., inch	.056
length exposed, feet	16.63
Condensing surface in each condenser, square feet	6,540
Air pumps, single acting, diameter, inches	31
stroke, inches	28½
Circulating pump, inlet, inches	14½
outlet, inches	15½

Circulating pump, engine, diameter of cylinder, inches	10
stroke, inches	10
bilge connection, diameter, inches	7
Crank shaft, diameter, inches	17
length of journals, inches	19½
coupling flanges, diameter, inches	30½
bolts (9), diameter, inches	3½
length of each section, feet and inches	10–3
Crank pins, diameter, inches	17½
length, inches	19
Line shaft, diameter, inches	16
length of journals (two in each section), inches	30
length of each of three sections, feet and inches	22–2
short section, feet and inches	5–6
Propeller shaft, diameter, inches	17¼
distance between axes of shafts, feet and inches	14–6
thickness of casing at bearings, inch	⅞
between bearings, inch	⅝
length of after bearing, feet and inches	5–9
forward bearing, feet	2
distance between axes at after end, feet and inches	14–6
Stern tube, length of starboard, feet and inches	19–11⅜
port, feet and inches	4–5⅝
Thrust shaft, diameter, inches	16½
between collars and in bearings, inches	16¾
over collars, inches	26¼
number of collars, each shaft	8
thrust surface each shaft, square inches	896
length of shaft bearings (two), inches	16½
Thrust block, length, including bearing at each end, feet and inches	11–9½
width, feet and inches	4–1⅝
holding down bolts (thirty-two), diameter, inches	1½
Screw propeller, number of blades	3
diameter, feet and inches	17–4
pitch, adjustable between, feet and inches	23–6 to 24–3
as set on trial, feet and inches	24–3
helicoidal area, each screw, square feet	75
diameter of boss, feet and inches	4–5
length of boss, feet and inches	3–11

The boilers are seven in number, five double and three single-ended, all of the same diameter, with three furnaces at each end, making a total of thirty-six furnaces. The boilers are arranged in two water-tight compartments, each set with its own smoke pipe, the top of which is 94 feet above the lowest grate. There are three double ended boilers in the forward compartment, and two double and two single-ended ones in the after compartment, the two latter being placed in the center. The fire rooms are open, but, in addition to the usual ventilators, there are fans on deck for ventilating the ship which discharge into the fire rooms.

The ash hoists in the after fire rooms are of the ordinary type, while those forward are of the See type. The hopper into which the ashes are shoveled has been placed against the bunker bulkhead in the fire room. From the lower part there is a discharge pipe 6 inches in internal diameter extending upward, the height being 25 feet, so that the discharge opening is 4 feet above the load water line. At the bottom of the hopper there is an ejector and jet cock connected with a duplex double-acting pump, having cylinders 12 inches by 7 by 12 inches stroke, supplying the water to the jet at a pressure of about 180 pounds. On the jet cock being opened, a current of water in the discharge pipe is formed, and the ashes forced up the discharge pipe as fast as they are shoveled into the hopper. In the case of the *Norman* they were thrown 20 feet clear of the ship's side. The objection formerly raised to the bends wearing out has been met by the adoption of a special arrangement of replace plugs made of metal almost impervious to friction.

BOILERS.

Number of double ended	5
single ended	2
Diameter of all, feet and inches	15-3
Length of double ended, feet and inches	17-6
single ended, feet and inches	10-3
Furnaces, total number (Morison's)	36
diameter, inside, inches	43¾
Tubes, number in each double ended	604
single ended	302
of stay (total)	1,224
of ordinary (total)	2,400
diameter, outside, inches	3¼
thickness, ordinary (No. 7 S. W. G.), inch	.176
stay, inch	$\frac{5}{16}$
length over tube sheets, feet and inches	7-2
spacing horizontally and vertically, inches	4½

Combustion chambers (common to each opposite furnace), depth, feet and inches	$3-3\frac{3}{4}$
Braces, longitudinal above tubes, number in each	18
diameter, upper row, inches	$2\frac{1}{2}$
second and third rows, inches	3
from combustion chamber to shell	12
diameter, inches	$2\frac{1}{4}$
Thickness of shell plates, inches	$1\frac{13}{32}$
upper heads, inch	1
tube sheets, front, inch	$\frac{7}{8}$
back, inch	$\frac{3}{4}$
lower front, inch	$\frac{7}{8}$
combustion chamber sheets, inch	$\frac{5}{8}$
Rivets, diameter, in shell sheets, inches	$1\frac{7}{16}$
Grate surface, total, square feet	720
Heating surface, total, square feet	25,423

Forward in the engine room, in a recess leading into the stokehold, are four of Weir's pumps with feed heater and filter, and here there is a wooden door for use on ordinary occasions, while the steel door is fitted with a rack, the shaft extending to the upper decks having a screw thread, but should it be desired to close the door quickly, there is an eccentric on the shaft with lever at top and bottom, so that the shaft and screw can be thrown out of gear, in which case the door will drop by its own weight, two independent air cylinders acting in such case as brakes. On the starboard side there are Weir's evaporators on the orlop deck level, with a condenser for use in connection with winches and auxiliary machinery, Hocking's feed heaters, ballast engine by Watson, of Newcastle, fresh water pump by Carruthers, of Glasgow. On the port side there is stowed away Thomson's patent coupling for use on the main shaft in emergency. This coupling is made in three parts, and while there is a recess to fit over the ordinary coupling flanges, the ends can be firmly clamped together. On this side, also, are duplex feed donkey pumps, by Messrs. Harland and Wolff, and also bilge, or wash, or general tank pumps by Watson, which may discharge on deck, overboard, or in the sanitary tanks, drawing from the bilge or sea.

There is also a duplex feed pump in the forward fire room.

There is one feed pump on each set of engines, of 6 inches diameter, and 28 inches stroke. The rams, valves, chests and valve seats are of brass. There is one bilge pump, too, on each engine, the bore being 6 inches and the stroke 28½ inches. It has a galvanized wrought iron rose box at each end of the engine room. The ballast donkey pumps are of the Westminster type, and have steam cylinders 10 inches and water cylinder 12 inches in diameter by 12 inches stroke. They draw from each ballast tank or engine room bilges direct, and discharge overboard below the water line, or through the main or winch condenser. Weir's pumps have a steam cylinder of 10 inches diameter and a water cylinder of 8 inches by 21 inches stroke. Weir's evaporators are each of 25 tons capacity. The donkey engines have been fitted by Messrs. Harland and Wolff themselves. They are of the duplex type, 9 inches and 6 inches in diameter by 10 inches stroke, the pump box, plungers, valves and seatings being of brass. They are almost universal in their suction and discharge. The pipes, for the most part, are of copper, those above 4½ inches in diameter being solid drawn. The main steam pipes are lapped with ½-inch steel bands 5 inches to 6 inches apart. The maximum length of the pipes is 10 feet.

All the auxiliary machinery may exhaust into a separate condenser, as already indicated, and this has a cooling surface of about 600 square feet.

The steering gear is of the Wilson and Pirrie type. The engines are of the vertical high pressure type with piston valves, the diameter of cylinders being 9 inches and the stroke of piston 10 inches. On the shaft is a worm geared to a manganese bronze wheel working in a horizontal plane on a vertical shaft, on which also there is a spur pinion working on the manganese bronze teeth of the quadrant fitted to the rudder head. The strong spiral springs are for taking up any shock conveyed from the rudder to the quadrant. These spiral springs are fitted up under compression in such a manner that whether the rudder is forced to port or starboard the springs are still further compressed, so that both are available for resisting the strain on the rudder. Neither is idle, no matter in which way the strain may come.

This steam steering engine is operated by shafting from the main bridge or from the poop, on which it is placed in a deck house. It can be readily thrown out of gear, whereupon the hand steering gear works direct on to the rudder head.

The vessel was supplied with a complete installation of electric light. The generating machinery consists of three double acting compound engines of the vertical type, driving dynamos capable of maintaining continuously alight 300 16-candle power lamps. The cylinders are 9½ inches and 14¾ inches in diameter by 8½ inches in length of stroke, and at 80 pounds of steam pressure they run at 250 revolutions per minute, indicating 40 horse power. The engines are provided with throttle valve governors, capable of adjustment by hand whilst running. The dynamos are of the inverted single horseshoe type, having drum wound armatures 15 inches in diameter. The total number of lights installed is 670, all of which are of 16-candle power, with the exception of those in the masthead and side lights, which are of 32-candle power, with double filaments for greater security against extinction.

The switchboard in the engine room is of large proportions, with three massive main switches for the three dynamos, and the several distributing circuits mounted on a slate base. A feature of interest, new to ship lighting, is that the three compound-wound dynamos are run in parallel on the single-wire system; each machine has its own ammeter, and by a special arrangement of the main switches the dynamo brushes are coupled together, as well as the terminals, which are connected to the omnibus bars. The whole ship is wired on the single-wire system; special precautions, however, were taken to prevent the compasses being affected by currents in their immediate neighborhood, and on the inspection and trial of the ship these precautions were found to have entirely attained their object. Large use has been made of distributing boxes from which the light is supplied to the different staterooms; by this arrangement each lamp has its own separate fuses, and the necessity for joints in the wires is very largely avoided.

The *Norman* is fitted with a complete refrigerating plant, of the type constructed by Messrs. J. and E. Hall, Limited, of Dartford. The machine itself, which is placed in the space at the entrance of the tunnel between the shafts in the main engine room, is on the maker's duplex system, consisting, in reality, of two complete machines, either of which is by itself capable of carrying out the entire work. These two refrigerating machines are so arranged that the steam cylinders can be made to drive either the one or the other, and thus a very considerable security is obtained as against a single machine. The principle of Hall's carbonic anhydride machine is so well known that we need hardly describe it here. It consists of the compression and liquefaction of a volatile gas, carbonic acid, which boils at an extremely low temperature, and constitutes a refrigerating medium giving the highest economy without any of the disadvantages attached to most of the liquefiable gases, which are of a poisonous or deleterious nature. By the action of the machine a large quantity of cold brine is circulated at a low temperature through the several cold chambers comprising the frozen meat room, which is maintained at 10 degrees of frost, there being separate rooms for keeping the fish and milk at about 12 degrees of frost. The vegetable room is maintained by its own circulation of brine at about four degrees above freezing point, whereas the fruit room can be regulated to whatever particular temperature may be necessary for the class of fruit constituting the cargo, and the arrangements are such that this temperature can be maintained with a variation not exceeding 1 degree or 2 degrees throughout the voyage and in all parts of the chamber.

The cold air chambers in the *Norman* are immediately above the refrigerating machinery. The floors and about 2 feet up the walls are 1 foot thick, covered with sheet lead, but the walls of the meat and thawing room are covered with white enameled tiles. The meat room has an area of 400 square feet, and a capacity of 2,800 cubic feet; the fish room has an area of 37½ square feet, and a capacity of 243¾ cubic feet; the milk room being of corresponding size, while the fruit room has a floor area of 373 square feet, and a capacity of 2,424 cubic feet. While having communication with the cargo hatches, all these rooms are arranged to open in a large vestibule forming the thawing room, having a floor area of 373 square feet, with a capacity of 2,424 cubic feet. The rooms are all 6 feet 6 inches high, and are plentifully fitted with racks.

In connection with the cooling chamber a fan engine by Messrs. W. H. Allen, Son and Co. is used. This engine is of their new single-acting type, with the moving parts running in a bath of oil, and thus adapted for high speed work. The fan is capable of passing from 6,000 to 8,000 cubic feet of air per minute.

Some of the more important weights of the machinery are:

	Tons.
Each double ended boiler, complete, with water, fittings, etc.	120
single ended boiler as above	68
Water in each double ended boiler	40.5
single ended boiler	23.3
Each section of crank shaft	8.2
long section of line shaft	12.9
Each propeller blade	2.42
boss	5.25
Each connecting rod	3.23

Alma.—A sister vessel of the *Columbia*, mentioned on page 839 of the last volume of the JOURNAL, and built also by Messrs. J. and G. Thomson for the London and South-Western Railway Company. She is 270 feet long, 34 feet beam, and has a gross tonnage of 1,145 tons.

She has twin screw triple expansion engines, both in the same water tight compartment, with four cylinders 19, 29 and 31½ inches diameter and 30 inches stroke, which on the measured mile trial developed 3,740 I.H.P. The revolutions were 191 for the starboard and 192 for the port engine, the steam pressure 160 pounds, and the vacuum 26½ inches. The boilers have Serve tubes.

On the measured mile the speed was 19.38 knots, and that for the six hours upwards of 18.5 knots.

Sylvania.—A twin screw cargo and cattle steamer, built by the London and Glasgow Engineering Company for the Cunard Line, was launched on the 24th of January. She is intended for the trade between Liverpool and New York and Boston, and is expected to make a speed of 14½ knots.

She is 460 feet long over all, 49 feet beam, 42.5 feet depth, and carries 6,500 tons dead weight. Her engines are of the triple expansion type, with cylinders 22½, 36½ and 60 inches diameter by 48 inches stroke, steam for which is supplied by two double-ended boilers working with Howden's system of forced draft.

Caledonia.—This, the latest Peninsular and Oriental steamer, was constructed by Messrs. Caird and Co., Greenock, Scotland, and is of the following dimensions:

Length, feet	486
Beam, feet	54
Depth, feet	37
Tonnage, gross, tons	7,500
Cargo capacity, tons	1,500

Her I.H.P. is 11,000, which, on a run from the Clyde to Queenstown, gave her a maximum speed of 18.2 knots. She has four masts and two funnels, and is fitted up for the accommodation of 320 first and 150 second class passengers.

Her engines are of the single screw triple expansion type with five cylinders driving three cranks, the cylinders farthest forward and farthest aft being tandem. That is, there are two high and two low pressure cylinders, and one intermediate pressure, and the high pressure cylinders are placed immediately above the low pressure. Their diameters are 33, 69 and 84 inches, respectively, and the stroke 72 inches. The high pressure piston valves are worked by rockshafts operated by the low pressure valve stems; the intermediate valve also is of the piston type, and the low pressure a slide valve; all are operated by Stephenson link motion.

The propeller is of manganese bronze, four bladed, with the pitch adjustable between 28.5 and 31.5 feet.

Steam at 150 pounds pressure is supplied by three double and four single ended boilers, all 15 feet in diameter, the double ended boilers having six furnaces, and the single ended ones three, making thirty in all. The total grate and heating surfaces are, respectively, 598 and 24,010 square feet.

She is lighted throughout by electricity, the plant consisting of three generating sets, each capable of 220 amperes at 105 volts. The engines are compound, 8 by 16 by 10 inches stroke, and run at 220 revolutions per minute. The mains in the engine and boiler rooms are enclosed in iron pipes. The ship is used for the return circuit.

Following are some of the particulars of the machinery:

Diameter of H.P. cylinders (2), inches	33
I.P. cylinder, inches	69
L.P. cylinders (2), inches	84
Stroke, inches	72
Piston rods, diameter, inches	11½
Crosshead pins, diameter, inches	11½
length, inches	12
Thrust shaft, diameter, inches	21⅛
number of thrust blocks	2
number of thrust collars	26
diameter over collars, inches	28½
inside collar, inches	21
surface, square inches	6,190
Screw propeller, diameter, feet	21
pitch as set, feet	30.5
length of blade, feet	9.65
area of blades, square feet	129

Alleghany.—A new steamer built for the Atlas Steamship Company by Messrs. R. Napier and Sons, Glasgow, was launched on the 14th of November. She is 322 feet long, 38 feet beam, and 26 feet deep, and in addition to large cargo capacity has accommodations for 60 passengers, there being 30 double state rooms amidships above the main deck. She has the usual poop and top gallant forecastle, the former serving as the quarters for the crew.

Her engine is of the triple expansion type, with cylinders 24, 40 and 68 inches diameter and 48 inches stroke, working with a boiler pressure of 200 pounds, and designed for 2,000 I.H.P. There are two single ended boilers working under forced draft on Howden's system. Her speed is expected to be 14 knots.

Tantallon Castle.—A steamer built by the Fairfield Shipbuilding and Engineering Company for the Castle line of steamers to South Africa, is of interest from the fact that she has the largest quadruple expansion engine in any vessel now in service. Her dimensions are:

Length over all, feet	455
Beam, feet	50.67
Depth, feet	35
Gross register, tons	5,800

She is a three-masted vessel with square sail on the foremast, has a double bottom, and ten water-tight bulkheads extending up to the spar deck. She has accommodation for 145 first-class and 100 second-class passengers, as well as for a number of third-class.

Her engine is of 7,500 I.H.P., and was designed to work with a boiler pressure of 200 pounds per square inch. The cylinders are 33½, 49, 67 and 98 inches in diameter by 66 inches stroke, and are arranged with the high pressure cylinder at the forward end, next the first intermediate, then the low pressure, and the second intermediate at the after end. The high pressure and first intermediate pressure cylinders are each fitted with a piston valve, and the second intermediate and low pressure cylinders are each fitted with a double ported slide valve, all being worked by the usual double eccentrics and link motion valve gear.

The crankshaft is in four pieces, each piece being built, and, together with the thrust, tunnel and propeller shafts, are forged of mild ingot steel. The crankshaft is 20½ inches in diameter, the thrust shaft 20½ inches in diameter, and the propeller shaft 21 inches. There are 11 thrust rings, of the ordinary horseshoe type. The screw propeller has four blades of manganese bronze, with a boss of cast steel. The diameter is 20 feet.

The water is circulated through the condenser by two large centrifugal pumps driven by independent triple expansion engines of the single acting direct acting type, with enclosed crank, each pump being capable of supplying sufficient water when the main engines are working at full power. The air pumps are worked by levers from the crosshead of the high and low engines. A feed water heater, with the necessary feed pumps and connections, is fitted alongside the main engines. There are also two evaporators, with the necessary pumps, working in combination with two distillers for supplying fresh water to the ship, and also for the boilers. An auxiliary condenser, with a separate air and circulating pump, is also fitted and connected to all the auxiliary exhaust pipes in the ship.

The vessel is fitted throughout with a cellular double bottom, which is arranged to be used for water ballast.

The boilers are five in number, viz., three double ended, the length of which is 19 feet 2 inches, and diameter 15 feet 2 inches; and two single ended, the length of which is 10 feet, and the diameter 16 feet. Each of the double ended boilers has six furnaces, and each of the single ended boilers has four furnaces, making a total of twenty-six furnaces, all having Purves' flues. Two large fans are fitted in the funnel casing to insure an abundant supply of air to the stokeholds. These fans are 6 feet in diameter, and are driven up to 200 revolutions per minute. The stokehold is open, and these fans are only for use in the tropics, or when necessary for ventilation.

She has a complete refrigerating plant of the ammonia type on the De la Verne principle. The machine is placed in the engine room, and consists of two vertical 6 by 10 inch double acting ammonia compressors which may be worked together or separately. They are driven direct by one vertical simple steam cylinder placed between the compressors. The machine occupies a space of 6 feet by 4 feet 6 inches by 7 feet 6 inches high, and the ammonia condensers are placed above the machine. These condensers, two in number, can be worked together or separately, as required, and are so constructed that the outer shell can be taken apart at any time for the inspection or cleaning of the coils. The meat room is of about 1,600 cubic feet space, the vegetable and wine room 800, and the fruit room 3,200, besides which the usual ice making tank is provided.

Three large Siemens dynamos, each driven by triple expansion engines of the direct single-acting inclosed type supply the necessary lights throughout the ship.

The lighting installation is for 596 incandescent lamps. The dynamos (three in number) are of Siemens H. B. type. Each machine has an output of 135 amperes and 105 volts at 250 revolutions per minute. The switchboard is of enameled slate, and is fitted with ammeters, voltmeters, fuses and switching apparatus for controlling the seven distributing circuits. The wiring throughout the ship has been carried out upon the single wire system, and in connection with Siemens patent distributing boxes, which permits of all joints being dispensed with. Each of these distributing boxes controls a section of not more than 10 lights, and is so arranged that the police lights are independent of the switching arrangements. These boxes are fitted with fuses, one for each lamp, placed under glass plates, and a cut-out which has fused is easily detected when the box is opened. The wires are insulated with vulcanized rubber, taped and braided, and are run throughout the ship partly in pine and partly in teak casing, with the exception of the engine room and exposed positions, where they are run in iron pipes. In addition to the electric light installation, eight electrically driven ventilating fans have been fitted, and two Siemens electric motors. The cargo lights consist of eight reflectors, each fitted with six incandescent lamps.

Alsace and *Lorraine*.—Two new steamers said to be in contemplation by the Compagnie Generale Transatlantique for their New York-Havre route. They will be 558 feet long, 59 feet beam, and, at 26 feet draught, will have a displacement of 13,600 tons. They will be twin screw steamers of great power, and their sea speed will be equal to that of the first class steamers now on the Atlantic. Their cost will be between three and a half and four million dollars.

YACHTS.

Giralda.—This is a magnificent twin screw yacht recently built by the Fairfield Shipbuilding and Engineering Company, Glasgow, for Mr. Hugh McCalmont, in which some of the features of a cruiser have been combined with those of a yacht. Her engines, which were illustrated in "Engineering," have a striking resemblance to many of the recent high speed cruiser engines. Her rig is that of a fore-and-aft schooner with three pole masts, with one yard on the foremast. She has one smoke pipe.

The following are the principal dimensions and data:

Length over all, feet	312
on water line, feet	275
Breadth, extreme, feet and inches	35–1½
Depth, feet	19
Yacht measurement, tons	1,508
I.H.P.	8,500
Speed in knots on measured mile	20.9

The deck erections consist of a topgallant forecastle, large midship house 160 feet long, and a small wheel house aft. In the midship house are situated the public rooms—the drawing and dining rooms at the after, and the smoking room at the fore end—all communicating with each other by an inclosed passage running along the starboard side of the casings. The deck in these apartments and the corridor is entirely covered with oak parquetry, and the rooms are framed and panelled in solid hard wood, satinwood, oak, etc., varied in each apartment with furniture and upholstery to harmonize. The sleeping accommodation is all arranged on the lower deck, the height between decks being 9 feet 6 inches. Forward of the boiler space are four large cabins entering from the vestibule abaft the smoking room on the main deck, and abaft of engine space are the owner's cabin and another large stateroom. All these cabins are substantially framed in mahogany, with light silk in the panels. The framing has been enamelled white throughout, thus giving the occupants all the advantage of the light which is here admitted by large side lights, with stained glass lanterns on the inside, and also from skylights on the deck. Neat fireplaces, with white metal grates, have been fitted up in all the public rooms and in the principal staterooms, the other apartments being comfortably heated by means of steam apparatus. Two upright grand pianos have been supplied, one being placed in the drawing room and the other in the owner's stateroom, on the cabin sole, each with case made to harmonize with the surrounding framing. All the apartments are furnished and upholstered in elegant style, with brass or hard wood bedsteads, wardrobes, chests of drawers, writing tables, chairs, couches, etc.; the floors covered with Axminster or Turkey carpets and rugs, silk curtains to windows and beds, and, in fact, everything which can be expected to assure the perfect enjoyment of a cruise.

There is a complete system of water-tight compartments cutting off the engines from the boilers, and dividing one set of boilers from another. Only in some bulkheads have doors been provided, and these can be closed from the main deck. The coal bunkers completely surround the boiler rooms, and the side bunkers are carried inwards over the top of the boilers to the height of the upper deck, and along the whole length of the engine space. The side plating is $\frac{13}{20}$ inch and $\frac{14}{20}$ inch thick, and the bottom plating is mostly $\frac{1}{2}$ inch thick. The frames are formed of heavy channel bars, spaced 2 feet apart, and the floors to every frame are $\frac{5}{8}$ inch thick. The bulkheads forming the water-tight compartments and the coal bunkers are all $\frac{16}{20}$ inch in thickness. The vessel is built of steel throughout. Two Gardner guns and four Hotchkiss guns, with two electric search lights of Admiralty pattern are carried.

The propelling machinery consists of two sets of triple expansion engines in the same compartment, each with four cylinders working on four cranks. Piston valves are fitted for the high pressure, and slide valves for the low pressure cylinders, and all are worked by the ordinary Stephenson link motion. The cylinder covers and pistons are of cast steel, and the shafting of fluid compressed steel. The crank shaft for each engine is in two sections, each with two double throw cranks, the cranks of each section being opposite each other and at right angles to those of the other section.

The condensers are cylindrical, and are made of sheet brass, and the circulating pumps of the centrifugal type. The air pumps are worked from the main engines, and are the only pumps so worked, the main and auxiliary feed pumps and the fire and bilge pumps being independent.

There are three double and two single ended boilers placed in two watertight compartments, and arranged to work with moderate forced draft on the closed fire room system. See's ash ejectors are fitted.

Steam pressure, pounds	170
Diameter of H.P. cylinder, inches	25
I.P. cylinder, inches	40
L.P. cylinder (2 for each engine), inches	45
Stroke, inches	27
Revolutions per minute on trial	220
Shaft, crank, diameter, inches	10¾
thrust, diameter, inches	10¾
propeller, diameter, inches	11
diameter of hole in all, inches	5
Boilers, diameter, feet and inches	12–1
length, double ended, feet and inches	18–3
single ended, feet	10
number of furnaces	16

From an examination of the above data, the I.H.P. said to have been obtained on the trial, 8,500, looks rather large. It is equivalent to 533 I.H.P. per furnace, which is unusual, even in naval vessels with boilers of corresponding size.

La Belle Sauvage.—The trial of this yacht took place in the Firth of Forth on the 27th of December, when a speed of 11.86 knots was made with 660 I.H.P.

ANNUAL MEETING.

The annual meeting for the election of officers and for the transaction of other business was held in the office of the Engineer-in-Chief, Navy Department, on the evening of December 22, 1894, Chief Engineer George W. Baird, U. S. N., in the chair.

The election of officers for 1895 resulted as follows:

President: Chief Engineer James H. Perry, U. S. Navy.

Secretary-Treasurer: Passed Assistant Engineer R. S. Griffin, U. S. Navy.

Members of Council, in addition to the President and the Sectary-Treasurer: Passed Assistant Engineer F. H. Bailey, U. S. Navy; Naval Constructor D. W. Taylor, U. S. Navy; Passed Assistant Engineer B. C. Bryan, U. S. Navy.

The report of the Secretary-Treasurer for the year ending December 22, 1894, was read and a committee appointed to audit the accounts, which has since been done and approved. The report follows:

WASHINGTON, D. C., *December 22, 1894.*

To the American Society of Naval Engineers.

Gentlemen: In accordance with the requirements of Section 14 of the By-Laws, I have the honor to submit the following report of the financial condition of the Society for the year ending to-day:

RECEIPTS:

Balance on hand December 22, 1893	$1,590.08
Annual dues	1,673.50
Subscriptions, reprints and sale of JOURNAL	782.80
Advertising	1,258.74
Interest on deposits	33.30
Total	$5,338.42

EXPENDITURES:

Printing	$2,447.56
Illustrations	471.57
Stationery, postage and incidental expenses	120.44
Purchase of Journals	65.50
Salary of Secretary-Treasurer	600.00
Total	$3,705.07
Leaving a balance on hand of	$1,633.35

All of which is respectfully submitted.

R. S. GRIFFIN,
Secretary-Treasurer.

OBITUARY.

CHARLES W. COPELAND.

In the death of Mr. Charles W. Copeland, which occurred in Brooklyn, on February 5th, the Society loses one of the oldest and most distinguished of its honorary members.

Mr. Copeland was born at Coventry, Connecticut, in 1815, and came by his engineering talents by inheritance, his father, Daniel Copeland, being the proprietor of a large engine and boat building business at Hartford, in which establishment, supplemented by a course of study at Columbia College, young Copeland received his professional education. While serving in his father's works he designed and built a number of steamers for use on the Connecticut river, and thus gained early in life the experience in marine engineering, then a new calling, that made him an ornament to the profession during a long, eventful, and exceedingly useful career.

When only twenty-one years of age he was selected for the responsible position of superintendent of the West Point Foundry Association, and was immediately employed on the design and construction of machinery for the naval steamer *Fulton*, for which the West Point company had a contract, he being assisted in this work by the engineer of the *Fulton*, Mr. Charles H. Haswell, who then enjoyed the distinction of being the first and only engineer in the naval service. While superintendent of the West Point Foundry Mr. Copeland also built the machinery for a number of Hudson river steamers famous in the early days of steam navigation on that river.

In 1839 Congress authorized the building of three sea steamers, and as there was then no established corps of engineers in the Navy to design and construct the required machinery, the Navy Department appointed Mr. Copeland to superintend this work with the title of Principal Engineer, a position which he held for about fourteen years, although his status was that of a civilian adviser, and not that of a regular member of the naval establishment. Two of these steamers were the *Mississippi* and the *Missouri*, the finest examples of war steamers of their day. Later, as a steam navy slowly came into existence, Mr. Copeland designed machinery for the famous *Susquehanna*, the *Saranac*, and the *Michigan*, being assisted in his work on the latter by Mr. Haswell.

After leaving the employment of the Navy Department, Mr. Copeland became superintendent of the Allaire Works, of New York, and there built machinery for many famous ocean steamers for the Collins and other lines; he also designed and built there the revenue cutter *Harriet Lane*, destined for a remarkably active career and a most tragic ending. Mr. Copeland was the first supervising inspector of steam vessels for the district of New York, and for many years was a director and consulting engineer of the Norwich and New York Transportation Company, in which latter capacity he designed the great steamers *City of New York*, *City of Boston*, and *City of Worcester* of that line.

Mr. Copeland's experience and knowledge of naval matters were frequently made use of by the Navy Department after he had left the employ of the Government, and he was frequently retained as an expert in important technical matters; notable instances of employment of this kind may be cited in the famous board appointed in 1863 to survey the monitor *Passaic* after she had been pounded by the guns of Fort Sumter and Rear Admiral DuPont had reported the ironclads unable to withstand such fire, of which board Mr. Copeland was the senior civilian member. He also served on the equally famous board of 1865 which established the method of conducting the competitive trials of the *Algonquin* and *Winooski* in the notorious Isherwood-Dickerson steam expansion controversy.

AMERICAN SOCIETY OF NAVAL ENGINEERS.

OFFICERS FOR 1895.

President:
Chief Engineer **James H. Perry**, U. S. Navy.

Secretary and Treasurer:
Passed Assistant Engineer **R. S. Griffin**, U. S. Navy.

Council:
Chief Engineer **James H. Perry**, U. S. Navy.
Passed Assistant Engineer **R. S. Griffin**, U. S. Navy.
Passed Assistant Engineer **Frank H. Bailey**, U. S. Navy.
Naval Constructor **D. W. Taylor**, U. S. Navy.
Passed Assistant Engineer **B. C. Bryan**, U. S. Navy.

HONORARY MEMBERS.

(EX-OFFICIO.)

The Secretary of the Navy.
The Assistant Secretary of the Navy.

Chief of Bureau of Steam Engineering:
Geo. W. Melville, Engineer-in-Chief, U. S. N., Navy Department.

Ex-Chiefs of Bureau of Steam Engineering:
Chas. H. Haswell, Civil and Marine Engineer, 42 Broadway, New York.
B. F. Isherwood, Chief Engineer, U. S. N. (retired), 111 East 36th street, New York.
J. W. King, Chief Engineer, U. S. N. (retired), 3231 Powellton avenue, Philadelphia.
Chas. H. Loring, Chief Engineer, U. S. N. (retired), 239 Clermont avenue, Brooklyn.
Wm. H. Shock, Chief Engineer, U. S. N. (retired), 1404 15th street, Washington, D. C.

MEMBERS.

Able, A. H., Chief Engineer, U. S. N., Navy Yard, League Island; residence, 2034 Mt. Vernon street, Philadelphia, Pa.
Addicks, W. R., Consulting Engineer........24 West street, Boston, Mass.
Aldrich, Wm. S., Professor Mechanical Engineering, and Director Department of Mechanic Arts, West Virginia University, Morgantown, W. Va.
Allderdice, W. H., Passed Assistant Engineer, U. S. N........U. S. S. *Bennington*.
Allen, F. B, Vice-President Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn.
Anderson, M. A., Passed Assistant Engineer, U. S. N........U. S. S. *New York*.
Andrade, Cipriano, Chief Engineer, U. S. N........U. S. S. *New York*.
Aston, Ralph, Chief Engineer, U. S. N........78 Hanson Place, Brooklyn, N. Y.
Ayres, S. L. P., Chief Engineer, U. S. N........Navy Yard, New York.

Bailey, F. H., Passed Assistant Engineer, U. S. N., Bureau Steam Engineering, Navy Department, Washington, D. C.
Baird, G. W., Chief Engineer, U. S. N........U. S. S. *Dolphin*.
Baker, C. H., Chief Engineer, U. S. N........1739 19th street, Washington, D. C.

Barnard, G. A., Mechanical Engineer..115 Lincoln Ave., Salem, Ohio.
Barrett, Thos. H., late Assistant Engineer, U. S. N...Room 156, Postoffice Building, New York.
Barry, J. J., Passed Assistant Engineer, U. S. N...........106 McDonough street, Brooklyn, N. Y.
Bartlett, F. W., Passed Assistant Engineer, U. S. N............ ..Naval Academy, Annapolis, Md.
Barton, J. K., Chief Engineer, U. S. N.................4708 Springfield avenue, W. Philadelphia, Pa.
Bates, A. B., Chief Engineer, U. S. N..U. S. S. *Bennington*.
Baughman, H. C., Assistant Engineer, U. S. N.................2000 N. 12th street, Philadelphia, Pa.
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DIGEST OF THE EXPERIMENTS MADE BY MR. MICHAEL LONGRIDGE, CHIEF ENGINEER OF "THE ENGINE, BOILER, AND EMPLOYERS' LIABILITY INSURANCE COMPANY" OF MANCHESTER, ENGLAND, ON THE TRIPLE EXPANSION PUMPING ENGINES AT THE EAST LONDON WATER WORKS, LEA BRIDGE, AND DESCRIBED IN HIS REPORT TO THE COMPANY FOR 1893.

BY CHIEF ENGINEER ISHERWOOD, U. S. NAVY.

Mr. Michael Longridge, the Chief Engineer of "The Engine, Boiler, and Employers' Liability Insurance Company" of Manchester, England, makes regularly an annual report to his company, in which, among much other interesting professional matter, he describes some of the principal engineering experiments made by him during the current year, in the course of his service as expert or as insurer.

As these reports are printed in very limited numbers simply for distribution to the members of the company, they are not easily accessible to the general public, and as the report for 1893 contains the description of a remarkably valuable experiment made simultaneously on duplicate, direct acting, triple expansion, condensing, steam jacketed, pumping engines, the writer believes he will do his profession a service by preparing a digest of it for the readers of this JOURNAL.

The data of the experiment are given with unusual fullness, and this completeness, taken in connection with the extreme accuracy with which the data were determined, adds enormously to the importance of the results.

The weight of the water of steam liquefaction drawn from the steam jackets of each of the three cylinders, was separately ascertained for each cylinder. The weight of the water of steam liquefaction drawn from the steam pipe was similarly ascertained. The heat radiated per hour from the exterior surfaces of the jackets of the steam cylinders was also ascertained, and separately for each cylinder. The capacity of the receiver between the small and intermediate cylinders, and between the intermediate and large cylinders, is given; together with the clearance surface in each of the three cylinders, and with the steam jacketed surface of each cylinder.

Each steam jacket was fitted at its highest point with a cock for the discharge of whatever air the jacket might contain at the commencement of the experiment; and with a pressure gauge showing the steam pressure in the jacket during the experiment. So far as the writer's knowledge extends, this is the first time that such a method has been followed, yet its necessity is evident, for no reliable experiment can be made on the effects of steam jacketing without it. Evidently, the air in the jackets at the commencement of an experiment cannot be expelled in any other way than by blowing them through with steam, and if this air remains in them, then just as evidently the steam jacketing must fall short of its possible and proper economic efficiency. Again there is no certainty of what the pressure in the jackets is (except in the case of some arrangements in which the steam passes from the steam pipe through the jackets into the valve chests of the cylinders, instead of passing directly into these chests from the pipe) otherwise than by the evidence of a pressure gauge.

With triple expansion marine engines having their intermediate and large cylinders jacketed with steam of about the initial pressure in those cylinders, and taken from the main steam pipe through reducing valves, the jackets are furnished with safety valves loaded to the intended pressures, so as to prevent the possibility of accident by either crushing the cylinder or exploding the jacket were full boiler pressure present. In such a case the jacket safety valves can be made to combine the functions of air discharge cock and of pressure gauge. Such an arrangement, however, is never used when the jackets of the cylinders are supplied with steam of presumably full boiler pressure. In that case, whether the air has been discharged from, or what may be the pressure in, the jackets, is a mere matter of inference, not of knowledge.

In many experiments on steam jacketed cylinders of all types of engine, using high pressure steam with large measures of expansion, the water of liquefaction drawn from the jackets has been, comparatively, quite insignificant in quantity; in fact, scarcely more than was due to external radiation of heat. These experiments have passed unchallenged as regards accuracy, and possibly they were accurate as far as the measured quantities were concerned; but the jackets themselves were faulty either in being largely filled with cores, when cast in one piece with the cylinder, or in leaky joints if the two were cast separately and bolted together, or were not filled with steam of the intended pressure, owing to too small area and too great length of the pipes supplying them with steam. The facts are certain that not less than 8 per centum of the feed water will be drawn from the steam jackets of the cylinders of the largest engines using greatly expanded steam of high pressure, nor less than 16 per centum of the feed water when drawn from the jackets of the cylinders of small engines working under the same conditions; these percentages being the aggregate for all the cylinders of the engine.

A test made of the joints of a steam jacket with the engine at rest, proves nothing as to their tightness when the engine is working. These joints, though tight in the former case, may leak much in the latter case. When the engine is at rest, the temperature of the cylinder and the jacket is the same, that is to say, the two walls of the jacket have the same temperature when the jacket is filled with steam and the engine is at rest. But as soon as the engine works, this equality ceases, the inner wall or cylinder then having a much lower temperature than the outer or jacket wall, which latter consequently expands more per inch of diameter of jacket than the former does per inch of diameter of cylinder, and there is developed as the result an annular gap between the metals of the jacket and of the cylinder, through which the steam in the jacket leaks into the cylinder, as the pressure in the latter is less than in the former. When the enormous cylinder liquefaction of steam is considered, and the proportional lowering of the temperature of the cylinder metal to cause that liquefaction, there can be easily understood how large must be the difference when the engine is working with greatly expanded high pressure steam, between the temperature of the cylinder metal and that of the outer jacket metal, which last temperature is sensibly constant and nearly the same as the temperature of the steam in the jacket. Further, when the length of the annular gap (which is equal to the outer circumference of the cylinder) is considered, and the difference between the pressures in the jacket and in the cylinder, a width of gap of less than a hair's breadth will be found sufficient to leak a considerable weight of steam per unit of time. The difference of temperature between the jacket metal and the cylinder metal, in a working engine, produces also an unequal elongation of these metals in the direction of the axis of the cylinder, tending to develop leaks between them wherever the design permits.

The discordant economic results from different steam engines, which, apparently, should give accordant results, are often due to mere unsuspected construction defects, producing accidental and unequal leakages of steam or other abnormal consequences; comparison, therefore, must not be depended on between isolated cases, but between averages for groups, and the more numerous the cases constituting a group, the more reliable will be these averages. The greatest caution and discrimination are required, combined with practical experience and theoretical knowledge, in ascertaining the true underlying general laws, which, in steam engineering, are overlaid, more or less, by the influence of extraneous causes, accidental conditions, qualities of material, faults of design and execution, and the whole chapter of annoying and uncertain inaccuracies, which, though suspected, cannot be detected, and vitiate to a greater or less extent, the experimental results.

Incompleteness of indispensable data which, by compelling the substitution of imaginary inferences for measured quantities, is a frequent misleader in attempts to determine a true generality. The importance of completeness of data cannot be overestimated; for want of it the great mass of engineering experiments are reduced enormously in value. A commencement may be made by accepting hypotheses, but the end must be reached with everything hypothetical rejected. Every fact must be experimentally ascertained and clearly described, nothing being included that has not been either counted, weighed or measured.

No one is more aware than the writer of the extreme difficulty of obtaining completeness of data in the case of experiments on large steam machinery, owing to the expense, time and labor involved. The difficulty is even greater than that of obtaining accuracy of such data as are observed. Moreover, in such cases, the difficulty of ascertaining whether the experimental mechanism is in good condition proper for the experimental purpose, is almost insurmountable. It is simply assumed to be so, but the uncertainty is distressing, and always justifies much doubt in the results, at least quantitively. Hence, the only safety is in basing conclusions on the average results of groups of experiments, each group consisting of machinery so allied in type, details, dimensions, principles and conditions, that consistent results *ought* to have been given, the correction of errors being relied on for neutralizing the numerical differences.

These ideas can best be realized by experiments on pumping engines, which for the purpose of ascertaining the practical conditions that influence, and the extent to which they do influence, the economic production of power by steam used in practical steam engines, are better adapted than engines employed in other work. Experiments on this class of engines, therefore, are of the highest value, their results being much more certain and free from error of observation or measurement than any other class.

For instance, in the important particular of the determination of the power developed by the engine, if the pressure of the water, or the "head of water" against which the engine works, be constant, then the pressure on the steam pistons will be constant also, let the speed of these pistons be what it may. One indicator diagram, therefore, if its accuracy be certain, is sufficient to determine in connection with the average speed of the piston, the average power developed by the engine during the experiment.

Now, if the steam pressure in the boiler be maintained constant, the speed of the piston will remain constant too, for, with opposing constant water pressure, the speed of the piston is only alterable by alterations in the boiler pressure, other things, of course, remaining the same. If the boiler pressure be increased, the piston speed will be increased, but the indicator diagram, that is to say the pressure on the piston, will remain exactly the same. Likewise, if the boiler pressure be decreased, the piston speed will be correspondingly decreased, but the indicator diagram will remain exactly the same as before, the lower limit of the boiler pressure being reached when that pressure becomes too small to equilibrate the statical water pressure plus the friction of the moving parts of the mechanism, *per se*, plus the resistances of the pump valves, plus the friction resistances of the various surfaces in contact with the moving water, and plus the friction of the load when the pumping power is passed through a rotating or vibrating mechanism, in which case the engine comes to rest, for in order to produce motion, the piston pressure must equal the water pressure added to the pressures equilibrating the above resistances, but after this equality is obtained, no more pressure can be produced upon the piston by increase of boiler pressure, such increase of pressure having for its effect only increased velocity of piston. Thus, with the boiler pressure infinitesimally greater than the sum of the statical water pressure and of the pressures equilibrating the above resistances, the piston will move with an infinitesimal velocity, which will increase, *pari passu*, as the boiler pressure is increased, the piston pressure remaining constant throughout all the changes of piston velocity, so that the power developed will be directly proportional to the velocity of the piston, and the work done will also be directly proportional to that velocity. Hence, the work done in pumping will be directly proportional to the power exerted, and the economy of the performance will not be affected by the velocity with which the work was done.

None of the foregoing named dynamical resistances in addition to the statical resistance of the water pressure, is affected by the velocity of the piston. They are all, except the resistance by the pump valves, simply frictional resistances uninfluenced by the velocity with which they are overcome. The resistance of the pump valves is also constant at all velocities of piston. Hence, the indicator diagram from the steam cylinder is also constant at all velocities of piston, the mean pressure from that diagram equilibrating the aggregate of all the resistances, represented by pressures, of whatever kind soever.

As an increased boiler pressure does not appear upon the piston, how does it operate to increase the piston speed? Simply by furnishing the steam from the boiler to the piston at the increased rate of the piston speed.

The steam is conveyed from the boiler to the cylinder partly by the push of the boiler pressure, and partly by the expansion of the steam itself, which takes place mainly within the steam pipe and cylinder; the conveying force being the difference between the pressure in the boiler and the pressure in the cylinder previous to the point of cutting off. There is a continuous decrease of pressure from the boiler heating surface generating the steam to the point in the cylinder at which the steam is cut off. The decrease is scarcely sensible in the boiler, owing to the large capacity of the steam room proportionally to the cross area of the steam pipe; but from the boiler end of the steam pipe to the point in the cylinder at which the steam is cut off, the fall of pressure and consequent expansion of the steam becomes more or less strongly marked according to circumstances. In fact, the steam is always used with some measure of expansion on the piston previous to being cut off by the closing of the expansion valve. The universal belief is, that the steam is worked expansively on the piston only after the cut off valve has closed. This is an entire mistake; it is always worked expansively throughout the entire stroke of the piston, before as well as after the closing of the cut off valve. Sometimes the expansive working prior to the closing of the cut off valve is very small, sometimes quite large, according to conditions, but it is always something. The only means by which the boiler pressure can be produced in the steam pipe, and in the cylinder previous to the closing of the cut off valve, is by backing against the piston an opposing resistance equal to the boiler pressure; that is to say, the boiler pressure on one side of the piston is to be balanced by an equivalent resistance against the opposite side of the piston, in which case there could not be any movement of the piston, or power developed. With any less opposed resistance, there must necessarily be a continuous decrease of the boiler pressure as described, and if the pressure is decreased, there must have been an accompanying corresponding expansion of the steam. Now, with an engine working with any given velocity of piston against a constant resistance, that is a resistance uninfluenced by the velocity with which it is overcome, as in the case of a pumping engine pumping against a constant head of water, the load due to which offers a constant resistance at all speeds of piston, the supply of steam from the boiler is just sufficient to maintain the given velocity of piston, the boiler pressure remaining constant. The piston velocity in this case cannot be increased, because the boiler cannot furnish more steam per unit of time to equilibrate the resistance moving at a higher speed; the steam supply and the work done per unit of time being exactly balanced. What is required, and it is all that is required, to increase the piston speed, is a delivery of more steam per unit of time upon the piston, *but of the same piston pressure as before.* This can be effected by simply increasing the boiler pressure, the initial pressure upon the piston remaining unchanged; or, in other words, by increasing the *head of steam* in order to produce a more rapid flow of steam from boiler to cylinder; the velocity of the flow having a definite relation to the difference between the pressure in the boiler and in the cylinder, the latter pressure remaining constant, or, in other words to the head of steam employed. Of course, other things being equal, the greater this head of steam the more rapid will be the piston speed, the consumption of steam per unit of time being in the direct ratio of the piston speed, as will also be the power developed and the work done, the economy of the steam remaining unchanged at all speeds of piston. The ratio of the useful to the prejudicial work done, will also remain constant at all speeds of piston.

The facts being experimentally indisputable that the resistance to a *perfectly smooth* plane surface moving through an indefinite extent of water, in the direction of the surface, is *nearly, but a little less than*, in the ratio of the square of the velocity of the surface, the power to produce different velocities being in the ratio of the cube of the velocity; while, in the case of a pumping engine, the resistance offered to the moving water pumped, by the surfaces of the mains or of the receiving and delivering pipes, is constant, that is, not affected by the velocity, requires an explanation.

The two phenomena are not only entirely distinct, but are of essentially different kinds. In the first case, that of the plane surface moving in an indefinite extent of water, in the direction of the surface, the resistance is due to the adhesion of the watery molecules to the surface, and to the cohesion of these molecules among themselves. The adhesion of the molecules to the moving surface, produces a movement of the layer of them in contact with the surface, in the direction of the surface, and the cohesion of the molecules to each other transmits this movement from the first layer to the next, and from that to its next, and so on, the velocity of each successive layer decreasing until the original force is sensibly spent. The first layer in contact with the surface has not the velocity of the surface but a much less velocity, as the adhesion is overcome by the weight and resistance of the successive layers of watery molecules attached to the first layer by cohesion, so that the first layer is continuously being dislodged from the surface by sliding along the surface in the reverse direction of the movement of the latter. The resistance to this sliding is constant, that is, it is not affected by the speed with which the molecules slide. Nor is the adhesion of the water to the surface affected by the pressure of the water, nor is the resistance of this adhesion similar in any way to the resistance of friction between the smooth surfaces of moving solids in contact with each other. Adhesion is a form of attraction between the solid surface and the liquid in contact with it. If there were no adhesion there would be no resistance of the liquid to the movement of the surface in it in the direction of the surface. When a surface is dipped into water and withdrawn, it remains *wetted* though held vertically, and the wetting is the result of an attractive force. The minimum resistance of liquid to surface, is when there is a repulsion between the two. The resistance overcome is consequently composed of the watery adhesion, which is a constant resistance at all speeds; and of the sensible movement of water, which is in the ratio of the square of the speed. Hence results that the resistance to the moving surface as a whole, is a little less than the square of the velocity of the surface, the exact power of the speed being variable with the smoothness of the surface, the rougher the surface the nearer will the law of the squares be approximated. The rougher the surface the greater will be its resistance at equal speeds, the roughnesses acting as projections from the surface into the water, and giving motion to not only a greater quantity of water, but imparting a greater velocity to that greater quantity than in the case of a smooth surface. The resistance in this case is the same as that of an oar projected into water from the side of a boat and held there. Evidently, for equal speeds of surface, as the resistance due to the putting of the water in motion, caused by the roughness of the surface, becomes greater and greater, while the resistance due to overcoming the adhesion of the water remains sensibly constant, the nearer will the aggregate resistance approach the law of the squares, though never actually attaining it. For practical purposes, and with the smoothest practical surfaces, the experimental results so nearly approach the law of the squares that, considering the uncertainty of the numerical coefficients, the law of the squares may be adopted as within the limits of experimental errors.

The coefficient of resistance of the unit of surface of plane surfaces of different lengths but equal breadths, moving at equal speed in an indefinite extent of water in the direction of the lengths of the surfaces, varies much from a constant, the longer the surface the less per unit of surface will be the coefficient of resistance. The law of the decrease in function of increase of length, has not been experimentally determined, but the decrease for equal increments of length becomes smaller and smaller as the lengths of the plane become greater and greater; a length is thus reached beyond which the coefficient of resistance per unit of surface decreases so slightly for additional lengths, that, although there must always be some decrease with increase of length, it becomes small enough to be practically negligible and the coefficient may be considered as constant.

A rigorous limitation must here be insisted on as regards the application of the principle, namely, that the law applies to only perfectly *plane* surfaces, and to such curved surfaces as have a uniform curvature crosswise or in the direction of their breadth and for their entire length, but no curvature in the direction of their length; it does not apply to either warped or twisted surfaces, nor to any other kind of curved surface except the one just described; consequently, it cannot be applied either to the external immersed surfaces of vessels, or to the helicoidal surfaces of screw propellers. In selecting the coefficient of resistance for the unit of both these surfaces, they must be considered as of infinitesimal length, and the proper coefficient will, in their cases, be the experimental maximum.

The reason why the coefficient of resistance per unit of the surface of plane surfaces of different lengths, but otherwise the same, moving with the same speed in the direction of their lengths in an indefinite extent of water, decreases as the length increases, is as follows: The speed of the water entrained by the moving surface, is constant at all points of the surface. The mass of this entrained water has a definite and uniform thickness, consequently, it presents an area in the direction of its motion equal to the product of this thickness into the breadth of the surface, and this area has to be forced against the quiescent water in front of it, displacing that water. In other words, it has a head area to be driven through the surrounding water, which offers a corresponding resistance, and this resistance is the same, let the length of the surface be what it may. Now the number of units of surface in planes of equal breadth but unequal length, is directly as their length, consequently, the head resistance of the mass of water entrained by the planes, will be, per unit of surface less and less as the length of the planes is more and more. This *particular portion*, therefore, of the *aggregate resistance* of water to a plane surface moving lengthwise in it, will diminish, *per unit of surface*, in the direct ratio of the length of the plane surface, the breadth being constant, and will cause the aggregate resistance to be correspondingly reduced per unit of surface. The fact that doubling the length of a plane surface moving lengthwise in water at constant speed does not double the aggregate surface resistance, has been experimentally known for a century, but this is the first time a correct explanation has been given of the cause.

The resistances by the inner surfaces of the pipes or mains through which water is pumped, follow entirely different laws from those which have been described for plane surfaces moving in an indefinite extent of water and in the direction of the surfaces. It is necessary that the laws in both cases should be developed, in order that either may be understood, and that the errors should be avoided which occur by applying to one case what is peculiar to the other.

The resistance of the water—apart from that of its weight—in the case of pumping it through *straight* pipes, is simply the resistance of its adhesion to the inner surface of the pipes, and the resistance due to the roughness of this surface, the less the adhesion of the water and the smoother the surface of the pipes, the less will be the resistance of the water to movement through them. The resistance of the water is also affected by its temperature, the higher the temperature the less will be the resistance; the law of the decrease, and the numerical value of the decrease are unknown. If the pipes are bent or have curvature, their resistance to the movement of water through them will be increased in the inverse ratio of the radii of the curvature, and in the direct ratio of the arcs of curvature. The resistances of pipes will also be in the direct ratio of their lengths, and in the inverse ratio of their diameters. The quantity of water momentarily in action does not increase with the speed of the pumping but remains constant, whereas the quantity of water momentarily in action over the surface of a plane moving in the water in the direction of that surface with different speeds increases in the ratio of the speed, so that the two cases are subject to widely differing laws.

The water in the pipes does not move with the same velocity in every part of the cross area of the pipe; the greatest velocity is at the axis of the pipe and the least velocity is at its periphery; the velocity increases from the periphery to the axis according to an unknown law; the mean velocity only is known, consequently, the force of the adhesion of the water per unit of surface of the pipe cannot be ascertained from a pumping experiment; such an experiment made with observation of the complete data allows in any case the determination of only the aggregate resistances of the pipe as a whole but not of these resistances separately.

Although in different pumping engines, the ratio of the resistances of the pipes relatively to the weight of water pumped per stroke of pistons, must vary largely, this ratio for the same engine will be constant for all speeds of pumping, so that the same indicator diagram will be obtained from the same steam cylinder let the number of strokes made by its piston per unit of time be what it may, provided the pumps are filled to the same capacity. The weight of water delivered by the pipes per unit of time multiplied by the height through which that water was lifted by the engine, and the product divided by the weight of fuel or of steam expended in the same time, does not give reliable comparisons of the economy of the pumping; such comparisons can only be obtained by dividing the work done per unit of time by the engine as measured by the indicator diagram, by the weight of the fuel or of the steam consumed during the same time. In other words, the economy of pumping engines, relative or absolute, can only be obtained in the same manner as for other engines. The dynamical resistances overcome by pumping engines is not only greater than the statical resistance, but greater in very different ratios according to the condition of the cases. The method of obtaining the dynamical resistance against which the pumps work, by means of pressure gauges inserted in the pipes beyond the delivery valves of the pumps, gives very uncertain results. The pressure of a fluid at rest can be accurately ascertained, but the pressure of a fluid in motion is a difficult datum to determine with certainty, and the uncertainty increases with the swiftness of the motion.

ENGINES.

The engines are two in number, and are of the triple expansion, vertical, direct acting, surface condensing, steam jacketed, type; they are exact duplicates. Each engine consists of three cylinders, the axes of which are in the same vertical plane, and all have the same stroke of piston, one piston rod, and no tail rod. The crosshead of each cylinder is sufficiently long to have a journal near each end, these journals being far enough apart to allow a connecting rod from each to clear the vertical pump which stands immediately below the cylinder and has its plunger or ram operated directly by an extension of the piston rod of the cylinder. Beneath the pump is the crank shaft, which is revolved by the two connecting rods from the crosshead journals, one rod on each side of the pump. The crankshaft has two flywheels, one at each end. The three crankshafts—one for each cylinder—are coupled together so as to form a single shaft underlying the whole engine, the pairs of cranks being equispaced around the shaft, or placed 120 degrees apart.

The cylinders are provided with Corliss valves, one for steam admission and one for exhaust delivery at each end of each cylinder, the steam valve acting also as cut off valve. Each cylinder is steam jacketed on top, bottom and side.

Each engine has a surface condenser, consisting of a group of iron tubes placed in the culvert through which the water to be pumped passes on its way to the suction pipe. The exhaust steam is within the tubes, and the refrigerating water is on the outside of them.

The pumps are single acting and vertical, one to each cylinder; they deliver their water directly into the mains.

The following are the principal dimensions and proportions of each engine:

Number of steam cylinders in each engine	3
Diameter of the small cylinder, inches	20
Diameter of the piston rod of the small cylinder, inches	5
Mean effective area of the piston of the small cylinder, square inches	304.3425
Stroke of the piston of the small cylinder, feet	4
Space displacement of the piston of the small cylinder per stroke, cubic feet	8 454
Space in the clearance and steam passages at one end of the small cylinder, cubic foot	0.4
Fraction which the space in the clearance and steam passages at one end of the small cylinder is of the space displacement of its piston per stroke,	0.047
Aggregate jacketed surfaces of the small cylinder, square feet	29 5
Aggregate surface in the clearance and steam passages at one end of the small cylinder, square feet	11.5
Diameter of the intermediate cylinder, inches	34
Diameter of the piston rod of the intermediate cylinder, inches	5
Mean effective area of the piston of the intermediate cylinder, square inches,	898.105
Stroke of the piston of the intermediate cylinder, feet	4
Space displacement of the piston of the intermediate cylinder per stroke, cubic feet	24.947
Space in the clearance and steam passages at one end of the intermediate cylinder, cubic foot	0.97
Fraction which the space in the clearance and steam passages at one end of the intermediate clyinder is of the space displacement of its piston per stroke	0.039
Aggregate jacketed surfaces of the intermediate cylinder, square feet	50.9
Aggregate surface in the clearance and steam passages at one end of the intermediate cylinder, square feet	25.2
Difference between the effective areas of the pistons of the small and intermediate cylinders, square inches	593 762
Diameter of the large cylinder, inches	57
Diameter of the piston rod of the large cylinder, inches	5
Mean effective area of the piston of the large cylinder, square inches	2,541.947
Stroke of the piston of the large cylinder, feet	4
Space displacement of the piston of the large cylinder per stroke, cubic feet,	70.609
Space in the clearance and steam passages at one end of the large cylinder, cubic feet	2.8
Fraction which the space in the clearance and steam passages at one end of the large cylinder is of the space displacement of its piston per stroke,	0.039

Aggregate jacketed surfaces of the large cylinder, square feet	88.0
Aggregate surface in the clearance and steam passages at one end of the large cylinder, square feet	63.8
Difference between the effective areas of the pistons of the intermediate and large cylinders, square inches	1,643.842
Ratio of the effective area of the piston of the large cylinder to the effective area of the piston of the small cylinder	2.951
Ratio of the effective area of the piston of the intermediate cylinder to the effective area of the piston of the small cylinder	8.352
Ratio of the effective area of the piston of the large cylinder to the effective area of the piston of the intermediate cylinder	2.830
Ratio of the aggregate space displacement per stroke of the piston of the intermediate cylinder and the space in the clearance and steam passages of that cylinder, to the aggregate space displacement per stroke of the piston of the small cylinder and the space in the clearance and steam passages of that cylinder	2.927
Ratio of the aggregate space displacement per stroke of the piston of the large cylinder and the space in the clearance and steam passages of that cylinder, to the aggregate space displacement per stroke of the piston of the small cylinder and the space in the clearance and steam passages of that cylinder	8.291
Ratio of the aggregate space displacement per stroke of the piston of the large cylinder and the space in the clearance and steam passages of that cylinder, to the aggregate space displacement per stroke of the piston of the intermediate cylinder and the space in the clearance and steam passages of that cylinder	2.832
Capacity of the receiver between the small and the intermediate cylinders, cubic feet	9.74
Capacity of the receiver between the intermediate and the large cylinders, cubic feet	53.80
Diameter of the air pump (one, single acting and lifting), inches	26
Stroke of the air pump piston, feet	2
Area of the air pump piston, square inches	530.930
Space displacement of the air pump piston per stroke, cubic feet	7.374
Number of iron tubes in surface condenser (each engine)	510
Outside diameter of surface condenser tubes, inches	1.25
Length of surface condenser tubes, feet	7.57
Aggregate surface of outside of condenser tubes, square feet	1,053
Number of pumps, vertical and single acting	3
Diameter of the plungers of the pumps, inches	30
Stroke of the plungers of the pumps, feet	4
Aggregate area of the plungers of the three pumps, square inches	2,120.58
Aggregate space displacement of the plungers of the three pumps, cubic feet	58.905
Ratio of the aggregate area of the plungers of the three pumps, to the area of the piston of the large cylinder, allowing for the single action of the pumps and the double action of the cylinder	2.397

MANNER OF MAKING THE EXPERIMENTS.

Before commencing the experiments the observers devoted considerable time to securing accuracy for the indicator diagrams, to producing proper circulation of the steam through the jackets of the cylinders, to calibrating the feed water tanks and the tanks which received the water of steam liquefaction drained from the jackets of the several cylinders and from the steam pipe, and to testing the tightness of the steam pistons, the steam valves, and the joints of the jackets.

Each jacket was fitted with an air cock at its upper extremity, to be operated by hand for the discharge of any air that might accidentally be present. The jackets of each cylinder had only one steam supply pipe, one drain pipe, one steam trap, one reducing valve, and one pressure gauge in common. During the experiments the reducing valve was not used, and the full boiler pressure was maintained in all the jackets of all the cylinders as nearly as the proportions of the supply pipe would admit, the strength of the cylinders and jackets being sufficient for that pressure. The water of steam liquefaction from the jackets of each cylinder was passed through a steam trap, collected and measured for each cylinder as an aggregate.

The steam pipe was of considerable length, and a portion of it was bare. Whatever water of steam liquefaction was in this pipe, was drained off near the engines into a well pipe and steam trap, from which it was delivered into a tank and measured.

The pressures in the cylinders were measured from indicator diagrams taken by Richard indicators. For the small and the intermediate cylinders, the indicators were coupled to three-way taps placed half way up the cylinders and connected to the cylinder ends by well clothed pipes. This arrangement was only adopted after it had been ascertained by trial to produce absolutely identical diagrams with those taken when the taps were screwed directly into the ends of the cylinders. In the case of the large cylinders, the indicators were coupled directly to the ends of the cylinders, as trial showed the diagrams to be lessened in area when the indicators were employed in connection with pipes. The springs for the indicators on the small cylinders were set to the pressure of 60 pounds per square inch, those for the indicators on the intermediate cylinders were set to the pressure of 30 pounds per square inch, and those for the indicators on the large cylinders were set to the pressure of 10 pounds per square inch. The springs of the indicators were tested after the completion of the experiments. At the temperature of 70 degrees Fahrenheit they were practically correct, and at the temperature of 190 degrees they were about one and a half per centum too weak. Considering the uncertainty which exists as to the temperature to which indicator springs are exposed, the diagrams from the small and intermediate cylinders were reduced by lessening the height of each ordinate two per centum. No correction was made for the diagrams from the large cylinder.

The head against which the pumps delivered was ascertained by means of a Richard indicator placed on the delivery main, and to the pressure thus shown was added the pressure due to the height of the indicator above the water level in the pump well. The pumps delivered their water directly into the main, and not into a reservoir.

The dimensions of the engines were given by their makers, Messrs. Yates and Thom of Blackburn; the capacities of the clearance and steam passages at one end of each cylinder, and the surfaces of the same, as well as the jacketed surfaces, were calculated from the drawings of the cylinders.

The boiler pressure and the pressures in the jackets were taken by gauges which were not tested, but which were believed to be very nearly accurate. The vacuum gauges on the condensers were mercurial columns. The number of revolutions made by each engine was taken by a counter attached to it.

The feed water was measured in two permanent concrete tanks, each 6 feet 6 inches long, 1 foot 6½ inches wide, and 4 feet 5 inches deep. They were calibrated with a narrow necked tin can that held exactly 100 pounds of water at the temperature of 65 degrees Fahrenheit. The weight measured into each tank was 2,000 pounds, occupying a depth of 3 feet 2⅝ inches. These tanks were filled alternately, the time when each was emptied being noted. From these measuring tanks the water was discharged into a larger tank from which the feed pump drew. This tank, which may be called the feed tank, was 12 feet long and 3 feet 10½ inches wide. The water level in it was ascertained by means of a float carrying a scale graduated in tenths of an inch. The float rose and fell in a cast-iron pipe placed vertically in the tank with the upper end above the water level, so that the float might not be disturbed by oscillations of the water. From the feed tank the water was pumped into the two boilers that supplied the engines with steam.

The experiments were commenced and ended with the water level and the steam pressure in the boilers exactly the same, and were limited to the six hours of the day when the consumption of water from the main was most uniform. The boilers were abundantly large for the work, and furnished dry steam. Indicator diagrams, and observations, were taken by numerous and competent assistants of all the quantities given in the following table. No regard was paid to the performance of the boilers, or to the economy of the coal consumed. With the large water heating surface in the boilers, and the slow rate of evaporation per square foot of that surface, the water level in the boiler gauge glasses was remarkably steady, admitting of very exact measurement.

The two boilers used were of the Lancashire type, each was 30 feet long and 7½ feet diameter, set in brick masonry and working in connection with one economizer of 192 cast-iron tubes. The aggregate water level surface was 396 square feet. Every possible water leakage, however insignificant, was detected, measured and deducted.

The experiments were made simultaneously on both engines, both being supplied with steam from the same two boilers. These engines are respectively designated the "North Engine" and the "Middle Engine."

The two experiments made—one on the 1st of March and the other on the 9th of March—were duplicates, and their results show the limits within which the experimental errors were confined, these limits were less than two per centum for the extremes, and less than one per centum for the means, an exceedingly close agreement, proving the great accuracy with which both experiments were conducted.

EXPLANATION OF THE FOLLOWING TABLE CONTAINING THE DATA AND RESULTS OF THE TWO EXPERIMENTS MADE BY MR. MICHAEL LONGRIDGE SIMULTANEOUSLY ON THE TWO TRIPLE EXPANSION, DIRECT ACTING, STEAM JACKETED, SURFACE CONDENSING, VERTICAL PUMPING ENGINES AT THE EAST LONDON WATER WORKS, LEA BRIDGE, ENGLAND.

In the following table the quantities, experimental and deductive, are arranged in groups and on numbered lines for facility of reference. The descriptions of the quantities on the lines are so full that but little additional explanation is necessary.

Total Quantities.—Lines 1 to 9, both inclusive, contain the total quantities experimentally ascertained in the manner previously described. The quantity on line 8 is the sum of the quantities on lines 5, 6 and 7.

The quantity on line 10 was obtained by subtracting from the quantity on line 4, the sum of the quantities on lines 8 and 9. This quantity (line 10) is the total weight of steam in pounds that entered the small cylinders of both engines simultaneously during each experiment, and is exclusive of the weights of steam liquefied in all the jackets of all the cylinders, and of the weight of steam liquefied in the steam pipe.

The quantity on line 11 is the quotient of the quantity on line 5 divided by the quantity on line 4.

The quantity on line 12 is the quotient of the quantity on line 6 divided by the quantity on line 4.

The quantity on line 13 is the quotient of the quantity on line 7 divided by the quantity on line 4.

The quantity on line 14 is the sum of the quantities on lines 11, 12 and 13.

The quantity on line 15 is the quotient of the quantity on line 9 divided by the quantity on line 4.

The quantities on lines 5 to 15, both inclusive, with the exception of the quantity on line 10, concern the waters of steam liquefaction drawn from the steam jackets of the cylinders and from the steam pipe; these quantities relate to these waters as weights of water only; they do *not* represent quantities of heat proportionally to the quantity of heat in the feed water vaporised in the boilers (line 4), because the heat taken out of them is only the latent heat of the steam of the respective pressures under which the liquefaction was effected, whereas, the heat in the water vaporized in the boilers (line 4) contains all the heat above the temperature of the feed water (line 65). The quantities on lines 10 and 16, however, represent both as water weights and as heat units relatively to the quantity on line 4, the proportion of the total weight of steam entering the small cylinders, to the total weight of steam evaporated in the boilers. The quantity on line 16 is the quotient of the quantity on line 10 divided by the quantity on line 4.

The quantities on lines 17, 18 and 19, were obtained by direct measurement, but how performed is not described in Mr. Longridge's report. They are important quantities, being the total number of pounds of water of liquefaction drawn respectively from the jackets of the small, the intermediate, and the large cylinders, due to their external radiation of heat. The trials by which they were obtained were not, of course, made simultaneously with the experiments on the engines doing work, but both before and afterwards with the engines at rest, the same pressure being maintained in the jackets that was there during the experiments with the engines at work. The trials were made on both engines separately at different times. The trial made on "North Engine" commenced at 5 hours 40 minutes P. M. on the 24th of February, and ended at 10 A. M. on the 25th, lasting sixteen and one-third consecutive hours. The trial made with the "Middle Engine" commenced at 10 hours 48 minutes A. M. on the 10th of March and ended at 2 hours 13 minutes, lasting consecutively three hours and twenty-five minutes. The quantities on lines 17, 18 and 19, are the averages of the hourly means given by both trials, multiplied by the number of hours of the experiments made with the engine at work, so that these quantities are proper for the two engines when working simultaneously. Strictly speaking, the trials should have been made with the cylinders filled with steam of the average pressure which was in them while the engines were working, as well as the jackets should have been filled with steam of the pressure in them while the engines were working. Also, the temperature of the air surrounding the engines should have been the same in both cases, but the report is silent as to whether such were the facts or not.

Line 20 contains the sum of the quantities on lines 17, 18 and 19.

The weights of water on lines 17, 18, 19 and 20, do not represent quantities of heat relatively to the heat imparted to the weight of water vaporized in the boilers (line 4), because the waters of liquefaction from the jackets had the temperature due to the steam pressure in the jackets, while the water vaporized in the boilers received heat above the temperature of the feed water (line 65), a much less temperature than that of the jacket water. The steam in the jackets parted with only its latent heat, while the heat imparted to the water in the boilers contained, in addition to the latent heat of the boiler steam, the heat required to raise the water from the temperature of the feed (line 65) to that of the boiler steam (line 51).

The quantities on line 21 are the quotients of the division of the quantities on line 20 by the quantities on line 4.

Engines.—The quantity on line 22 is the quotient of the quantity on line 4 divided by the number of hours on line 1. And the quantity on line 23 is the quotient of the quantity on line 10 divided by the same number of hours.

The quantity on line 24 is the number of Fahrenheit units of heat that would have been imparted to the feed water in the boiler (line 4), had its temperature been the temperature on line 65 instead of the temperature on line 61. The boiler being fed during the experiments from the main, the feed water (line 4), had the experimental temperature on line 61, the waters of steam liquefaction from all the jackets of all the cylinders (line 8), and from the steam pipe (line 9), being wasted, that is, not returned to the boilers, but when the engines were in regular work, these waters were fed to the boilers as part of the feed water, and their greater temperature than the condenser temperature (line 63) proportionally increased the temperature of the entire feed, so that in the case of the experiments had these waters been used as part of the feed, the temperature of the feed water would have been the temperature on line 65, which temperature is exclusive of an allowance of 3.9 degrees supposed lost by external radiation from the feed pipe between the engines and boilers. In determining the number of Fahrenheit units of heat imparted to the feed water (line 24), the calculation has been made not simply for differences of temperature of the waters, but for differences of units of heat normal to the different temperatures.

Lines 25 and 26 are the quotients respectively of the quantities on lines 2 and 3 by the number of minutes on line 1. The quantity on line 27 is the average of the quantities on lines 25 and 26. The variation between these quantities is too slight to be productive of any sensible effect.

The quantity on line 28 is the product of the quantity on line 27 multiplied by 8 feet, or twice the stroke of the steam pistons.

The quantities on lines 29 to 39, both inclusive, were by direct observation of gauges.

The pressure in the steam jackets of the small cylinders (line 32), was 4 pounds per square inch less than the boiler pressure (line 30), in both experiments.

The pressure in the steam jackets of the intermediate cylinders (line 34), was 5 pounds per square inch less than the boiler pressure for the experiment of March 1st, and 6 pounds per square inch less for the experiment of March 9th.

The pressure in the steam jackets of the large cylinders (line 36), was 7 pounds per square inch less than the boiler pressure in both experiments.

There will be observed that the difference between the pressure in the boilers and in the jackets differs for the different cylinders, increasing as the capacities of the cylinders increase. For the small cylinders the difference is 4 pounds per square inch; for the intermediate cylinders it is (mean of both experiments) 5½ pounds; and for the large cylinders it is 7 pounds. Supposing the steam for the jackets of all the cylinders to be taken from the same place—either boiler or steam pipe—by means of small pipes of the same diameter, which was probably the case, the increasing difference of pressure for the different cylinders must have been due to the insufficient cross area of these pipes. As the cylinders enlarged, not only was a greater volume of steam required for the jackets, but the liquefaction in the jackets became greater per square foot of jacket surface because of the greater difference between the jacket pressure and the mean steam pressure in the cylinders due to the expansion of the steam in the latter. The volume of steam in the case of each cylinder that was passed through its respective jacket pipe, was the volume due to the weight of the water of liquefaction drawn from its jackets and to the pressure in those jackets. Had the cross area of the pipes been given, an experimental determination of value could have been made in this respect. A report should contain every detail and dimension of the apparatus. From the foregoing data as regards the steam jacket pressure, will be seen the necessity of always having a pressure gauge upon every jacket, as the usual inference in the absence of a gauge that the boiler pressure is present in the jacket, is wholly fallacious. The jacket pressure may be, and generally is, much lower than the boiler pressure. The writer knows of cases wherein the jacket pressure was scarcely one-half the boiler pressure, and yet the cylinders of these jackets were supposed to be steam jacketed with boiler pressure steam. The proof tests were made in consequence of the writer's doubts, based on the economic indications, that there was any reasonably close approach to the boiler pressure in the jackets.

The initial pressure in the small cylinders was 6.3 pounds per square inch less than the boiler pressure; the length of the steam pipe and its diameter are not given. If the steam for the jackets was taken from the steam pipe near the small cylinders, a part of the discrepancy between the boiler pressure and the jacket pressure would be accounted for, but not the increasing discrepancy due to the increasing capacities of the cylinders and their diminishing steam pressure. But no matter how large the cross area of the pipes supplying the jackets with steam, or how short their lengths, and supposing them to bring the steam direct from the boilers, they could not deliver the boiler pressure into the jackets; there would always be a less pressure in the latter than in the boiler, how much less depending on whatever modifying circumstances existed. Hence, under no conditions can the inference be accepted that the pressure in the jackets is equal to the pressure in the boilers, and any calculations based on it must always be false in some degree, and perhaps largely false. There should, in all experiments involving jacketing, be a pressure gauge upon the jacket and its indications recorded.

When steam is generated in a boiler in free communication with the cylinder of a working steam engine, it begins to expand at the moment it is generated, and continues to expand until the cut off valve closes in the small cylinder, if the engine be a multiple cylinder one, the reduction of pressure being continuous from the heating surface in the boiler up to the instant that the cylinder communication with the boiler is interrupted. As regards the jacket, the reduction of the pressure is continuous from the heating surface of the boiler to the liquefaction of the steam in the jacket. This condition of continuously decreasing pressure is essential for the continuous flow of the steam. With equality of pressure there could be no current anywhere, such equality being predicable for an elastic fluid only when that fluid is at rest.

The temperature of the water of liquefaction in the jackets is necessarily less than the temperature of the steam in them. This water is deposited on all the inner surfaces of the jacket, on those opposite the cylinder as well as those of the cylinder, and from these surfaces it trickles to the bottom of the jacket whence it is drawn off by a pump or by a trap. This water must, of course, have the temperature of the surfaces on which it was deposited, and not the higher temperature of the steam from which it was precipitated; the only cause of its precipitation was the lower temperature of these surfaces; and that lower temperature was caused by the facts that they radiated heat externally to the surrounding air and imparted it to the steam within the cylinder. How much the temperature of the water is below the temperature of the steam can be ascertained only by measurement, and the water temperature should always be thermometrically determined in the case of exact experiment. The temperature of the feed water as it enters the boilers should also be thus ascertained instead of being assumed to be the same as the temperature of the hot-well, whereas it is always less, and, in many cases, much less.

The quantities on lines 40 to 48, both inclusive, are taken directly from the indicator diagrams, and are the means given by all these diagrams.

Line 49 gives the number of times the steam was expanded in the small cylinders, calculated by first adding the length of the stroke of the piston, taken as unity, to the fraction of the stroke equivalent to the waste spaces at one end of the cylinder, and then dividing this sum by the fraction of the stroke of the piston completed when the steam was cut off (line 40) plus the fraction of the stroke equivalent to the waste spaces at one end of the cylinder.

Line 50 gives the number of times the steam was expanded in the engines, calculated by multiplying the quantity on line 49 by the ratio which the space displacement of the piston of the large cylinder per stroke plus the waste spaces at one end of that cylinder, is to the space displacement of the piston of the small cylinder per stroke plus the waste spaces at one end of the small cylinder. The intermediate cylinders need not be considered.

The quantities on lines 49 and 50 cannot be exact, owing to the complicated liquefactions of the steam and to the irregular revaporizations of the waters of these liquefactions in the cylinders, and to the superheatings given by the excess of the temperature of the steam in the jackets. What is exactly shown is the ratio of the spaces previous and subsequent to the closing of the cut-off valves on the small cylinders. The real expansions undergone by the steam must be greater in a marked degree than those on lines 49 and 50.

Temperatures.—The temperatures are all given in Fahrenheit degrees. Lines 51, 52, 53 and 54 give, respectively, the temperatures normal to the steam pressures in the boilers and in the steam jackets of the different cylinders.

Lines 55, 56 and 57 give the mean temperatures of the steam in the small, the intermediate, and the large cylinders. These temperatures are normal to the mean of the entire cycle of pressures in each cylinder from the commencement of the steam stroke of the piston to the end of the exhaust stroke, these pressures being taken from the indicator diagrams.

The quantity on line 58 is the difference between the quantities on lines 52 and 55.

The quantity on line 59 is the difference between the quantities on lines 53 and 56.

The quantity on line 60 is the difference between the quantities on lines 54 and 57.

The quantities on lines 61, 62 and 63, were given directly by the thermometer.

The quantity on line 64 is the temperature the feed water (line 4) would have had, had the waters of liquefaction from all the jackets of all the cylinders, and from the steam pipe (lines 5, 6, 7 and 9) been used for part of the feed, the remaining part consisting of water taken from the hot well at the temperature of 72 degrees (line 63). In this calculation the temperatures of the waters of liquefaction from the jackets have been taken as normal to the respective jacket pressures, and the temperature of the water of liquefaction from the steam pipe has been taken as normal to the boiler pressure. Consequently, the quantities on line 64 are somewhat in excess of the truth, but the data allows no nearer an approach.

Line 65 contains the *assumed* temperature at which the feed water would have entered the boilers under normal conditions. This quantity is the quantity on line 64 less 3.9 Fahrenheit degrees, allowed for loss of temperature by radiation from all the feed pipe surfaces, etc., between the condensers and the boilers. From the temperature on line 64, and the boiler pressure on line 30, the heat imparted to the feed water in the boilers has been calculated, lines 24, 66 and 67.

Heat.—The quantity on line 66 is the product of the multiplication of the quantities on lines 22 and 24.

The quantity on line 67 is the product of the multiplication of the quantities on lines 23 and 24.

The quantity on line 68 is the product of the multiplication of the quantity on line 17 by the latent heat of steam of the pressure in the jackets of the small cylinders (line 32), divided by the number of hours on line 1.

The quantity on line 69 is the remainder of the quantity on line 80 after subtraction of the quantity on line 68.

The quantity on line 70 is the quotient of the quantity on line 69 divided by the number of square feet (59) of jacketed surface in the small cylinders.

The quantity on line 71 is the product of the multiplication of the quantity on line 18 by the latent heat of steam of the pressure in the jackets of the intermediate cylinders (line 34) divided by the number of hours on line 1.

The quantity on line 72 is the remainder of the quantity on line 81 after subtraction of the quantity on line 71.

The quantity on line 73 is the quotient of the quantity on line 72 divided by the number of square feet (101.8) of jacketed surface in the intermediate cylinders.

The quantity on line 74 is the product of the multiplication of the quantity on line 19 by the latent heat of steam of the pressure in the jackets of the large cylinders (line 36) divided by the number of hours on line 1.

The quantity on line 75 is the remainder of the quantity on line 82 after subtraction of the quantity on line 74.

The quantity on line 76 is the quotient of the quantity on line 75 divided by the number of square feet (176) of jacketed surface in the large cylinders.

The quantity on line 77 is the quotient of the quantity on line 70 divided by the quantity on line 58.

The quantity on line 78 is the quotient of the quantity on line 73 divided by the quantity on line 59.

The quantity on line 79 is the quotient of the quantity on line 76 divided by the quantity on line 60.

The quantities on line 77, line 78 and line 79, are the number of Fahrenheit units of heat passed per hour respectively from the steam in the jackets of the small, the intermediate, and the large cylinders into the steam within those cylinders per square foot of their jacketed surface and per degree Fahrenheit of difference between the temperature of the steam in the jackets and within the respective cylinders. Now to test the quantities on the above three lines, there are required the additional data of the densities of the steam of the different pressures, and the different specific heats of this steam; these densities and specific heats entering inversely into the problem. Other things being equal, the less the density of the recipient the slower the flow of the heat into it, and the less the specific heat of the recipient the slower the flow of heat into it. The transfer of heat per unit of time per unit of surface from the steam in the jacket to the less pressure steam within the cylinder, will be in the ratio of the difference of temperature of the two steams multiplied by the difference of their densities, and the product multiplied by the difference of their specific heats. This law of the transfer of heat from steam of one pressure to steam of a less pressure, applies, of course, to dry steam only for both the delivering and the receiving steam, and the effect is to superheat the latter. In the case of an unjacketed multiple cylinder engine, such steam is found only in the small cylinder previous to the closing of the cut-off valve. Subsequent to that closing the steam is always wet, owing to the liquefaction of a portion of it to furnish the heat transmuted into the power developed by the expanding steam, a liquefaction which takes place molecularly, that is upon a portion of each molecule, so that the water of the liquefaction is uniformly disseminated among the steam and remains suspended in it producing the appearance of fog or mist. Steam doing work expansively is the only kind of wet steam; the only kind in which the appearance of fog or mist is produced. Steam doing work without expansion remains perfectly transparent and dry.

The liquefaction of steam in a cylinder due to the radiation of heat, occurs solely at the radiating metallic surfaces, and the water of such liquefaction is deposited on those surfaces only, unintermingled with steam. The water is a mass by itself, and the steam is another mass by itself. In the case of "foaming" or "priming," the water comes over from the boiler into the cylinder in masses accompanying the steam but not intermingled with it. The steam and the water occupy distinct spaces, the water flows along the bottom of the steam pipe with the steam flowing along above it, the two forming separate masses without uniform intermixture. The same remarks apply to the liquefaction of steam in cylinders, produced by the interaction of the heat of the steam with the metal of the cylinder. The deposition of the water of this liquefaction is entirely and in mass upon the metallic surfaces.

If the small cylinder be jacketed with steam of sufficiently high temperature to more than prevent liquefaction previous to the closing of the cut-off valve, then the additional heat transferred from the jacket to the steam within the cylinder will superheat that steam, in which case the specific heat will be practically constant at 0.48. The steam in the remainder of the stroke of the piston of the small cylinder, would necessarily be superheated also, and would not contain any water of the molecular liquefaction due to the expansive working. Steam cannot be superheated and contain this water at the same time. Superheated steam is not a vapor but a gas, and the heat transmuted into the work done by the expansion of such gas produces a corresponding lowering of the temperature of the superheated steam, but no precipitation of water. When the precipitating point has been reached, the steam is a vapor again; on either side of this point, it is subject to different laws. If the heat received by the steam within the small cylinder from the steam in the jacket previous to the closing of the cut-off valve be not sufficient to prevent surface liquefaction, the water of such liquefaction will be revaporized during the remaining portion of the stroke of the piston and during the following exhaust stroke of the piston, the heat being supplied partly from the contained heat in the water rendered available by the lessening of the pressure upon it, and partly from the heat in the jacket steam.

Thus, in the actual steam engine, the heat transferred from the steam in the jacket, is transferred to both water and steam in the cylinder, vaporizing the former and superheating the latter. The ratio of the weight of water to the weight of steam is, of course, a very variable one, depending on many circumstances. No superheating, however, can be done until all the water present in the cylinder, however derived, is vaporized. Under such complex and varying circumstances, unknown and unknowable, no calculation can be made as regards the quantitative distribution of the heat taken from the steam in the jacket to the steam within the cylinder.

An important result of these experiments is the showing of how large a portion of the heat taken from the jacket steam is due to external radiation, which, of course, must be subtracted from the total loss of heat by the jacket steam to give the heat imparted to the steam and water within the cylinder. A most erroneous idea will be formed if all the heat lost by the jacket steam be supposed transferred to the water and steam in the cylinder. The economy produced by jacketing is effected by much less heat than is commonly imagined.

The quantity on line 80 is the product of the multiplication of the quantity on line 5 by the latent heat due to the steam pressure on line 32 divided by the number of hours on line 1.

The quantity on line 81 is the product of the multiplication of the quantity on line 6 by the latent heat due to the steam pressure on line 34 divided by the number of hours on line 1.

The quantity on line 82 is the product of the multiplication of the quantity on line 7 by the latent heat due to the steam pressure on line 36 divided by the number of hours on line 1.

The quantity on line 83 is the sum of the quantities on line 80, line 81 and line 82.

The quantity on line 84 is the product of the multiplication of the quantity on line 22 by the quantity on line 24.

The quantity on line 85 is the fraction which the quantity on line 83 is of the quantity on line 84.

The quantity on line 86 is the sum of the quantities on line 68, line 71 and line 74.

The quantity on line 87 is the remainder of the quantity on line 83 after subtraction of the quantity on line 86.

The quantity on line 88 is the fraction which the quantity on line 86 is of the quantity on line 84.

The quantity on line 89 is the fraction which the quantity on line 87 is of the quantity on line 84.

Steam Pressures in the Small Cylinders.—The quantities on lines 90 to 100, both inclusive, are taken by measurement from the indicator diagrams.

Steam Pressures in the Intermediate Cylinders.—The quantities on lines 101 to 112, both inclusive, are taken by measurement from the indicator diagrams.

Steam Pressures in the Large Cylinders.—The quantities on lines 113 to 124, both inclusive, are taken by measurement from the indicator diagrams.

Equivalent Steam Pressures for the Large Cylinders.—The quantities on lines 125 to 129, both inclusive, show what would be the indicated, net, total and back pressures on the pistons of the large cylinders, were these pressures on the pistons of the small and intermediate cylinders reduced in the ratio of the net area of the pistons of the large cylinders to the net areas respectively of the pistons of the small and intermediate cylinders, and the quotients added to the respective experimental pressures on the pistons of the large cylinders.

In all multiple cylinder engines, the dimensions of the large cylinder are the same as those of the single cylinder of a single cylinder engine using the steam with the same regimen as the multiple cylinder engine. For the purpose of comparison, moreover, the various pressures on the pistons of the multiple cylinder engine, must be reduced to a single expression.

The total pressure on line 127 supposes no cushioning of the back pressure, consequently, the quantity on line 128, being the difference of the quantities on lines 125 and 127, is the back pressure supposing no cushioning. With the experimental cushioning in the large cylinder (beginning at 0.75 of the return or exhaust stroke of the piston of that cylinder) the back pressure for this 0.75 of the stroke would be the quotient of the quantity on line 128 divided by 0.75, which quotient is the quantity on line 129. If, now, the power due to the indicated pressure on line 125 be calculated, using the entire area of the piston of the large cylinder; and if the power due to the back pressure on line 129 be calculated, using 0.75 of the area of the piston of the large cylinder, the sum of these two powers will equal the aggregate total power, line 150, developed by the engine.

A comparison of the experimental equivalent total pressure (line 127) on the pistons of the large cylinders, with the corresponding calculated total pressure which would be obtained on the supposition that the steam expanded according to the law of Mariotte, will be interesting and instructive, as this calculated pressure would be the mean total experimental pressure obtained in the single cylinder of a single cylinder engine using the steam with the same regimen as in the three cylinders of the triple expansion engine.

The mean pressure of steam during its expansion in the single cylinder of a single cylinder engine, as shown by the results of a vast number of indicator diagrams taken with steam of widely varying regimen in cylinders of widely varying dimensions, both jacketed and unjacketed, agrees almost exactly with the mean pressure due to the expansion, as calculated by the Mariotte law. The coincidence is, of course, purely accidental, arising from the numerous and complex conditions acting upon the steam pressure in a working cylinder, some of which increase while others decrease the pressure, the final result, as a balance of the opposing conditions, causing the pressure to be what it would be if calculated according to the Mariotte law. This coincidence is of great practical value, allowing many important comparisons to be conveniently made as regards the performances of engines, which would otherwise be difficult and uncertain.

If the steam used in the experimental triple expansion engine, were used with exactly the same regimen in the single cylinder of a single cylinder engine, having the dimensions of the large cylinder of the experimental engine, the following would be the data for such a single cylinder :

Fraction completed of the stroke of the piston when the steam was cut off,	0.0509
Fraction completed of the exhaust stroke of the piston when the cushioning of the back pressure began..........	0.75
Fraction of stroke of piston displacing the same space as the aggregate spaces in the clearance and steam passage at one end of the cylinder, and in the cylinder up to the point of cutting off..........	0.056
Number of times the steam was expanded, line 50....	18.385
Mean steam pressure in pounds per square inch above zero on the piston previous to the point of cutting off, line 99......	128.129

Steam pressure in pounds per square inch above zero on the piston at the point of cutting off, line 91	119.500
Mean pressure of the expanding steam alone, in pounds per square inch above zero, subsequent to the point of cutting off, calculated according to the Mariotte law	20.732
Mean steam pressure in pounds per square inch above zero on the piston during its entire stroke, according to the Mariotte law for the expansion portion of the stroke	26.197

The experimental mean pressure of the expanding steam in the cylinders of the triple expansion engine, was 17.903 pounds per square inch above zero, being (20.732—17.903=) 2.829 pounds per square inch less than the mean pressure of the expanding steam calculated by the Mariotte law, or ($\frac{2.829}{20.732}$=) 0.1365 of the calculated expansion pressure alone.

The experimental mean pressure of the steam during the entire stroke of the pistons in the cylinders of the triple expansion engine, was 23.5114 pounds per square inch above zero, line 127, being (26.1969—23.5114=) 2.6854 pounds per square inch less than the mean pressure during the entire stroke of the pistons calculated for the expansion portion of the stroke according to the Mariotte law, or ($\frac{2.6854}{26.1969}$=) 0.1025 of the calculated mean pressure for the entire piston stroke.

These are very serious losses and are referred to the total horses-power developed by the engines, line 150, for the latter fraction, and to the horses-power developed by the expanding steam alone after the closing of the cut-off valve on the small cylinder, line 151, for the former fraction. When they are referred to the indicated and to the net horses-power developed by the engine, and to the horses-power doing the net pumping, they become still more serious; for instance:

The mean experimental equivalent indicated pressure on the pistons is, for the experiment of March 9th, 19.699 pounds per square inch, line 125. The mean calculated equivalent indicated pressure, with the same back pressure, line 128, of 3.812 pounds per square inch, is (26.197—3.812=) 22.385 pounds per square inch, a difference of 2.685 pounds per square inch, as before, but now amounting to ($\frac{2.685}{22.385}$=) 0.1199 of the indicated horses-power, line 148.

The mean equivalent experimental net pressure on the pistons is, for the experiment of March 9th, 18.622 pounds per square inch, line 126. The mean calculated equivalent net pressure, allowing the equivalent pressure on the pistons of the large cylinders of 1.077 pounds per square inch for working the engines *per se*, or unloaded, is (22.385 — 1.077 =) 21.307 pounds per square inch, a difference of (21.307—18.622=) 2.685 pounds per square inch as before, now amounting to ($\frac{2.685}{21.307}$=) 0.126 of the net horses-power, line 149.

The mean equivalent experimental pressure in pounds per square inch on the pistons of the large cylinders, of the pressure in the main just outside of the delivery valves of the pumps, supposing the pumps to fill to 0.98 of their capacity, is, for the experiment of March 9th, 17.160, line 131. The mean equivalent calculated pressure, will therefore be (17.160+2.685=) 19.845 pounds per square inch, and the difference of the 2.685 pounds per square inch will amount to ($\frac{2.685}{19.845}$=) 0.1353 of the net horses-power expended in the pumping, line 132.

As the object of a pumping engine is to pump, the economy of the pumping is the commercial value of the performance, consequently, the economy of the experimental engine was lessened 13½ per centum by the less mean pressure of the steam during the stroke of the pistons of the triple expansion engine, than the corresponding mean pressure would have been in the case of a single cylinder engine with a single cylinder of the dimensions of the large cylinder of the triple expansion engine, the steam being used with the same regimen in both cases.

This fraction represents a very important loss for the triple expansion engine, consequently, the tracing of it to its cause is an equally important investigation. The loss results wholly from the too small capacity of the receivers between the small and intermediate cylinders, and between the intermediate and large cylinders. The too little capacity of the receivers relatively to the capacity of the cylinders in connection with them, causes the steam passing through the receivers to undergo expansion in them, so that the steam pressure in the cylinder drawing steam from a receiver is less than it should be, and less than it would be had the steam not thus expanded. Also the back pressure in the cylinder delivering steam into a receiver is greater than it should be, and greater than it would be if the receiver was of larger capacity. A complete experiment on a multiple cylinder engine includes indicator diagrams taken from its receivers, as these diagrams are the only means of showing the degree of expansion undergone by the steam in passing through the receivers. A pressure gauge (wanting in the present experiments) on the receivers shows only the mean pressure in them, not the initial and terminal pressures, which are the pressures needed. Such diagrams are rarely ever, perhaps never taken, but if taken they would afford conclusive evidence of the expansion in question, and, if it exist, then the work that might have been obtained from it is as surely lost. The proper capacity for any receiver is, strictly speaking, infinite, as in that case alone there would be no expansion of the steam in passing through it, and therefore no loss from such expansion. The larger the capacity of the receiver the less will be the loss due to the expansion of the steam passing through it, but, on the other hand, the larger the capacity of the receiver the greater will be the extent of its surface exposed to external radiation of heat operating liquefaction of the steam within, and thus causing an economic loss of another kind. There is, therefore, a capacity of receiver, differing for different cases and conditions, in which the sum of the losses by the expansion of the steam within it, and by its external radiation of heat is a minimum. In general practice, owing to convenience of construction, money cost, and ignorance, the capacities of receivers are much below the limit required to obtain this minimum. The greater the number of cylinders employed to form an engine, the greater will be the losses of both kinds due to the use of receivers. These losses, of course, do not exist for the single cylinder engine.

The loss of useful effect by the expansion of the steam in the receiver, is additional to the loss of useful effect by the difference between the back pressure, exclusive of the cushioning, in the cylinder delivering into the receiver, and the steam pressure up to the point of cutting off in the cylinder taking steam from the receiver; such difference constitutes additional back pressure to the experimental back pressure, exclusive of cushioning, in the large cylinder. There would be a loss from this additional back pressure, even were the receiver infinite in capacity, because in the practical multiple cylinder engine the steam can get out of the one cylinder into the succeeding cylinder only by a difference of pressure measured by the resistance of the steam ports and passages of the two cylinders. If these steam ports and passages were made so large in area and so direct as to offer no sensible obstruction to the flow of the steam, the back pressure exclusive of cushioning in the delivering cylinder would be the same as the steam pressure up to the point of cutting off in the receiving cylinder.

The effective or equivalent back pressure in a multiple cylinder engine, the condenser pressure remaining constant, can be made very small or very large according to the area of the steam ports; and the cross area, length and sinuosity of the steam passages connecting the cylinders; and to the reciprocating speed of the piston; and to the capacity of the receiver. The expansion of the steam in the receivers can likewise be made much or little according to the same conditions. Hence, the economic performance of multiple cylinder engines is greatly affected by the proportions of the parts just enumerated, so that variations of from 10 to 20 per centum are easily possible between different engines of the same type working with substantially the same regimen of steam, but having these parts differently proportioned, and more especially in cases where the steam having an excessive measure of expansion, has necessarily a small mean indicated equivalent pressure when referred to the large cylinder, in which cases the losses of effective pressure by the additional back pressure due to the transfer of the steam from one cylinder to the succeeding cylinder, and by the expansion of the steam in the receiver, become a large percentage of the mean pressure on the piston during its stroke. The economic performances of single cylinder engines, not being influenced by the variable effects due to the employment of receivers, are much more uniform when the steam is used with the same regimen.

Pumps.—A portion of the quantity on line 130, ascertained by means of a pressure gauge in the main just outside of the delivery valves of the pumps, is the pressure equilibrating the mean pressure in the main during the experiments, the remaining portion being the resistance of the statical weight of a column of water having a vertical height equal to the vertical distance apart of two horizontal planes, one passing through the center of the orifice for the gauge, and the other coinciding with the surface of the water in the pump well. The aggregate pressure, line 130, is less than the pressure against which the pistons of the pumps act by the pressures due to the resistance of the surfaces moved over by the water between the gauge and the lower edge of the suction main, to the resistance caused by the sinuosities of those surfaces, and to the resistance due to the opening of the receiving and delivering valves of the pumps, and to the forcing of the water through these valves. The quantity on line 130 may be considered the net resistance against which the pump pistons pump, that is, the resistance due to the mere weight of the water alone, and exclusive of the resistances due to the pumping mechanism alone. Strictly speaking, there should be included in the latter, additionally, the frictions of the pump pistons and the pump stuffing boxes. In the present case, however, these frictions are included in the pressure required to work the engines *per se* or unloaded.

The pressure on line 131 is the pressure on line 130 divided by the ratio of the net areas of the pistons of the large cylinders to the net areas of the pistons of the pumps and the quotient multiplied by 0.98, this being the assumed fraction of the capacity of the pumps to which they will fill with water, the remaining 0.02 being what is technically known as the "slip" of the pump.

The horses-power on line 132 is calculated for the pressure on line 130 multiplied by 0.98.

The quantity on line 133 is the difference of the quantities on lines 126 and 131.

The quantity on line 134 is the fraction which the quantity on line 132 is of the quantity on line 148.

The quantity on line 135 is the difference between the fraction on line 134 and unity.

Horses-Power.—Line 136 contains the number of indicated horses-power developed in the small cylinders. They are calculated for the entire net area of the pistons of these cylinders, for the piston speed on line 28, and for the indicated pressure on line 96.

Line 137 contains the number of net horses-power developed in the small cylinders. They are calculated for the entire net area of the pistons of these cylinders, for the piston speed on line 28, and for the net pressure on line 97. This power is exclusive of the power required to work the engines *per se*, or unloaded, but it includes the power due to the pressure caused upon the working surfaces of the fly-wheel mechanism by whatever portion of the load is passed through that mechanism.

Line 138 contains the number of total horses-power developed in the small cylinders exclusive of the power required to overcome the cushioning. They are calculated for the entire net area of the pistons of these cylinders, for the piston speed on line 28, and for the total pressure on line 98. This power is calculated for the entire steam pressure down to the zero of pressure, and is the whole power developed by the steam in the small cylinders produced by the weight of water on line 22. It excludes the power required to overcome the cushioning, because the weight of steam cushioned is precisely the weight that is required to produce the power which overcomes the cushioning. If the power required to overcome the cushioning be included in the total power developed by the cylinders, then the weight of steam cushioned per hour must be added to the weight on line 22 for the total weight of steam producing this new total horses-power. Of course, the result would be the same as regards the economic performance of the engine let whichever method be used, but the one adopted by the writer has the advantage of greater simplicity.

Lines 140 and 141 contain respectively the number of indicated and of net horses-power developed in the intermediate cylinders. They are calculated for the entire net area of the pistons of these cylinders, for the piston speed on line 28, and for the indicated and net pressures on lines 107 and 108.

Line 142 contains the number of total horses-power developed in the intermediate cylinders exclusive of the power required to overcome the cushioning. This power is calculated for the entire steam pressure down to the zero of pressure, line 109, and is the whole power developed by the steam in the intermediate cylinders corresponding to the weight of water on line 22. It excludes the power required to overcome the cushioning. It is calculated for the piston speed on line 28, and for what remains of the net area of the pistons of the intermediate cylinders after subtracting the net area of the pistons of the small cylinders. This subtraction is necessary because the power due to the total pressure down to zero, line 109, for the portion of the net area of the pistons of the intermediate cylinders equal to the net area of the pistons of the small cylinders, has been already included in the total horses-power, line 138, developed by the pistons of the small cylinders.

Line 143 contains the number of horses-power developed by the expanding steam in the intermediate cylinders, including the power required to cushion the back pressure steam in those cylinders. Were there no cushioning, this power would be the same as that on line 142, because all the power developed in the intermediate cylinders is produced by expanding steam, previous to, as well as subsequent to, the closing of the cut-off valves on those cylinders. The power, therefore, on line 143 exceeds the power on line 142 by the power required to cushion the back pressure in the intermediate cylinders. The reason for including the power expanded in this cushioning, is that the expanding steam really overcomes it, and a knowledge of the whole power effect of that steam is necessary in order to calculate the number of units of heat transmuted from the mean latent heat of the expanding steam into the work done by that steam. As the expanding steam in this connection has no relation to economic performance, only the whole power developed by it is required to be known, irrespective of the water weight on line 22.

Line 144 contains the number of indicated horses-power developed in the large cylinders, calculated for the entire net area of their pistons, for the piston speed on line 28, and for the indicated pressure on line 119.

Line 145 contains the number of net horses-power developed in the large cylinders, calculated for the entire net area of their pistons, for the piston speed on line 28, and for the net pressure on line 120.

Line 146 contains the number of total horses-power developed in the large cylinders exclusive of the power required to overcome the cushioning. This power is calculated for the entire steam pressure down to the zero of pressure, line 121, and is the whole power developed by the steam in the large cylinders corresponding to the weight of water on line 22. It excludes the power required to overcome the cushioning. It is calculated for the piston speed on line 28, and for what remains of the net area of the pistons of the large cylinders after subtracting the net area of the pistons of the intermediate cylinders. This subtraction is necessary because the power due to the total pressure down to zero, line 121, for the portion of the net area of the pistons of the large cylinders equal to the net area of the pistons of the intermediate cylinders, has been already included in the total horses-power, line 142, developed by the pistons of the intermediate cylinders.

Line 147 contains the number of horses-power developed by the expanding steam in the large cylinders, including the power required to cushion the back pressure steam in those cylinders. Were there no cushioning, this power would be the same as that on line 146, because all the power developed in the large cylinders is produced by expanding steam, previous to, as well as subsequent to, the closing of the cut-off valves on those cylinders. The power, therefore, on line 147 exceeds the power on line 146 by the power required to cushion the back pressure in the large cylinders. The power on line 147 is needed for the calculation of the number of units of heat transmuted into the work done in the large cylinders by the expanding steam, and has no reference to the weight of water on line 22. It is calculated for the pressure on line 124, for the piston speed on line

28, and for what remains of the net areas of the pistons of the large cylinders after subtraction of the net areas of the pistons of the intermediate cylinders.

The number of total horses-power developed in the small cylinder, *including* the power required to overcome the cushioning, was 318.983, adding to which the number of total horses-power developed in the intermediate cylinder, including the power required to overcome the cushioning, 212.796, line 143, and the number of total horses-power developed in the large cylinder, including the power required to overcome the cushioning, 160.298, line 147, there is obtained the aggregate 692.077 horses-power. Of this sum 515.936 horses-power, line 151, were developed by the expanding steam alone, so that the latter quantity was $(\frac{515.936}{692.077}=)$ 0.745 of the total horses-power developed by the engine, including the power to overcome the cushioning. These latter determinations have no reference to the quantity of feed water consumed on line 22. They simply give the relation of the absolute total work done in the engine, to the portion of that work done by the expanding steam. The assumption is made that the work done by the steam in the small cylinder previous to the closing of the cut-off valve is work done by non-expanded steam. This assumption is erroneous, because the steam was, and necessarily always has to be expanded from the commencement of the stroke of the piston to the point of cutting off. This expansion may be insignificant or considerable according to the proportions and conditions of the mechanism; to calculate the quantity of work done by it is difficult, and, in the case of the present experiment, not necessary, because it was very small, the difference between the initial pressure in the small cylinder (line 90), and the mean pressure between the initial and the cut-off pressure (line 99) being only (128.5 — 128.129 =) 0.371 pound per square inch, a negligible quantity.

The quantity on line 148 is the sum of the quantities on lines 136, 140 and 144.

The quantity on line 149 is the sum of the quantities on lines 137, 141 and 145.

The quantity on line 150 is the sum of the quantities on lines 138, 142 and 146.

The quantity on line 151 is the sum of the quantities on lines 139, 143 and 147.

The quantity on line 152 is the difference between the quantities on lines 149 and 148. This difference is the number of horses-power due to the entire net area of the pistons of the large cylinders, the piston speed on line 28, and the difference between the pressures on lines 125 and 126, namely, 1.077 pounds per square inch, which is assumed as the equivalent pressure required on the pistons of those cylinders to work the engines, *per se*, or unloaded.

The quantity on line 153 is the difference between the quantities on lines 149 and 132.

The quantity on line 154 is the difference between the quantities on lines 150 and 148.

ECONOMIC RESULTS.

The quantities on lines 155, 156, 157 and 158, are the quotients, respectively, of the quantity on line 22 divided by the quantities on lines 148, 149, 150 and 132.

The quantities on lines 159, 160, 161 and 162, are the products, respectively, of the multiplication of the quantities on lines 155, 156, 157 and 158, by the quantity on line 24.

Assuming 789.25 foot-pounds of work as the mechanical equivalent of one Fahrenheit unit of heat; and assuming the horse-power to be 33,000 pounds raised one foot high per minute, or ($33{,}000 \times 60 =$) 1,980,000 foot-pounds of work per hour, the horse power per hour is equal to ($\frac{1{,}980{,}000}{789.25} =$) 2508.711 Fahrenheit units of heat, and if the entire *vis viva* of the steam could be transmuted into mass work, a horse-power developed by the engine would be obtained by the expenditure of this number of Fahrenheit units of heat. Now the quantities on lines 159, 160, 161 and 162, are the number of Fahrenheit units of heat experimentally expended per hour per indicated, net and total horse-power developed by the engines, and per horse-power applied by the pumps to the net pumping, consequently, the quotients of the division of 2,508.711 by the number of Fahrenheit units of heat respectively on the lines 159, 160, 161 and 162, will give the fraction of the heat imparted in the boilers to the feed water, that has been experimentally utilized or transmuted into the different horse-powers. These quotients are the quantities on lines 163, 164, 165 and 166.

The true measure of the efficiency of the experimental engines as transmutors of the heat imparted in the boilers to the feed water, into mass *vis viva* or mechanical work, is given by the quantity on line 160, from which is seen that 19 per centum of this heat was transmuted into mass *vis viva*. Of course this fraction was not realized commercially, because of the unavoidably imperfect design of the engines, the imperfect liquefaction of the steam in the condenser, and the various frictions, etc., already pointed out, to be overcome, which, in the aggregate, reduce the efficiency from 19 to 14 per centum, line 166, a huge difference which the efforts of engineers should be directed to diminish.

Weight of Steam Present in the Cylinders, per Indicator.—To calculate the quantity on line 167, the aggregate number of cubic feet in the clearance, steam passage, and portion of the small cylinder up to the point of cutting off the steam, is multiplied by the number of strokes of the piston made per hour and by the weight, in fractions of a pound, of a cubic foot of steam of the pressure at the point of cutting off. From this last product is subtracted a quantity obtained by multiplying the aggregate number of cubic feet in the clearance, steam passage, and portion of the small cylinder included between the end of the stroke of the piston of that cylinder and the point at which the cushioning of the steam began, by the number of strokes of the piston made per hour, and by the weight, in fractions of a pound, of a cubic foot of steam of the pressure at the point where the cushioning began. The remainder is the quantity on line 167, and is all the steam that is accounted for by the indicator at the point of cutting off in the small cylinder, the heat transmuted into the power developed by the steam up to that point being supplied directly by the furnace and not taken from the latent heat of the steam itself.

The calculation of the quantity on line 168 is made in a similar manner to the calculation of the quantity on line 167, substituting for the space in cubic feet between the steam valve and the point of cutting off, the space between the steam valve and the end of the stroke of the piston, and for the weight in fractions of a pound per cubic foot of steam of the pressure at the point of cutting off, the weight in pounds per cubic foot of steam of the pressure at the end of the stroke of the piston. The subtrahend will be the same as in the case of the quantity on line 167. The quantity on line 168 is not the entire weight of steam that can be accounted for by the indicator, as it does not include the weight of steam liquefied to furnish the heat transmuted into the power developed by the steam between the point at which the cut-off valve closed and the end of the stroke of the piston; that is to say, the power developed by the expanding steam alone.

The quantity on line 169 is calculated by first ascertaining the number of foot-pounds of work done per hour equivalent to the number of horses-power (line 139) developed by the expanding steam alone in the small cylinder, that is, multiplying this power by 33,000 and by 60, the number of minutes in an hour; then dividing this product by 789¼, the number of foot-pounds of work equivalent to one Fahrenheit unit of heat, to ascertain the number of Fahrenheit units of heat equivalent to the foot-pounds of work done by the expanding steam; finally, the last quotient is divided by the latent heat of the mean pressure (line 100) of the expanding steam to obtain the number of pounds weight of steam required to be liquefied in order to furnish the heat transmuted into the work done by the expanding steam alone. This last quantity is the quantity on line 169. It is a quantity accounted for by the indicator, and, when added to the quantity on line 167, the sum is the number of pounds weight of steam accounted for per hour in the small cylinder at the end of the stroke of its piston by the indicator, line 170.

The quantity on line 171 is calculated in the same manner as the quantity on line 167, substitution being made of the corresponding data.

All the work done in the intermediate cylinder is done by expanding steam, a fact not affected by the closing of the cut off on that cylinder. The cutting off of the steam in cylinders succeeding the small cylinder affects the problem to the extent of increasing, relatively, the capacity of the receivers between the cylinders, so as to lessen to a certain degree the "drop" and "gap" between their indicator diagrams, to regulate the back pressures in the cylinders so as to equalize approximately the indicated powers developed in them, and to enable the steam due to the revaporization of the water of liquefaction in the preceding cylinders to be used expansively in the succeeding cylinders. In comparing the back pressure of a preceding with the steam pressure of a succeeding cylinder, the back pressure to be considered is the absolute back pressure exclusive of the cushioning; and the steam pressure to be considered is the absolute pressure between the commencement of the stroke of the piston and the point of cutting off.

The quantity on line 172 is the sum of a quantity calculated in the same manner (for the power on line 143) as the quantity on line 169, substitution being made of the corresponding data, and of the quantity on line 169; the quantity on line 172 being the number of pounds weight of steam liquefied to furnish the heat transmuted into the power (calculated for pressure down to zero) developed by the expanding steam from the closing of the cut-off valve on the small cylinder to the end of the stroke of the piston of the intermediate cylinder.

The quantity on line 173 is the sum of the quantities on lines 171 and 172, and is the number of pounds weight of steam accounted for by the indicator per hour at the end of the stroke of the piston of the intermediate cylinder.

The quantities on lines 174, 175 and 176 are calculated in the same manner as the respective quantities on lines 171, 172 and 173, substitution being made of the corresponding data.

Of course, all the calculations in this paper, like all calculations which involve physical measurement, are subject to corrections, many of which, however, are slight enough to be negligible, and most of which neutralize each other, that is to say, some increase and some decrease the result to about an equal extent. The diameter of the cylinders, and the length of the cylinders (the latter involving variations in the waste spaces at the cylinder ends), are from measurements made with the metal at the atmospheric temperatures; but when the engine is in operation, the temperature of the cylinders and other parts is very much greater, and must cause a corresponding increase of the dimensions; moreover, neither the extreme nor the mean temperature of the cylinder metal, etc., are known. Even the length of the stroke of the piston, though controlled by the crank, does not remain constant, the more or less slackness of the brasses of the connecting rod, and the variable temperature of the piston rod during a stroke, affect the length of the stroke. There is, on the other hand, variation in the strength of the springs of the indicator, which becomes weaker with increase of temperature, and *vice versa*, so that the scale of the spring can only be correct for the temperature at which it was adjusted, and must be erroneous at all other temperatures, and the temperaature must be in continuous variation between certain limits during the time a diagram is taken. Here then is an instance in which the errors of two variables (the temperature of the cylinder and the temperature of the indicator) more or less neutralize each other. If the scale of the spring be adjusted for an imagined mean temperature when the indicator is in use, it will show too much pressure when the temperature is greater and too little when the temperature is less. The inertia of the moving parts of the indicator cause error; also, the frictions of the piston, and of the pencil of the indicator, and of the indicator mechanism. Strings stretch, thus producing an everyway erroneous diagram, and the stretching is not uniform, depending wholly on the pull accidentally or momentarily acting on the string. The very paper on which the diagram is traced varies in dimensions (the diagram dimensions varying accordingly) corresponding to the hydroscopic condition of the atmosphere or rather of the particular portion of the atmosphere surrounding the indicator when the diagram was taken. The moister the air the larger the area of the diagram will be, and *vice versa*, so that there is always the error due to the difference between the dimensions of the diagram when taken from the cylinder and its dimensions when measured sometime afterwards in the comparatively dry air of an office. The air surrounding the indicator in the engine room of a steamer, saturated with the steam leaking from the stuffing boxes and various cocks of the engine, particularly the indicator cocks, and derived from the vaporization of water always in the bilge of the vessel by the high temperature of the engine room, must always be greatly more humid than the air of an office, so that a considerable error can thus result apparently decreasing the power of the engine.

As the indicator must be connected with the interior of the cylinder by means of a pipe more or less long, the steam pressure on the indicator diagram cannot possibly be as great as the corresponding pressure in the cylinder, and the back pressure or exhaust pressure on the diagram cannot possibly be as little as the corresponding back pressure in the cylinder, so that the diagram gives too small an indicated pressure at every ordinate, both for the steam and the exhaust pressures. The steam cannot get from the cylinder into the indicator unless the pressure in the latter is less than the pressure in the former; nor can the exhaust steam get out of the indicator into the cylinder unless the pressure in the indicator is greater than in the cylinder. Let the area of the indicator pipe be as large as it may, and let the length of this pipe be as short as it may, the corresponding pressures in the cylinder and in the indicator cannot be equalized, though the difference may thus be made quite small. It will become large just in proportion to the smallness of the area and the greatness of the length of the pipe, and to the rapidity of the revolutions of the engine.

The inner surfaces of the steam cylinders are covered with a more or less thick coating of water of steam liquefaction, which, though not decreasing the power developed by the cylinder, decreases the bulk of steam contained in it in proportion to the decrease that the water causes in the capacity of the cylinder. This decrease interferes with the accuracy of the calculations of the quantities of steam accounted for in the cylinder by the indicator; moreover, the water of molecular liquefaction suspended in the steam in the form of mist or fog, likewise interferes with the accuracy of such calculations. The foregoing considerations are patent qualitative facts, but the corresponding quantitative effects cannot be ascertained. As many, and probably most of these errors in data correct each other, they, in the aggregate, affect the final result to only a negligible extent absolutely, and to scarcely any extent relatively, as they apply about equally to all cylinders and to all indicators.

The weight of steam liquefied by the interaction of the heat of the steam in the cylinder with the metal of the cylinder, and also the weight of steam molecularly liquefied to furnish the heat transmuted into the power developed by the expanding steam alone, are not only calculable quantities, but have been calculated and will be found in the following table. There would have been required, additionally, only the division of these quantities by the weight in pounds per cubic foot of water of the temperature of the steam in contact therewith, to obtain the quantities to be subtracted from those on lines 167, 168, 171 and 174, in order to make the corrections required for the water present in the cylinder. The corrections thus obtained, however, are insignificant enough to be negligible. Unless *all* the corrections can be made, all had better be omitted, and reliance placed on the correction of errors where a moiety increases and a moiety decreases the final result; consequently, the writer in his many experimental investigations, has never applied any of these corrections, for they would only have made what was not quite satisfactory still more unsatisfactory.

Differences between the Weight of Steam entering the Small Cylinders and the Weights of Steam accounted for in those and their Succeeding Cylinders by the Indicator.—The quantity on line 177 is the remainder of the quantity on line 23 after subtraction of the quantity on line 167. The quantity on line 177 is the total number of pounds weight of steam liquefied per hour in the small cylinders by the interaction of the heat in the steam with the metal of these cylinders. It is wholly a surface liquefaction notwithstanding the heat received by the surfaces from the steam in the jackets, and the water is deposited in drops or layers uniformly on all the interior surfaces of the cylinders. This

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quantity is, of course, exclusive of any loss of heat by external radiation, for such loss is prevented by the jackets.

The quantity on line 178 is the fraction which the quantity on line 177 is of the quantity on line 23. The quantity on line 179 is the remainder of the quantity on line 23 after subtraction of the quantity on line 170. The quantity on line 179 is the total number of pounds weight of steam remaining liquefied per hour in the small cylinders at the end of the stroke of their pistons from the interaction of the heat in the steam with the metal of these cylinders. The subtraction of the quantity on line 179 from the quantity on line 178, gives the number of pounds of water of liquefaction revaporized in the small cylinders per hour between the point of cutting off the steam and the end of the stroke of the piston. This revaporization was only made possible by the reduction of the pressure due to the expansion of the steam, and was made at the expense partly of the contained heat in the water, and partly at the expense of the heat in the metal, and partly at the expense of the heat in the steam in the jackets. It amounted to $\left(\frac{1{,}737.952-822.950}{1{,}737.952}=\right)$ 0.5265 of the water of liquefaction present in the small cylinders at the point of cutting off, the remaining 0.4735 being revaporized during the return or expansion stroke of the piston and the resulting steam passed into the intermediate cylinders for the production of pressure on their pistons. Had there been no surface liquefaction of steam in the small cylinders, the whole of the 1,737.952 pounds weight of steam liquefied per hour during the portion of the stroke of the pistons previous to the closing of the cut-off valve, would have produced its corresponding power. This water of liquefaction had been once vaporized in the boiler and the steam from it had produced no power up to the point of cutting off. Subsequent to the point of cutting off, the revaporization of 0.5265 of this water produced power during the portion of the stroke of the pistons between the point of cutting off and the end of their stroke, and the remaining 0.4735 of it passed to the intermediate cylinders, producing power pressure upon their pistons the same as produced by the steam exhausted as such from the small cylinders. The revaporization of the 0.5265 part of the water of liquefaction between the point of cutting off and the end of the stroke of the small cylinders, produced but very little power relatively to what it would have produced had it been vaporized in the boiler and used expansively from the point of cutting off to the end of the stroke of the piston, because, subsequent to the point of cutting off, the whole of the space between the steam valve and any point at which part of the water of liquefaction might be revaporized, acted as waste space to the steam thus generated, its pressure being distributed uselessly through that space, the steam being expanded backwards as well as forwards, so that really the power produced by the steam of the revaporized water in the small cylinders was of not much benefit absolutely, and still less relatively when considered with reference to the power that might have been produced from it, had it been vaporized in the boiler. The steam produced from the 0.4735 part of this water during the exhaust stroke of the pistons of the small cylinders passed into the receivers, and was properly used upon the pistons of the intermediate cylinders during their entire stroke. The 0.4735 part produces the same power effect as though it had been vaporized in the boiler at the receiver pressure, delivered directly into the receiver, and used throughout the succeeding cylinders. The power thus produced is, nevertheless, much inferior to what it would have been had the water been vaporized in the boiler at the boiler pressure and then delivered into the small cylinders.

Obviously, the weight of steam liquefied in the small cylinders by the interaction of its heat with the metal of the cylinders, was twice evaporated, once in the boiler and once in the small cylinders, and that scarcely any power was derived from it in those cylinders. This weight of liquefied steam was much less than it would have been had there been no jackets to the cylinder; it was roundly as much less as the weight of the water of liquefaction drawn per hour from the jackets of the small cylinders, the steam liquefied in the jackets having been evaporated but once and, by having prevented the equivalent liquefaction in the cylinders, prevented the second vaporization there. Hence, the economic effect of steam jacketing the small cylinders was, as regards those cylinders alone, 0.019 (line 11) of the heat imparted to the feed water in the boiler, or, say, 2 per centum.

All the steam that entered the small cylinders, enters the receivers between them and the intermediate cylinders with the exception of the steam molecularly liquefied to furnish the heat transmuted into the power developed by the expanding steam alone in the small cylinders. The water of this liquefaction being suspended in the steam in the state of the water in fog or mist, and excessively comminuted, is swept as such with and by the exhaust steam from the small cylinders into the receivers between them and the intermediate cylinders. The weight of steam that as such entered the receivers per hour, was (6,598.833 pounds, line 23, less 399.780 pounds, line 169) 6,199.053 pounds. In the receivers there is more liquefaction of steam, due to external radiation. Some of this water will be revaporized in the receivers under the fluctuations of pressure therein, by its own contained heat and by the heat of the metal; the remainder will, from time to time as the accumulations become great enough, be driven into the intermediate cylinders as water along with the steam. But although the intermediate cylinders will, therefore, receive a decidedly less weight of steam as such than the small cylinders, they will receive the same aggregate weight of steam and water.

The quantity on line 180 is the fraction which the quantity on line 179 is of the quantity on line 23.

The quantity on line 181 is the remainder of the quantity on line 23 after subtraction of the quantity on line 173. The quantity on line 181 is the total number of pounds weight of steam remaining liquefied per hour in the intermediate cylinders at the end of the stroke of their pistons. All the water, however caused, which entered the intermediate cylinders with the steam from the receivers, had then been converted into steam together with a large portion of the water of molecular liquefaction due to the total power, including overcoming the back pressure, developed in these cylinders, for all the pressure in them was produced by expanding steam. The weight due to this molecular liquefaction per hour was (963.371, line 172, minus 399.780 line 169=) 563.591

pounds, all of which except the 77.301 pounds on line 181 was vaporized. Thus of the entire weight of steam which entered the small cylinder per hour, all, except one and one-sixth per centum (line 182) was present as steam at the end of the stroke of the pistons of the intermediate cylinders; this small fraction, however, maintained the steam in the saturated state. The production of this condition was due entirely to the heat passed from the steam jackets into the cylinders, and they must have acted very efficiently.

Of the 6,598.833 pounds weight of steam and water, line 23, which entered per hour the intermediate cylinders, the jacket heat could produce no economic effect upon the molecular liquefaction 963.371 pounds, line 172, nor upon the 77.301 pounds of surface liquefaction, line 181, making a total of 1,040.672 pounds per hour, leaving as the weight of steam subject to the economic action of the jacket heat (6,598.833—1,040.672=) 5,558.161 pounds per hour, or the fraction 0.8423, because any portion of this weight of steam could be both liquefied and its water of liquefaction revaporized in the cylinder without doing any work of consequence, so that it would be twice evaporated, once in the boiler and afterwards in the cylinder. Now, by the action of the jacket heat, a weight of steam equivalent in heat to the weight liquefied in the cylinder, has only to be evaporated once (in the boiler), thus saving the heat of one evaporation, namely, the one in the cylinder. Hence, the economic value of the jackets as regards the intermediate cylinders, will be represented by the fraction of steam liquefied in the jackets, line 12, multiplied by the fraction 0.8423 above obtained, or, by $(0.040294 \times 0.8423 =)$ 0.03394; that is to say, the economy produced by the jackets on the intermediate cylinders was, roundly 3.4 per centum of the heat imparted to the feed water in the boilers, adding to which the, say, 2 per centum of such economy given, as above shown, by the jackets of the small cylinders, there results for the aggregate economy of the jackets of the small and of the intermediate cylinders, 5.4 per centum of the heat imparted to the feed water in the boilers. If some allowance be made of the power produced by the revaporization of the water of liquefaction in the cylinders between the point of cutting off and the end of the stroke of the pistons, this percentage can be reduced to 5.

Owing to the fact that there were no liquefactions of steam in the large cylinders, and that the steam from the intermediate cylinders entered the large ones sensibly free of water, the jackets on the large cylinders produced no economic effect, notwithstanding the considerable weight of steam liquefied in them, this liquefaction being, under the circumstances, a mere transfer of equal quantities of heat from jacket steam to cylinder steam, producing superheating of the latter but no economic effect, the production of such effect being restricted to the prevention by the jacket heat of surface liquefaction of steam in the cylinder.

The absence of economy by the use of jackets on the large cylinders, limits the jacket economy of the experimental engine to the above 5 per centum. The result thus obtained coincides closely with the results of comparative experiments on triple expansion engines using steam with and without jacketing. So small an economy is difficult to determine experimentally because the experimental errors may easily, and generally do, amount to that per centum as extremes. In the case where only the barrels or sides of the cylinders are steam jacketed, and not the whole of them because the valve chests cover a considerable fraction of their area, the gain by steam jacketing is, of course, still less, and may easily fall to 2 per centum, steam of the boiler pressure being used in the jackets.

The quantity on line 182 is the fraction which the quantity on line 181 is of the quantity on line 23.

The quantity on line 183 is the remainder of the quantity on line 176 after subtraction of the quantity on line 23, and shows that the steam in the large cylinders at the end of the stroke of their pistons was superheated sufficiently to make the pressure there, considered as the pressure of saturated steam, great enough to show an excess of weight of steam of 162.028 pounds per hour over the quantity entering the small cylinders per hour, line 23.

The quantity on line 184 is the fraction which the quantity on line 183 is of the quantity on line 23.

TABLE CONTAINING THE DATA AND RESULTS OF THE TWO EXPERIMENTS MADE BY MR. MICHAEL LONGRIDGE SIMULTANEOUSLY ON THE TWO TRIPLE EXPANSION, DIRECT ACTING, STEAM JACKETED, SURFACE CONDENSING, VERTICAL PUMPING ENGINES AT THE EAST LONDON WATER WORKS, LEA BRIDGE, ENGLAND.

Date of the Experiment.	1893. 1st March.	1893. 9th March.
TOTAL QUANTITIES.		
1. Duration of the experiment in consecutive minutes	406.	360.
2. Total number of double strokes made by the pistons of the North Engine	8,729.	7,925.
3. Total number of double strokes made by the pistons of the Middle Engine	8,625.	7,858.
4. Total number of pounds of feed water vaporized in the boilers	48,055.	44,870.
5. Total number of pounds of water of steam liquefaction drawn from the jackets of the small cylinders	930.	862.
6. Total number of pounds of water of steam liquefaction drawn from the jackets of the intermediate cylinders	2,180.	1,808.
7. Total number of pounds of water of steam liquefaction drawn from the jackets of the large cylinders	2,757.	2,421.
8. Total number of pounds of water of steam liquefaction drawn from all the jackets of all the cylinders	5,867.	5,091.
9. Total number of pounds of water of steam liquefaction drawn from the steam pipe	241.	186.
10. Total number of pounds weight of steam that entered the small cylinders	41,947.	39,593.
11. Fraction which the water of steam liquefaction drawn from the jackets of the small cylinders is of the feed water vaporized in the boilers	0.019	0.019
12. Fraction which the water of steam liquefaction drawn from the jackets of the intermediate cylinders is of the feed water vaporized in the boilers	0.045	0.040
13. Fraction which the water of steam liquefaction drawn from the jackets of the large cylinders is of the feed water vaporized in the boilers	0.057	0.054
14. Fraction which the water of steam liquefaction drawn from all the jackets of all the cylinders is of the feed water vaporized in the boilers	0.122	0.113

	1 Mar., '93.	9 Mar., '93.
15. Fraction which the water of steam liquefaction drawn from the steam pipe is of the feed water vaporized in the boilers......	0.005	0.004
16. Fraction which the weight of steam that entered the small cylinders is of the weight of steam evaporated in the boilers......	0.873	0.882
17. Total number of pounds of water of steam liquefaction produced in the jackets of the small cylinders by their external radiation of heat....	433.067	384.000
18. Total number of pounds of water of steam liquefaction produced in the jackets of the intermediate cylinders by their external radiation of heat......	663.133	588.000
19. Total number of pounds of water of steam liquefaction produced in the jackets of the large cylinders by their external radiation of heat....	1.745.800	1,548.000
20. Total number of pounds of water of steam liquefaction produced in all the jackets of all the cylinders by their external radiation of heat,	2,842.000	2,520.000
21. Fraction which the water of steam liquefaction produced in all the jackets of all the cylinders by their external radiation of heat, is of the weight of water vaporized in the boilers.... ...	0 059	0.056

ENGINES.

22. Number of pounds of feed water vaporized in the boilers per hour......	7,101.724	7,478.333
23. Number of pounds weight of steam that entered the small cylinders per hour......	6,199.064	6,598.833
24. Number of Fahrenheit units of heat imparted to each pound of water vaporized in the boilers, supposing the temperature of the feed water to be 3.9 degrees Fahrenheit less than what is due to the condenser temperature of 72 degrees and to the temperatures of the waters of steam liquefaction drawn from all the jackets of all the cylinders and to the temperature of the water of steam liquefaction drawn from the steam pipe, supposing these waters of steam liquefaction to be used as part of the feed water as they would be in the regular service of the engines	1,117.539	1,120.582
25. Mean number of double strokes made per minute by the pistons of the North Engine......	21.500	22.014
26. Mean number of double strokes made per minute by the pistons of the Middle Engine......	21.244	21.828

	1 Mar., '93.	9 Mar., '93.
27. Mean number of double strokes made per minute by the pistons of both engines..................	21.372	21.920
28. Mean speed of the pistons of both engines in feet per minute..................................	170.975	175.367
29. Steam pressure in the boilers in pounds per square inch above the atmosphere.....................	120.0	120.0
30. Steam pressure in the boilers in pounds per square inch above zero..............................	134.6	134.8
31. Steam pressure in the steam jackets of the small cylinders, in pounds per square inch above the atmosphere..................................	116.0	116.0
32. Steam pressure in the steam jackets of the small cylinders, in pounds per square inch above zero	130.6	130.8
33. Steam pressure in the steam jackets of the intermediate cylinders, in pounds per square inch above the atmosphere..........................	115.0	114.0
34. Steam pressure in the steam jackets of the intermediate cylinders, in pounds per square inch above zero..................................	129.6	128.8
35. Steam pressure in the steam jackets of the large cylinders, in pounds per square inch above the atmosphere..................................	113.0	113.0
36. Steam pressure in the steam jackets of the large cylinders, in pounds per square inch above zero,	127.6	127.8
37. Pressure of the atmosphere in pounds per square inch..................................	14.6	14.8
38. Pressure in the condenser below the atmospheric pressure in pounds per square inch by gauge...	14.0	14.26
39. Pressure in the condenser in pounds per square inch above zero..................................	0.6	0.54
40. Fraction completed of the stroke of the pistons of the small cylinders when the steam was cut off,	0.40	0.425
41. Fraction completed of the stroke of the pistons of the intermediate cylinders when the steam was cut off..................................	0.40	0.44
42. Fraction completed of the stroke of the pistons of the large cylinders when the steam was cut off,	0.55	0.55
43. Fraction completed of the stroke of the pistons of the small cylinders when the steam was released..................................	0.97	0.97
44. Fraction completed of the stroke of the pistons of the intermediate cylinders when the steam was released..................................	0.97	0.97
45. Fraction completed of the stroke of the pistons of the large cylinders when the steam was released,	0.90	0.90

	1 Mar, '93.	9 Mar., '93.
46. Fraction completed of the exhaust stroke of the pistons of the small cylinders when the cushioning of the back pressure began	0.15	0.15
47. Fraction completed of the exhaust stroke of the pistons of the intermediate cylinders when the cushioning of the back pressure began	0.125	0.125
48. Fraction completed of the exhaust stroke of the pistons of the large cylinders when the cushioning of the back pressure began	0.25	0.25
49. Number of times the steam was expanded in the small cylinders	2.341	2.217
50. Number of times the steam was expanded in the engines	19.412	18.385

TEMPERATURES IN DEGREES FAHRENHEIT.

51. Temperature of the steam in the boilers	349.8	349.9
52. Temperature of the steam in the jackets of the small cylinders	347.47	347.59
53. Temperature of the steam in the jackets of the intermediate cylinders	346.88	346.41
54. Temperature of the steam in the jackets of the large cylinders	345.69	345.81
55. Mean temperature of the steam in the small cylinders, including back pressure	......	304.6
56. Mean temperature of the steam in the intermediate cylinders, including back pressure	......	232.1
57. Mean temperature of the steam in the large cylinders, including back pressure	......	155.8
58. Difference between the temperature of the steam in the jackets of the small cylinders, and the mean temperature of the steam in those cylinders	......	45.3
59. Difference between the temperature of the steam in the jackets of the intermediate cylinders, and the mean temperature of the steam in those cylinders	......	117.8
60. Difference between the temperature of the steam in the jackets of the large cylinders, and the mean temperature of the steam in those cylinders	......	194.1
61. Temperature of the feed water entering the "economizer" from the tank	55.	62.3
62. Temperature of the feed water entering the boilers from the "economizer"	151.	131.6
63. Temperature of the water and steam in the condenser	72.	72.

	1 Mar., '93.	9 Mar., '93.
64. Temperature which the feed water entering the "economizer" would have had, had it been supplied from the hot well of the air pump and from all the jackets of all the cylinders, together with the drainage from the steam pipe, and had it suffered no loss of temperature by external radiation of heat during its transits................	106.9	104.3
65. Temperature of the feed water entering the "economizer," from which the total heat of vaporization is calculated, being the temperature on the immediately preceding line less 3.9 degrees allowed for the loss due to external radiation from the feed pipes, etc................	103.0	100.4

HEAT.

66. Number of Fahrenheit units of heat imparted per hour to the feed water vaporized in the boilers,	7,936,455.388	8,380,086.830
67. Number of Fahrenheit units of heat imparted per hour to that portion of the feed water vaporized in the boilers which furnished the steam entering the small cylinders........................	6,927,697.309	7,394,534.830
68. Number of Fahrenheit units of heat externally radiated per hour by the steam in the jackets of the small cylinders........................	55,579.686	55,574.176
69. Number of Fahrenheit units of heat passed per hour from the steam in the jackets of the small cylinders into the steam within those cylinders,	63,776.321	69,178.271
70. Number of Fahrenheit units of heat passed per hour from the steam in the jackets of the small cylinders into the steam within those cylinders, per square foot of jacketed surface................	1,080.955	1,172 513
71. Number of Fahrenheit units of heat externally radiated per hour by the steam in the jackets of the intermediate cylinders................	85,148.580	85,182.466
72. Number of Fahrenheit units of heat passed per hour from the steam in the jackets of the intermediate cylinders into the steam within those cylinders..	194,770.849	176,739.131
73. Number of Fahrenheit units of heat passed per hour from the steam in the jackets of the intermediate cylinders into the steam within those cylinders, per square foot of jacketed surface...	1,913.269	1,736.141
74. Number of Fahrenheit units of heat externally radiated per hour by the steam in the jackets of the large cylinders................................	224,391.369	224,368.790

	1 Mar., '93.	9 Mar., '93.
75. Number of Fahrenheit units of heat passed per hour from the steam in the jackets of the large cylinders into the steam within those cylinders,	129,971.700	126,533 562
76. Number of Fahrenheit units of heat passed per hour from the steam in the jackets of the large cylinders into the steam within those cylinders per square foot of jacketed surface..................	738.475	718.941
77. Number of Fahrenheit units of heat passed per hour from the steam in the jackets of the small cylinders into the steam within those cylinders per square foot of jacketed surface per degree difference of temperature between the temperature of the jacket steam and the mean temperature of the steam within the small cylinders...	......	25 883
78. Number of Fahrenheit units of heat passed per hour from the steam in the jackets of the intermediate cylinders into the steam within those cylinders per square foot of jacketed surface per degree difference of temperature between the temperature of the jacket steam and the mean temperature of the steam within the intermediate cylinders..................................	......	14.733
79. Number of Fahrenheit units of heat passed per hour from the steam in the jackets of the large cylinders into the steam within those cylinders per square foot of jacketed surface per degree difference of temperature between the temperature of the jacket steam and the mean temperature of the steam within the large cylinders...	......	3.704
80. Number of Fahrenheit units of heat lost per hour by the steam in the jackets of the small cylinders..	119.356.007	124,752.447
81. Number of Fahrenheit units of heat lost per hour by the steam in the jackets of the intermediate cylinders..	279,919.428	261,921.597
82. Number of Fahrenheit units of heat lost per hour by the steam in the jackets of the large cylinders..	354,363.069	350,902.352
83. Aggregate number of Fahrenheit units of heat lost per hour by the steam in all the jackets of all the cylinders....................................	753,638.505	737,576.396
84. Number of Fahrenheit units of heat imparted per hour to the feed water vaporized in the boilers,	7,936,455.389	8,380,086.830
85. Fraction which the aggregate number of units of heat lost per hour by the steam in all the jackets of all the cylinders is of the number of units		

	1 Mar., '93.	9 Mar., '93.
of heat imparted per hour to the feed water vaporized in the boilers.	0.095	0.088
86. Aggregate number of Fahrenheit units of heat exteriorly radiated per hour by the steam in all the jackets of all the cylinders	365,119.634	365,125.432
87. Aggregate number of Fahrenheit units of heat passed per hour from the steam in all the jackets of all the cylinders to the steam within those cylinders	388,518.870	372,450.964
88. Fraction which the aggregate number of units of heat exteriorly radiated per hour by the steam in all the jackets of all the cylinders is of the number of units of heat imparted per hour to the feed water vaporized in the boilers	0.046	0.043
89. Fraction which the aggregate number of units of heat passed per hour from the steam in all the jackets of all the cylinders to the steam within those cylinders, is of the number of units of heat imparted per hour to the feed water vaporized in the boilers	0.049	0 044

STEAM PRESSURES IN THE SMALL CYLINDERS.

90. Pressure on the pistons of the small cylinders at the commencement of their stroke, in pounds per square inch above zero	......	128.5
91. Pressure on the pistons of the small cylinders at the point of cutting off the steam, in pounds per square inch above zero	......	119.5
92. Pressure on the pistons of the small cylinders at the end of their stroke, in pounds per square inch above zero	......	56.0
93. Mean back pressure, including cushioning, against the pistons of the small cylinders, in pounds per square inch above zero	......	53.0
94. Mean back pressure, excluding cushioning, against the pistons of the small cylinders, in pounds per square inch above zero	......	52.5
95. Back pressure against the pistons of the small cylinders at the point where the cushioning began, in pounds per square inch above zero	......	43.5
96. Mean indicated pressure on the pistons of the small cylinders, in pounds per square inch	......	45.615
97. Mean net pressure on the pistons of the small cylinders, in pounds per square inch	......	42.615
98. Mean total pressure, exclusive of cushioning, on the pistons of the small cylinders, in pounds per square inch above zero	......	90.240

	1 Mar., '93.	9 Mar., '93.
99. Mean pressure on the pistons of the small cylinders, inclusive of cushioning, previous to the point of cutting off, in pounds per square inch above zero	......	128.129
100. Mean pressure on the pistons of the small cylinders of the expanding steam alone after the closing of the cut-off valve, in pounds per square inch above zero	......	76.800

STEAM PRESSURES IN THE INTERMEDIATE CYLINDERS.

101. Pressure on the pistons of the intermediate cylinders at the commencement of their stroke, in pounds per square inch above zero	......	52.50
102. Pressure of the pistons of the intermediate cylinders at the point of cutting off the steam, in pounds per square inch above zero	......	36.75
103. Pressure on the pistons of the intermediate cylinders at the end of their stroke, in pounds per square inch above zero	......	17.75
104. Mean back pressure, including cushioning, against the pistons of the intermediate cylinders, in pounds per square inch above zero	......	13.985
105. Mean back pressure, excluding cushioning, against the pistons of the intermediate cylinders, in pounds per square inch above zero	......	13.271
106. Back pressure against the pistons of the intermediate cylinders, in pounds per square inch above zero	......	12.500
107. Mean indicated pressure on the pistons of the intermediate cylinders, in pounds per square inch,	......	19.735
108. Mean net pressure on the pistons of the intermediate cylinders, in pounds per square inch	......	18.718
109. Mean total pressure, exclusive of cushioning, on the pistons of the intermediate cylinders, in pounds per square inch above zero	......	31.347
110. Mean pressure on the pistons of the intermediate cylinders, inclusive of cushioning, previous to the point of cutting off, in pounds per square inch above zero	......	45.947
111. Mean pressure on the pistons of the intermediate cylinders subsequent to the point of cutting off, in pounds per square inch above zero	......	24.113
112. Mean pressure, inclusive of cushioning, on the pistons of the intermediate cylinders of the expanding steam throughout their stroke, in pounds per square inch above zero	......	33.720

STEAM PRESSURES IN THE LARGE CYLINDERS.

	1 Mar., '93.	9 Mar., '93.
113. Pressure on the pistons of the large cylinders at the commencement of their stroke, in pounds per square inch above zero	......	13.5
114 Pressure on the pistons of the large cylinders at the point of cutting off the steam, in pounds per square inch above zero	......	9.0
115. Pressure on the pistons of the large cylinders at the end of their stroke, in pounds per square inch above zero	......	5.5
116. Mean back pressure, including cushioning, against the pistons of the large cylinders, in pounds per square inch above zero	......	1.91
117. Mean back pressure, excluding cushioning, against the pistons of the large cylinders, in pounds per square inch above zero	......	1.416
118. Back pressure against the pistons of the large cylinders at the point where the cushioning began, in pounds per square inch above zero	......	1.5
119. Mean indicated pressure on the pistons of the large cylinders, in pounds per square inch	......	7.265
120. Mean net pressure on the pistons of the large cylinders, in pounds per square inch	......	6.906
121. Mean total pressure, exclusive of cushioning, on the pistons of the large cylinders, in pounds per square inch above zero	......	8.327
122. Mean pressure on the pistons of the large cylinders, inclusive of cushioning, previous to the point of cutting off, in pounds per square inch above zero	......	11.453
123. Mean pressure on the pistons of the large cylinders subsequent to the point of cutting off, in pounds per square inch above zero	......	6.39
124. Mean pressure, inclusive of cushioning, on the pistons of the large cylinders of the expanding steam throughout their stroke, in pounds per square inch above zero	......	9.175

EQUIVALENT STEAM PRESSURES FOR THE LARGE CYLINDERS.

125. Indicated pressure, in pounds per square inch, that would be on the pistons of the large cylinders were the indicated pressure on the pistons of the small cylinders divided by the ratio of the net areas of these pistons and the quotient added to the experimental indicated pressure on

	1 Mar., '93.	9 Mar., '93.
the pistons of the large cylinders; and were the indicated pressures on the pistons of the intermediate cylinders divided by the ratio of the net areas of the pistons of the large cylinders to the net area of the pistons of the intermediate cylinders and the quotient also added to the experimental indicated pressure on the pistons of the large cylinders	19.609	19.699
126. Net pressure, in pounds per square inch, that would be on the pistons of the large cylinders were the net pressure on the pistons of the small cylinders divided by the ratio of the net areas of these pistons and the quotient added to the experimental net pressure on the pistons of the large cylinders; and were the net pressure on the pistons of the intermediate cylinders divided by the ratio of the net area of the pistons of the large cylinders to the net area of the pistons of the intermediate cylinders and the quotient also added to the experimental net pressure on the pistons of the large cylinders	18.532	18.622
127. Total pressure, in pounds per square inch above zero, that would be on the pistons of the large cylinders to correspond to the number of total horses-power developed by the engines, supposing the entire net areas of the pistons of the large cylinders to be employed	......	23.511
128. Back pressure, in pounds per square inch above zero, that would be against the pistons of the large cylinders, supposing the entire net areas of the pistons of the large cylinders to be employed	......	3.812
129. Back pressure, in pounds per square inch above zero, that would be against the pistons of the large cylinders, for the portion of the stroke of those pistons previous to the commencement of the cushioning	......	5.082

PUMPS.

130. Pressure, in pounds per square inch per gauge, in the main just outside of the delivery valves of the pumps, including the pressure of the water due to the height between the gauge and the water level in the pump well	41.09	41.98

131. Pressure, in pounds per square inch, on the pistons of the large cylinders, equivalent to the

	1 Mar., '93.	9 Mar., '93.
pressure in the main just outside of the delivery valves of the pumps, supposing the pumps to fill to 0.98 of their capacity..........................	16.796	17.160
132. Net horses-power expended in the pumping of the water, that is to say, exclusive of the power required to open the receiving and delivering valves of the pumps, and to force the water through their openings; and to overcome the surface resistance of the suction main and the resistance of its water deflection; supposing the pumps to fill to 0.98 of their capacity............	442.422	462.564
133. Pressure, in pounds per square inch, on the pistons of the large cylinders equivalent to the pressure required to open the receiving and delivering valves of the pumps and to force the water through their openings, and to overcome the friction of the load due to whatever power may have been transmitted through the fly-wheel mechanism, and to overcome the surface resistance of the suction main and the resistance of its water deflection	1.735	1.462
134. The efficiency of the entire mechanism from the steam pistons of the engines, as mechanism, the maximum being unity, as shown by the fraction which the net horses-power expended in the pumping of the water, is of the indicated horses-power developed by the engines.................	0.856	0.869
135. Fraction of the indicated horses-power developed by the engines, expended in working the engines, *per se*, or unloaded, in overcoming the friction of the load passed through the fly-wheel mechanism, in opening the receiving and delivering valves of the pumps and in forcing the water through the openings of the valves, and in overcoming the surface resistance of the suction main; supposing the pumps to fill to 0.98 of their capacity..................................	0.143	0.131

HORSES-POWER.

136. Indicated horses-power developed in the small cylinders....................................	......	147.548
137. Net horses-power developed in the small cylinders,	......	137.844
138. Total horses-power developed in the small cylinders, excluding overcoming the cushioning.....	......	291.894
139. Total horses-power developed in the small cylinders by the expanding steam alone................	......	142.841

	1 Mar., '93.	9 Mar., '93.
140. Indicated horses-power developed in the intermediate cylinders	......	188.377
141. Net horses-power developed in the intermediate cylinders	......	178.669
142. Total horses-power developed in the intermediate cylinders by the annular surface of their pistons remaining after deducting from the area of those pistons the area of the pistons of the small cylinders, excluding overcoming the cushioning	......	197.821
143. Total horses-power developed in the intermediate cylinders by the expanding steam acting upon the annular surface of their pistons remaining after deducting from the area of those pistons the area of the pistons of the small cylinders, including overcoming the cushioning	......	212.796
144. Indicated horses-power developed in the large cylinders	......	196.275
145. Net horses-power developed in the large cylinders	......	186.576
146. Total horses-power developed in the large cylinders by the annular surface of their pistons remaining after deducting from the area of those pistons the area of the pistons of the intermediate cylinders, excluding overcoming the cushioning	......	145.483
147. Total horses-power developed in the large cylinders by the expanding steam acting upon the annular surface of their pistons remaining after deducting from the area of those pistons the area of the pistons of the intermediate cylinders, including overcoming the cushioning	......	160.298
148. Aggregate indicated horses-power developed by the engines	516.501	532.200
149. Aggregate net horses-power developed by the engine	488.133	503.089
150. Aggregate total horses-power developed by the engines, excluding overcoming the cushioning,	......	635.197
151. Aggregate total horses-power developed by the expanding steam, including overcoming the cushioning	......	515.936
152. Aggregate horses-power consumed in working the engines, *per se*, or unloaded	28.368	29.110
153. Aggregate horses-power consumed in overcoming the resistances of all the valves of all the pumps to opening, the resistances of the water to being driven through the openings of these valves,		

	1 Mar., '93.	9 Mar., '93.
and the resistances of the frictions of the load upon the mechanism of the fly-wheel system....	36.682	40.525
154. Aggregate horses-power consumed in overcoming the back pressure against the steam pistons of the engines, excluding overcoming the cushionings..	......	102.997

ECONOMIC RESULTS.

155. Pounds of feed water consumed per hour per indicated horse-power developed by the engines,	13.749	14.052
156. Pounds of feed water consumed per hour per net horse-power developed by the engines..........	14.549	14.865
157. Pounds of feed water consumed per hour per total horse-power developed by the engines...	......	11.773
158. Pounds of feed water consumed per hour per horse-power employed in pumping the net water..	15.731	15.865
159. Fahrenheit units of heat consumed per hour per indicated horse-power developed by the engines..	15,365.794	15,746.127
160. Fahrenheit units of heat consumed per hour per net horse-power developed by the engines......	16,258.788	16,657.250
161. Fahrenheit units of heat consumed per hour per total horse-power developed by the engine.....	......	13,192.888
162. Fahrenheit units of heat consumed per hour per horse-power employed in pumping the net water..	17,579.890	17,754.246
163. Fraction of the total *vis viva* in the steam transmuted into the work of the indicated horses-power..	0.163	0.159
164. Fraction of the total *vis viva* in the steam transmuted into the work of the net horses-power...	0.154	0.151
165. Fraction of the total *vis viva* in the steam transmuted into the work of the total horses-power..	......	0.190
166. Fraction of the total *vis viva* in the steam transmuted into the work of the horses-power employed in pumping the net water................	0.143	0.141

WEIGHT OF STEAM PRESENT IN THE CYLINDERS, PER INDICATOR.

167. Pounds weight of steam per hour in the small cylinders at the point of cutting off the steam......	......	4,860.881
168. Pounds weight of steam per hour in the small cylinders at the end of the stroke of their pistons,	......	5,376.103
169. Pounds weight of steam per hour liquefied in the small cylinders to furnish the heat transmuted		

	1 Mar., '93.	9 Mar., '93.
into the power developed in those cylinders by the expanding steam alone	......	399.780
170. Sum of the two immediately preceding quantities,	......	5,775.883
171. Pounds weight of steam per hour in the intermediate cylinders at the end of the stroke of their pistons	......	5,558.162
172. Pounds weight of steam per hour liquefied in the intermediate and in the small cylinders to furnish the heat transmuted into the power developed in these cylinders by the expanding steam alone	......	963.371
173. Sum of the two immediately preceding quantities,	......	6,521.532
174. Pounds weight of steam per hour in the large cylinders at the end of the stroke of their pistons,	......	5,392 668
175. Pounds weight of steam per hour liquefied in the large, intermediate and small cylinders to furnish the heat transmuted into the power developed in these cylinders by the expanding steam alone	......	1,368.193
176. Sum of the two immediately preceding quantities,	......	6,760.861

DIFFERENCES BETWEEN THE WEIGHT OF STEAM ENTERING THE SMALL CYLINDERS AND THE WEIGHTS OF STEAM ACCOUNTED FOR IN THOSE AND THEIR SUCCEEDING CYLINDERS BY THE INDICATOR.

177. Difference in pounds between the weight of steam entering the small cylinders per hour and the weight of steam accounted for per hour in those cylinders by the indicator at the point of cutting off	......	1,737.952
178. Difference in fractions of the weight of steam entering the small cylinders per hour, between that weight and the weight of steam accounted for per hour by the indicator in the small cylinders at the point of cutting off	......	0.263
179. Difference in pounds between the weight of steam entering the small cylinders per hour and the weight of steam accounted for per hour in those cylinders by the indicator at the end of the stroke of their pistons	......	822 950
180. Difference in fractions of the weight of steam entering the small cylinders per hour, between that weight and the weight of steam accounted for per hour by the indicator in the small cylinders at the end of the stroke of their pistons,	......	0.125

	1 Mar., '93.	9 Mar., '93.
181. Difference in pounds between the weight of steam entering the small cylinders per hour and the weight of steam accounted for per hour in the intermediate cylinders by the indicator at the end of the stroke of their pistons..................	......	77.301
182. Difference in fractions of the weight of steam entering the small cylinders per hour, between that weight and the weight of steam accounted for per hour by the indicator in the intermediate cylinders at the end of the stroke of their pistons,	......	0.012
183. Difference in pounds between the weight of steam entering the small cylinders per hour and the weight of steam accounted for per hour in the large cylinders by the indicator at the end of the stroke of their pistons (superheated)..........	......	+162.028
184. Difference in fractions of the weight of steam entering the small cylinders per hour, between that weight and the weight of steam accounted for per hour by the indicator in the large cylinders at the end of the stroke of their pistons (superheated)..	......	+0.024

LAWS OF SIMILITUDE REGARDING QUESTIONS OF NAVAL CONSTRUCTION.

By Mr. J. A. Normand.

[Translation of a Paper read before L'Association Technique Maritime.]

The theory of similitude, as now established, would doubtless suffice for the solution of the problems investigated in this Note; but would the rules thus determined give the necessary degree of accuracy? I prefer to treat these questions in a manner which is unquestionably less elegant, but in one which leaves no room for doubt as to the results.

SIMILITUDE IN STEAM ENGINES.

When the plans of engines working at a fixed pressure have been drawn to a certain scale, can they be applied on a different scale and give the same assurance of good working?

Let us first examine the statical strains, assuming that the weight of the parts may be neglected in comparison with the strains produced by the steam.

Friction.—The pressures on the moving and rubbing surfaces varying as the square of the linear dimensions, the load per unit of surface will not change.

Resistance of Parts.—For the same reason, the parts which are in compression and tension support the same load per unit of section, whatever the scale may be.

For those which are subjected to bending, the load R per unit of section is:

$$R = \frac{PLd}{I},$$

in which

P is the load,

L the length of the arm,

d the distance of the fiber furthest from the neutral axis,

I the moment of inertia.

P is proportional to the square of the linear dimensions, L and d to the first power only, and I to the fourth; R is therefore independent of the scale.

The same is true of the strains of torsion.

For cylindrical shapes subjected to uniform internal or external pressures, the material is equally loaded when the thickness varies with the linear dimensions. This rule may also be extended to volumes of any form.

So also, in all that concerns statical loads, the material is subject to identical strains per unit of section, and, if the strength is independent of the dimensions, the conditions of safety remain the same, whatever the scale.

Let us now consider the strains due to the inertia of the moving parts. It is hardly necessary to state that what follows does not apply to slow running engines, such as those for paddle wheels.

As these strains do not vary with the scale, it is evident that, like the statical ones, they should be proportional to the square of the linear dimensions.

It will suffice to consider the principal inertia strains, such as those of the pistons and their accessories.

Let F = strain in pounds due to inertia,
P = weight in pounds of the moving parts,
C = stroke of pistons in feet,
N = number of revolutions per second,
φ = angle which the crank makes with the axis of the cylinder produced,
m = ratio of connecting rod to crank.

Then

$$F = -6.59\, PCn^2 \left(\cos.\ \varphi + \frac{1}{m}\cos.\ 2\,\varphi\right).$$

P varying as the cube, and C as the first power of the linear dimensions, in order that F may be proportional to the square, the number of revolutions n must be inversely proportional to those dimensions.

Other things remaining the same, the ordinary rule on which we compute the value of the inertia on the basis of the linear velocity of the piston is therefore correct.

Strains set up in the vessel when in motion due to the inertia of the fixed and moving masses of the engine.—From this point of view, the law of similitude is faulty, and account must be taken of the rapidity and the amplitude of the vibrations of the parts whose resistance is brought into play.

Here one remark is necessary. Some powerful engines set up in very light hulls can not work satisfactorily without being tied to the hull at several points. Such ties are indispensable, not only on account of the weakness of the bed plate, but also on account of the insufficient bracing of the upper parts of the engine to the foundation. As a matter of fact, the hull adds to the solidity of the engine. Without special arrangements, this plan would be inadmissible in very large hulls, on account of the excessive strains which would be brought upon the engine. The dimensions of engines of this kind could not, therefore, be increased indefinitely.

I have built engines on this plan, but those of my latest torpedo boats, although tied to the hull at several points, are tied there for a different purpose. Although of the same appearance, they present greater stiffness than the hull, whose close tying to the engine reduces the vibration, and if fastened solely upon a sufficiently solid bed-plate, they would work under the same conditions as on board ship. The rules given hereafter are then applicable with the following restrictions:

If we consider that angles of roll of 40 to 45 degrees have been observed, sometimes coincident, as in some foreign battleships, with a relatively short period of oscillation, it seems that it would be well to give vertical engines, tied to the hull only by the bed-plate, a resistance against strains of this kind, such that the engine may be set up in the shop, with the axes of the cylinders horizontal, without strain or appreciable bending. In this position, the load per unit of section, on the foundations, is proportional to the linear dimensions. Therefore, the parts subjected to those particular strains should increase with the size more quickly than the scale indicates. Furthermore, the weight of the engine increases a little more rapidly than the cube of the linear dimensions.

Passages under pressure.—The sections of the steam passages varying as the square, and the volume as the cube, it is necessary, just as in the case of the inertia strains of the moving parts, that the number of revolutions be inversely proportional to the linear dimensions, in order that the steam passages may be independent of the scale of the drawing.

To sum up, and with the limitations above specified, a *drawing of an engine working at a fixed pressure may be used on any scale, without the load on the material and the rubbing surfaces or the steam passages being modified, provided the number of revolutions be made inversely proportional to the linear dimensions.*

The power of the engines, under the same conditions as regards inertia strains, is then proportional to the square of the linear dimensions, and its weight per I.H.P. to the linear dimensions.

It must be remembered that by engine is meant the cylinders and the parts depending upon them: shafts, bed-plates, connecting rods, etc., but not the condensers and boilers.

I have frequently built engines of different sizes from the same drawings by simply changing the scale and figures. A great saving of time and labor is thus effected. Thus, the engines of the Russian torpedo boats *Revel* and *Sveaborg*, built in 1885, are like those of the *Balny* type, the scale having been increased in the ratio of 1.19; and in 1891 the drawings of the engines of the first class torpedo boats, type 147, were used for building those of the twin screw torpedo boats of the *Lancier* type and of the steamer *Augustin Normand*, the scale having been reduced to .9 in the first case, and to .81 in the second.

Metallurgical industry has made such rapid progress in the manufacture of large pieces of cast and forged steel that I should not hesitate to use these last plans in the construction of much larger engines, as high as 3,000 to 4,000 I.H.P., after having introduced in them the improvements which experience has shown to be useful, and keeping in mind also the special strains due to the motion of the ship at sea.

The following table gives the laws of similitude as applied to engines and hulls, the efficiency being assumed to be constant. It is clear that the similitude of hulls should not hold when the absolute size and speed vary; the expressions containing the speed *V*, and the displacement *D*, are, therefore, simply approximate. In fine, the proportions of the screws sometimes make it necessary to modify the number of revolutions. So the table has two columns: in the first, the number of revolutions is supposed to be independent; in the second, it is supposed to have a maximum value—that is, such that the engine remains always in the same condition relative to the moments of inertia. The values of the first column only are of general application.

		Proportional values, the number of revolutions being	
		Independent of the linear dimensions of the engine.	Maximum—that is, such that the ratio of the inertia strains to the statical strains shall be constant.
Power, ...	F	$n\lambda^3$ $V^3D^{\frac{2}{3}}$	λ^2
Linear dimensions of engine, . . .	λ	$\left(\frac{F}{n}\right)^{\frac{1}{3}}$ $\frac{VD^{\frac{2}{9}}}{n^{\frac{1}{3}}}$	$F^{\frac{1}{2}}$ $V^{\frac{3}{2}}D^{\frac{1}{3}}$
Number of revolutions, ...	n	$\frac{F}{\lambda^3}$ $\frac{V^3D^{\frac{2}{3}}}{\lambda^3}$	$\frac{1}{\lambda}$ $\frac{1}{F^{\frac{1}{2}}}$ $\frac{1}{V^{\frac{3}{2}}D^{\frac{1}{3}}}$
Speed of ship, ...	V	$\left(\frac{F}{D^{\frac{2}{3}}}\right)^{\frac{1}{3}}$ $\lambda\left(\frac{n}{D^{\frac{2}{3}}}\right)^{\frac{1}{3}}$	$\left(\frac{\lambda}{D^{\frac{1}{3}}}\right)^{\frac{2}{3}}$
Displacement, ...	D	$\left(\frac{F}{V^3}\right)^{\frac{3}{2}}$ $\left(\frac{n\lambda^3}{V^3}\right)^{\frac{3}{2}}$	$\left(\frac{\lambda}{V^{\frac{3}{2}}}\right)^3$

	Proportional values, the number of revolutions being Independent of the linear dimensions of the engine.	Proportional values, the number of revolutions being Maximum—that is, such that the ratio of the inertia strains to the statical strains shall be constant.
Weight of engine proper* without condenser	λ^3 $\frac{F}{n}$ $\frac{V^3 D^{2/3}}{n}$	$F^{3/2}$ $V^{9/2} D$
Weight per I.H.P. of engine proper* without condenser, ...	$\frac{1}{n}$ $\frac{F}{n^2 \lambda^3}$	λ $F^{1/2}$ $V^{3/2} D^{1/3}$
Ratio of linear dimensions of the engine to those of the hull, . . .	$\frac{\lambda}{D^{1/3}}$ $\left(\frac{F}{nD}\right)^{1/3}$	$V^{3/2}$ $\left(\frac{F}{D^{2/3}}\right)^{1/2}$

*On account of the strains due to the motion of the ship, and the reduction of the strength of parts of large dimensions, the absolute weight and the weight per I.H.P. should generally vary a little more rapidly than shown.

This table will be useful in getting out rough drafts when we have satisfactory types of engines and hulls, and as similar as possible to that which we have in view. In fact, it allows of the approximate determination of the principal elements, the others being assumed beforehand.

Suppose, for example, that we want to design a cruiser having a certain power and speed, and that the screws will permit us to use the maximum number of revolutions consistent with the moments of inertia: these are the most favorable conditions as regards weight and complication.

The table shows that the linear scale of the engines is proportional to $F^{1/2}$. The height of the engines is thus known from the types selected, and we have at once the lowest position that can be given to the armored deck to admit vertical engines, and what the dimensions and the height of the engines should be. The table further gives the weight of the engine proper as proportional to $F^{3/2}$, and the displacement proportional to $\left(\frac{F}{V^3}\right)^{3/2}$

If the displacement and speed were given, we would find the scale of the engine proportional to $D^{\frac{1}{3}} V^{\frac{3}{2}}$, the power proportional to $V^3 D^{\frac{2}{3}}$, and the weight of the engine proper to $V^{\frac{9}{2}} D$.

But before definitely deciding anything, it is always well to see whether the number of revolutions is suitable for good proportions of screws.

It would be interesting to calculate the coefficients of the several proportional values in the table for the most recent types, and for those which are considered the best.

The ratio of the linear dimensions of the engine to those of the hull is proportional to the $\frac{3}{2}$ power of the speed, and is independent of the absolute size.

Suppose we have a section of a ship of the cruiser type, in which the engine is shown, and let us assume that it is desired to increase the speed from 20 to 22 knots. Whatever the scale of the drawing, or even the displacement, which might be anywhere from 4,000 to 6,000 tons, the linear dimensions of the engine relative to those of the hull should be increased in the ratio of $\left(\frac{22}{20}\right)^{\frac{3}{2}} = 1.152$.

It can at once be seen whether the solution of the problem is possible without greatly modifying the arrangement of the engines, the protection of the hull, or the form of the bottom.

Moreover, it must not be forgotten that the ratio of the length of the engines and boilers to that of the hull increases in the same proportion; the engines will, therefore, extend further toward the fined portions of the bottom, which will increase the difficulty of getting them in, unless the boiler system is divided into two groups, one forward and the other abaft the engines.

It will be seen from the table that, while the weight of the boilers and condensers varies simply as the power F, that of the engine proper varies at least as $F^{\frac{3}{2}}$. In fact, the former weights should increase a little more rapidly than the power, the difficulties in feeding increasing with a number of boilers; and the second weights a little more rapidly than $F^{\frac{3}{2}}$, because the strength of materials decrease slightly as the size is increased, and because the parts subjected to strains which are the result of the vibration of the ship should increase more rapidly than the scale. The expression for the weight of the motive apparatus is, therefore, at least of the form :

$$aF + bF^{\frac{3}{2}}.$$

The second term being much larger than the first in large engines, it can be readily seen how much the proportion of weight to power, which we frequently use within wide ranges, varies from the truth.

Thus, in my "Note upon the Variation in the Scantlings of Ships," read here two years ago, I fell into this error. I stated that the weight of the motive apparatus complete, in the equation for the displacement, was, like the power, proportional to $L^2 V^3$, L being the linear dimension of the hull and V the speed.

The true expression should have been of the form :

$$aL^2V^3 + bL^3V^{\frac{9}{2}}.$$

The importance of the weights varying as the cube of the dimensions of the hull being greater, it would have then been found that the advantage of absolute size from a speed point of view is less, and that, on account of the weights of the framing, which should vary partly as the 4th power of the dimensions, the displacement corresponding to the maximum speed is less than I supposed it. The opinion which I expressed upon the futility of indefinitely increasing the dimensions of large steamers in order to increase their speed alone, aside from any commercial consideration, is therefore strengthened.

We have seen that the ratio of the linear dimensions of the engine to those of the hull is simply proportional to $V^{\frac{3}{2}}$; that is, that it is independent of the absolute dimensions, and that it increases rapidly with the speed.

Now, while in large, fast, twin-screw steamers, the engines reach as high as the spar deck, the vertical engines of many cruisers of equal and even greater speed have to be placed below an armored deck, placed at the height of the water line; and even if the engines of the former, like those of the latter, should be lowered as much as the shape of the hull permits, the disproportion in height of the engines would still be excessive. In the mail steamers, with triple expansion engines, the stroke is sometimes equal to the diameter of the intermediate cylinder; in cruisers, it is always very much less than the diameter of the high pressure. Ought we then to be astonished when engineers, whose commercial engines work for six, eight and even twenty days without stopping, consider themselves fortunate when they have successfully finished a full speed trial of a few hours' duration in a naval vessel?

The stroke is really the most useful linear dimension for good running and for an increase of mechanical duty, and it is almost impossible to give it sufficient value with the system of protection generally adopted, whatever means are employed. One consists in dividing the power between two engines placed in line with each other on the same shaft. Theoretically, the height is reduced in the proportion of $\sqrt{2}$ to 1; but on account of the fining of the hull, and sometimes also on account of the inclination of the shaft, the lengthening of the engines reduces, in a great degree, the apparent advantage. This arrangement carries with it, besides, the great disadvantage of doubling the number of parts, and consequently the chance of accident—an accident to one part involving the stopping of the entire apparatus. The arrangement is in no sense to be compared with two independent engines.

The reduction of the dimensions in the ratio of $\sqrt{2}$ to 1 presupposes that the engine is in the same condition as regards the forces of inertia; that is, that the number of revolutions is increased in the inverse ratio of the dimensions. If, on the contrary, the number of revolutions remains the same as with a single engine, either for the purpose of improving the running, or because the proportions of the screws demand it, the reduction of the dimensions would be only in the ratio of $\sqrt[3]{2}$ to 1.

The other method consists in returning to horizontal or slightly inclined engines, notwithstanding the serious disadvantages which accompany them, and the fact that this arrangement does not give suitable proportions of engines when the speed required is very high.

The engineer to whom we have denied sufficient height, while waiting for the time when he will be able to use higher pressures than he can now, finds himself fatally led to adopt a stroke that is too short, too great a number of revolutions, or to double the number of separate engines on the same shaft: three factors which increase the chances of wear and accident to engines. Space is as necessary for horse power as for horses themselves; it is as indispensable for the endurance of the personnel as for the incessant surveillance of the machinery. But the contest for speed is ever on. The continual reduction of weight of boilers, and progress in the economical return from engines, lead to the reduction of weights, which all navies are tempted to make use of in order to increase speed. The protective deck near the water line, which yesterday was an annoyance, to-morrow will become an absolutely insurmountable obstacle. Evidently we must get rid of it; it can be done without regret.

Is it well to always economize in weight in order to get an increase of maximum speed? At the present speeds, if we gave vertical engines the proportions that they should have, they would come way above the water line. The armor, especially that on the sides, is indispensable, not only for the protection of the motive machinery, but, what is much more important, to insure the floatability and the stability of the ship, and would absorb the greater part of the saving in weight; and the importance of this armor would increase very rapidly with the dimensions of the engines, that is to say, with the maximum speed. If any weight is left at the disposition of the architect, should it not rather be utilized in increasing not the maximum speed, but that which the ship can maintain in heavy weather?

An increased weight of hull would undoubtedly result therefrom because this result could not be obtained solely by forming the stern lines properly, immersing the screws so as to keep them always submerged, and in so arranging the top sides that no dangerous mass of water can be retained there. The scantlings of the frame and deck erections must also be generally increased.

The reduction of the fineness, a consequence of the reduction of maximum speed, would furnish an augment of displacement of quite 3 per cent. per knot. The ship could then get through any sea without distress, just as the mail steamers, which the war ship is destined to capture whatever the condition of the sea may be, now do, and the state of the sea does not increase their time of voyage more than a few hours during the worst weather.

If the power is not increased, the arrangement of the engines should be less complicated, and it would then be possible to give them proportions consistent with good working.

ON THE SIMILITUDE IN THE TRIALS OF MODELS AND OF SHIPS.

Reech first, and Froude afterwards, showed that, as regards the direct resistance, and more especially as regards the formation of waves, the "corresponding speeds" of the model and the similar ship are proportional to the square root of the linear dimensions."*

It is interesting to see whether this law holds as regards lifting, or the reduction of displacement which seems to accompany very high speeds, and also for the phenomena attending the rupture of the column of water put in motion by the propellers, upon which I addressed the Association a year ago.

Lifting.—In every ship in motion, there is a vertical component of the direct resistance, which tends to raise the bow and to lower the stern. The forward component increases indefinitely with the speed, while the after one tends towards a finite limit, which is reached when a complete vacuum is obtained in this part. At very high speed, the former is greater and causes lifting.

The richochet of projectiles is the most familiar demonstration of this phenomenon.

Does this effect manifest itself at high speed in light vessels, such as torpedo boats? It is probable, although the increased efficiency may be due to other causes.

If it does manifest itself, it is clear that the like points of the phenomonon are those in which the ratio of the direct resistance to the displacement is the same in the model and in the ship, for the direction of the resisting forces cannot be different in the model from that in the ship. The following table shows that it

* In 1870 I extended this law to variations in coefficient of fineness.

is so when the speeds are proportional to the square root of the linear dimensions:

	Model.	*Ship.*
Linear dimension, ...	1	Λ
Resisting surface, ...	1	Λ^2
Displacement, ...	1	Λ^3
Speed, ...	1	$\Lambda^{\frac{1}{2}}$
Direct resistance, ...	1	$\Lambda^2(\Lambda^{\frac{1}{2}})^2=\Lambda^3$
Ratio of direct resistance to the displacement, ...	1	1

Therefore, *if the speeds of the model and of the ship are increased indefinitely*, their displacement will be reduced by the same fraction at speeds which are proportional to the square root of the linear dimensions.

In the trials made at Brest, the greatest speeds obtained scarcely exceed the half of that at which the phenomenon would have clearly manifested itself, or, what amounts to the same thing, the linear dimensions of the models are three or four times too great.

RUPTURE OF THE COLUMN OF WATER SET IN MOTION BY THE PROPELLERS.

Let us begin by establishing the fact that the slip appropriate to the speed is the same when the latter is proportional to the square root of the linear dimensions.

	Model.	*Ship.*
Linear dimensions, ...	1	Λ
Propulsive surface in square feet, . .	A	$\Lambda^2 A$
Resisting surface in square feet, . .	S	$\Lambda^2 S$
Speed in feet per second, . . .	V	$\Lambda^{\frac{1}{2}} V$
Speed of water acted upon in feet per second, ...	V^1	$\Lambda^{\frac{1}{2}} V^1$

If we designate by R the resistance in pounds per square foot of resisting surface, which is the same in each case, the resistance of the model in pounds, assuming no "cavitation," is

$$RSV^2 = \frac{43.3\,AV^1}{g}(V^1 - V),$$

and that of the ship

$$R\Lambda^2 S\Lambda V^2 = \frac{43.3\,\Lambda^2 A\Lambda^{\frac{1}{2}} V^1}{g}(\Lambda^{\frac{1}{2}} V^1 - \Lambda^{\frac{1}{2}} V).$$

The two equations are identical, which proves the correctness of the proposition. Therefore, the speed of the slip of the water is, like the speed of the ship, proportional to the square root of the linear dimensions.

Now, the rupture of the column of water is produced when the speed of replacement, which varies as the square root of the height of the point considered below the water line (linear dimension), becomes less than the speed of the ship.

Therefore, for every similar point of the screws, the rupture takes place in the model and in the ship at speeds which are proportional to the square root of the linear dimensions.

The theory of similitude is thus extended to the two phenomena of lifting and of rupture of the column of water propelled. The augmentation of resistance due to the sucking of the screws, and the longitudinal inclination due to the speed, also follow the same law.

It is, therefore, probable that, in general, it is safe to admit complete similitude, except as regards friction.

The propellers have such an influence upon the resistance, and their dynamic effects are so important for efficiency, that, if a more complete study should confirm this opinion, it would probably be necessary to replace traction trials of models by propulsive trials. The latter would give results that could be immediately applied, which is far from the case now.

While waiting until we can transmit an exactly measurable electric power, capable men, of whom there are many, will certainly construct sufficiently powerful and light mechanical motors which will give a series of couples of uniform constant rotation. The course need be only long enough for the determination of the speed of the model after it has obtained a uniform rate. An initial impulse would greatly reduce the time necessary for reaching a uniform speed, and consequently the length of the course. We might, perhaps, be able thus to more easily elucidate the phenomena which are present at extreme speeds.

The expense of such trials would probably be less than those of towing, as a permanent outfit would be unnecessary.

THE DETERMINATION OF THE DRYNESS OF STEAM.

By Professor W. Cawthorne Unwin, F. R. S.

[Paper read before the Institution of Mechanical Engineers.]

Every engineer who has to do with the manufacture or use of steam machinery will know that a large amount of experimental research has been carried out during the last ten or fifteen years, on the action of steam in the engine, and on the causes of waste of energy in the production and application of steam power. The testing of boilers and engines with a view to determine their comparative economy has come to be a matter of considerable practical and commercial importance. Not only are boilers and engines contracted for under stringent guarantees as to the amount of coal and steam they will use, but the results of trials are published in a kind of open competition ; and there is a tendency to record-breaking in engine tests, as well as in trials of a more sporting kind. For commercial reasons, therefore, as well as for scientific reasons, it is important that the observations taken in an engine or boiler trial should be complete and accurate, and that the instruments used should be of the most satisfactory and trustworthy character.

In such trials there has been one important observation which has hitherto been difficult, and which has been made by methods of doubtful trustworthiness. The dryness of the steam is a quantity which, in either a boiler trial or an engine trial, it is important to determine. If a boiler produces wet steam, it is credited with greater evaporative efficiency than it deserves, if the amount of unevaporated water is not ascertained. If an engine is supplied with wet steam, its thermal efficiency will be diminished, and it will be undeservedly discredited unless the quality of the steam is known. It has long been understood that it is desirable in both boiler trials and engine trials to determine the quality of the steam; but the methods for measuring the amount of moisture in steam were troublesome to carry out, and when used they gave results which were more or less discordant and doubtful. It occurred to the author to suggest at the Edinburgh meeting of the British Association that a committee should be constituted to examine the various methods of determining the dryness of steam. A committee was formed with Sir Frederick Bramwell, Bart., as chairman; and a report was presented at last year's Oxford meeting. The present paper contains some account of the methods described in that report, and of the conclusions arrived at in trials of different methods.

The earliest attempts to determine the amount of moisture in steam, of which records have been found, were made during some boiler trials carried out by a committee of the Société Industrielle of Mulhouse, in 1859. This committee tried three different methods—a method of separation, a condensing method suggested by Hirn, and a chemical method. In these early trials the condensing method only, in which the total heat of a sample of the steam was measured, appeared to give satisfactory results. But although the committee did not place full reliance on any of their methods, these have all been used by various experimenters down to the present time.

Origin of the Water Suspended or Entrained in Steam.—The water found in a sample of steam may have come there in one of three ways.

1. Water projected into the steam space during ebullition may be carried forward in the current of steam. The extent to which wetness is thus produced depends on the activity of the ebullition, the area of the water surface, the volume of the steam space, the position of the steam valve, the density of the steam, and, probably more than anything else, on the quality of the water and its liability to produce foam. Mr. Thornycroft has made some instructive observations on the priming produced when water foams. He constructed a boiler with glass ends, through which the process of boiling could be seen. As the result of observations on this boiler he states that waters which

cause priming produce foam on boiling. Water which is very bad produces bubbles so durable as to remain a considerable time without breaking; and by them the steam space of a boiler may be entirely filled. So soon as this takes place, instead of simply steam leaving the boiler, the discharge consists of foam, which becomes broken up in its rapid passage through the steam pipe. With pure water, steam retains no film of liquid long enough to be seen.

2. Water may be produced in steam from the expansions to which it is subjected. Fluctuations of pressure arise from the intermittent demand for steam, and from the steam passing from places of higher to places of lower pressure. But it is difficult to believe that any great amount of wetness arises in this way in ordinary cases.

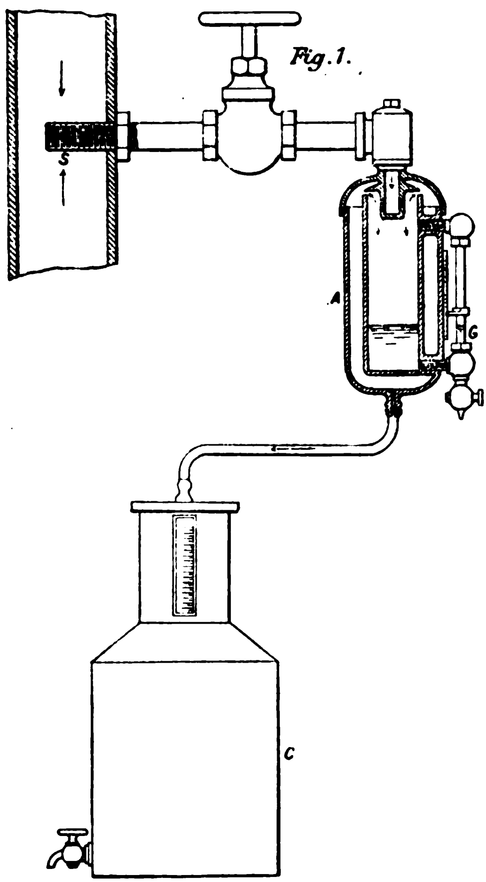
3. The steam in the steam space of the boiler, and when flowing through the steam pipes, loses heat by radiation from the boiler roof and the surfaces of the pipes, and there is consequently a condensation of part of the steam. Probably in some cases considerable wetness is produced in this way. In the case of any individual steam plant, the absolute amount of moisture produced by radiation in a given time will be constant and independent of the demand for steam. The wetness of the steam, therefore, so far as it is due to this cause, will increase as the demand for steam diminishes.

METHODS OF DETERMINING THE WETNESS OF STEAM.

1. *Weighing Method.*—The density of saturated or very approximately saturated steam, of the quality of that in Regnault's total heat experiments, can be directly determined on thermodynamic principles, and the result is confirmed by Fairbairn's experiments. Hence, if a known volume of steam is weighed, any excess of weight above that of a corresponding volume of dry saturated steam must be due to the water present. A method of direct weighing has been proposed by Guzzi ("Revue Industrielle," 1878, page 102), and by Knight ("Journal of the Franklin Institute," 1877, page 358). The method is obviously one of excessive difficulty.

2. *Separating Method.*—It is common to separate in a steam separator a great part of the water entrained in steam. In ordinary steam separators, however, the volume passing through is very large compared with the capacity of the separator, and the action is no doubt imperfect. In a separator dealing with only a small fraction of the steam, more perfect separation might be expected. Mr. G. A. Barrus, using a small separator in connection with a superheating calorimeter, noticed that nearly all the entrained water was trapped, and that the steam passing into the superheating vessel was nearly dry. More recently, Professor Carpenter, of Cornell University, has introduced a form of separating calorimeter of small size, which appears to give highly consistent and trustworthy results, and can be used with great facility. It consists of a vessel *A*, Fig. 1, about 12 inches high by 5 inches in diameter, consisting of an inner chamber and a jacket. The steam from the steam pipe *S* passes first into the inner chamber, where the moisture is separated, and then into the outer chamber. The separating chamber is therefore perfectly protected from radiation. As the water accumulates in the inner chamber its level is shown by a gauge glass *G*, and the amount in hundredths of a pound can be read off on a scale. A very small orifice at the bottom of the outer chamber regulates the amount of steam discharged. The escaping steam passes through a flexible tube to a simple form of condenser *C*. The increase of weight in any given time in the condenser is noted, and the amount accumulated in the same time in the separator. If x is the dryness fraction of the steam, w the weight of water caught in the separator, and W the weight of steam condensed, then $x = W \div (W + w)$. There is a gauge glass and scale on the condenser, graduated to read pounds and tenths at a temperature of 110 degrees Fahrenheit. But as the variation of volume in the condenser with temperature affects the readings considerably, it is best to place the condenser on a platform weighing machine. Professor Carpenter states that the dryness of the steam after passing the separator was tested in the laboratories at Sibley College by several observers, and with steam carrying from ¼ per cent. to 60 per cent. of moisture. In every case the separation

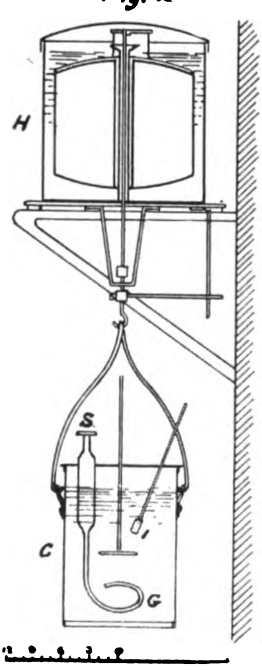
of the water from the steam was complete and perfect. Other tests have been made with moderately dry steam, using the throttling and separating calorimeters simultaneously, and the results were practically identical. The instrument is very simple to use, and requires no pressure gauge or thermometers.



3. *Condensing Method.*—Suppose a known weight of the steam to be condensed, and its total heat to be determined by the rise of temperature of the condensing water. By comparing the total heat per pound of a sample of steam with that of a pound of dry

saturated steam according to Regnault's tables, the amount of moisture in the steam can be determined. This method was first suggested by Hirn, and the apparatus which he designed for use in the Mulhouse Boiler Trials of 1859 is, perhaps, the most convenient form of apparatus for determinations by this method. It consists of an iron vessel *C*, Fig. 2, about 1 foot in diameter, furnished with a loose cover; this forms the condenser. A small pipe and cock in the steam pipe deliver steam through a small orifice near the steam pipe into the pipe *S*, through which it passes into the condensing water. An agitator *G* and a sensitive thermometer *I* are provided in the condenser. For weighing the amount of steam condensed, the whole condenser is suspended from a hydrostat *H*, which permits extremely accurate determination of any change of weight. The hydrostat is balanced by weights till the pointer is at a fixed mark before and after condensing the steam.

Fig. 2



Let x be the dryness fraction of the steam, w the increase of weight of the condenser during the test. Then the condenser has received xw pounds of dry steam, and $(1-x)\,w$ pounds of water at the steam temperature. Let W be the weight of water initially in the condenser, plus the equivalent of the condenser itself reckoned as water. Let t be the temperature of the steam, and i and f the initial and final temperatures of the condenser water. Then using the ordinary approximate equations,

$$xw\,(1{,}116 - 0.71\,t) + w\,(t-f) = W\,(f-i);$$

$$\text{whence } x = \frac{W\,(f-i) - w\,(t-f)}{w\,(1{,}116 - 0.71\,t)}.$$

To arrive at satisfactory results, the temperatures must be read to $\frac{1}{10}$ degree Fahrenheit at least, and the weight of steam condensed must be very accurately determined. It is desirable that the initial temperature i of the condenser water should be about as much below the temperature of the place where the test is made as the final temperature f is above it. A correction for radiation during the time that the agitator is used before the final temperature f is read can be made thus: Suppose the agitator is used for two minutes, and the temperature is then f_1, and that two minutes later a temperature f_2 is observed. Then the true value of the final temperature f at the moment when condensing ceased is $f = 2f_1 - f_2$. In the Mulhouse tests the initial and final temperatures were about 60 degrees and 110 degrees Fahrenheit, and the steam generally showed from 2½ to 5 per cent. of moisture, but in particular cases as much as 12 to 16 per cent. of moisture was observed.

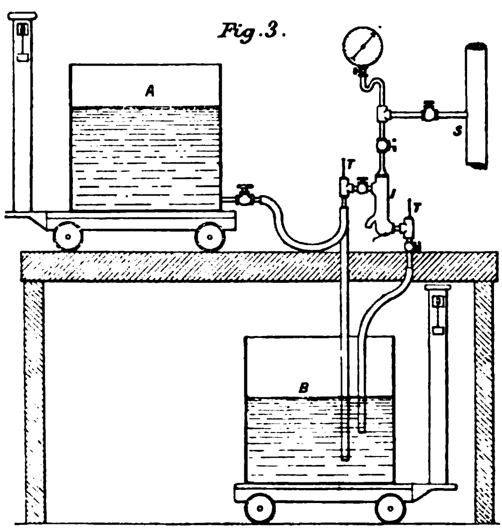
The condensing or total-heat method of ascertaining the dryness of steam has been used by many observers during the last thirty years. An apparatus for making this test is known in America as the barrel calorimeter. An ordinary oil barrel is used, fitted with an outlet valve. The barrel is filled with cold water, and steam is led into it by a pipe and condensed. The barrel is placed on a weighing machine, and the weight and temperature before and after condensing are noted. The proceeding is a rough one, and has given anomalous results in practice. Mr. Willans used this method in his trials of a non-condensing steam engine. He sought to evade the known difficulties of the method by carrying it out on a very large scale. The condensing tank, weighing with water about three tons, was placed on a platform weighing machine. This was balanced by the sliding weight of the weighing machine. Then a standard hundredweight was placed on the platform, and the machine lever again put in balance. The hundredweight was then removed, the temperature noted, and steam condensed till the added weight of condensed steam just lifted the lever, making an electric signal. Then the water was stirred, and the temperature again noted. The thermometers were very sensitive, and were accurately compared with standard thermometers. A small correction was made for radiation.

The value of the dryness fraction found on different days was 0.9986, 0.9638, 0.9949, 0.9646, 0.9976, 0.9893, 1.0072, 1.0048, 0.9987. The mean of all was 0.9911, showing an average of about 1 per cent. of moisture in the steam. Probably this test was never more carefully carried out; but the results are not so accordant as could be wished. Two of the results indicate superheating, which under the circumstances was probably impossible.

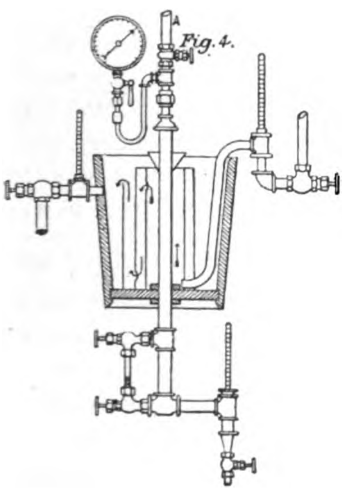
The condensing or total-heat method is strictly accurate in principle, but it is difficult to carry out satisfactorily. It is not easy to make the proper allowances or corrections for the heat absorbed by the condensing vessel itself, and for radiation and loss by evaporation from the condenser. The thermometers must be very sensitive; and very sensitive thermometers are difficult to use.

4. *Continuous Condensing Methods.*—The difficulties of the ordinary condensing method were so obvious that Mr. Barrus, Mr. Hoadley and other observers were led to propose methods of continuous condensation. Steam and cold water being both supplied at a constant rate, the condenser requires a steady temperature, which can be very accurately observed. The steam may be condensed either in the condensing water or in a surface condenser. Fig. 3 shows a continuous injection condenser.

Fig. 3.



Steam passes from the steam pipe *S* to a small injector *I*. The condensing water is drawn from the tank *A*, and the mixed water and condensed steam are discharged into the tank *B*. The two tanks are placed on platform weighing machines. Thermometers *T*, *T* give the temperatures of the condensing water and of the mixture of condensed steam and condensing water. The difference of the total weight in the two tanks after any interval of time is the steam condensed in that time. Fig. 4 shows a continuous surface condenser, consisting merely of a small pipe *A* in a vessel, through which flows a steady stream of condensing water. As the condensing surface is constant, the rate of condensation is constant; and the rise of temperature of the condensing water is constant. The condensed steam is drawn off steadily from the condenser for weighing, and simultaneously a series of readings are taken of the water entering and leaving the condenser. The continuous condensing method seems likely to be more accurate than the ordinary method; but it involves more elaborate arrangements, and it does not seem to have been much used in practical trials.



5. *Superheating Method.*—About 1890 Mr. G. H. Barrus devised a calorimeter, in which the steam to be tested passed through an inner chamber jacketed by superheated steam. The sample of steam to be tested was thus dried and superheated at the expense of heat borrowed from the jacket. To avoid measuring the steam, an attempt was made to secure that equal weights of steam passed through the inner chamber and through the jacket. In that case the wetness of the steam can be calculated from observation of the temperatures only. The method is accurate in principle, but appears to be difficult to carry out satisfactorily.

6. *Wiredrawing Method.*—A method in which the steam to be tested is dried and slightly superheated by wire drawing was proposed by Professor Peabody. Mr. Barrus and others have devised modified forms of the apparatus. Fig. 5 shows Mr. Barrus's arrangement. The steam passes from a chamber A to a chamber B through a very small aperture, about $\frac{1}{16}$ inch in diameter. The full steam pressure is in A, and the pressure in B differs little from atmospheric pressure. Thermometers T,T give the temperatures in the chambers, which are protected from radiation by a thick coating of asbestos and felt. The steam is allowed to flow through the apparatus for 20 minutes or more, when the temperatures become nearly steady. Let t_1, t_2 be the temperatures of the steam before and after wiredrawing, t_3 the temperature of saturated steam corresponding with the pressure in the second chamber B. Then the steam in B has been superheated $t_2 - t_3$ degrees by wire drawing. Let h_1, L_1 be the total heat and latent heat of steam at t_1, and h_3, L_3 corresponding quantities for steam at t_3 Taking as usual the specific heat of water as unity, and that of steam as 0.48, the dryness fraction $x = \frac{t_3 - t_1 + L_3 + 0.48\ (t_2 - t_3)}{L_1}$. No weighing is required, and temperatures only have to be observed. The observations can be continued as long as desired, so as to obtain a mean value for the dryness fraction x from a considerable quantity of steam. If the steam is very wet, the temperature in B falls to about 212 degrees, showing that wiredrawing to atmospheric pressure is insufficient to dry the steam. Practically, the instrument cannot be used if the wetness exceeds the values given in the following table, the pressures being in pounds per square inch, and the atmospheric pressure being assumed at 14.7 pounds.

Initial Pressure (Absolute).	Initial Pressure (Gauge).	Initial Temperature.	Initial Wetness.
		Deg. Fahr.	*Per Cent.*
29.9	15 2	250	0.80
67 2	52.5	300	2 44
135.1	123.4	350	4.21
247.7	233.0	400	6.13

Two conditions are necessary for accuracy in using this method. The chamber B must be large enough for the eddies to die out before the steam leaves the chamber. Radiation must be so far prevented that the steam in the chamber is not sensibly cooled. As a large quantity of heat is passing through the chamber, it appears that, when reasonable precautions in clothing the apparatus are taken, the loss by radiation is so small a fraction that it produces no important effect.

7. *Combined Separating and Wiredrawing Methods.* — To extend the usefulness of the wiredrawing method, Mr. Barrus added a separator C, Fig. 5. The steam in passing through the

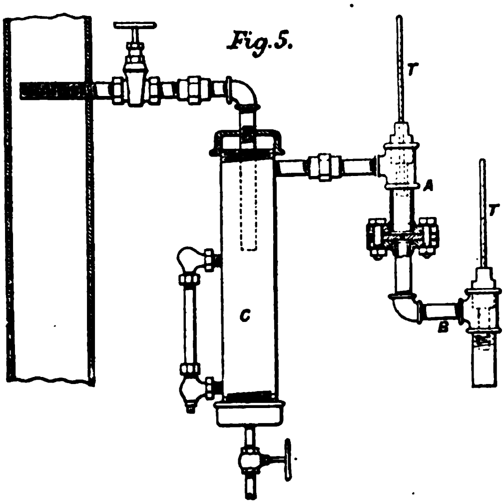
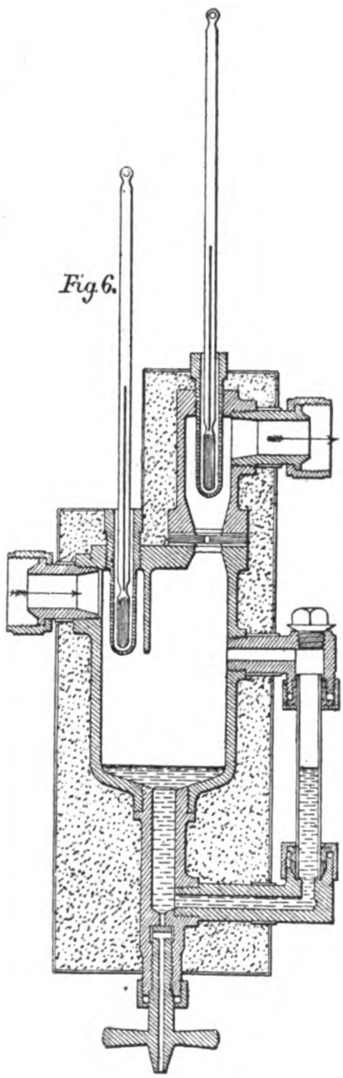


Fig. 5.

separator leaves most of its moisture there; and the remainder is measured in the wiredrawing part of the instrument. When thus arranged the use of the instrument is much more troublesome, as the amount of steam passing through in a given time must be observed, and the amount of moisture collected in the same time must be weighed. A condenser must therefore be used, at least occasionally, in order to determine the discharge per minute by the apparatus at different pressures. A formula can be found, connecting the discharge per minute with the fall of pressure in the chambers A and B; but it is not clear that the calculation of the steam used from the formula is quite accurate enough for the purpose; and using the condenser in every test is troublesome.

Fig. 6 shows a modification of Mr. Barrus' apparatus, which is manufactured by the Globe Engineering Company. A gauge glass is added to the separator, for facilitating the observation of the quantity of steam trapped. At the bottom of the separator is a cock, by which the water can be drawn off, or the level in the gauge glass regulated. The Globe calorimeter is well arranged and neatly made; but a condenser should be supplied with it, and be capable of easy attachment to the discharge pipe. The separating and wiredrawing parts in this instrument cannot be used independently.

Fig. 6.



8. *Second Superheating Method.*—Mr. W. R. Cummins has suggested another method. A vessel is filled with the steam to be tested, and then heated by a jacket. As it is heated, the rise of pressure in the inner vessel is observed, the volume being constant. So long as the steam is moist, the pressure will rise with the temperature according to the law for saturated steam. The moment all the moisture is evaporated, the rate of rise of pressure with temperature will become much slower. Both inner chamber and jacket are first blown

through with steam from the steam pipe. Next both are closed, and heat is supplied to the jacket. During this process the temperature and pressure in the inner chamber are observed at short intervals of time; and the temperature t_2 is found, at which, from the change in the rate of increase of pressure, the steam has just become dry. Let t_1 be the initial temperature of the steam, and v_1, v_2 the specific volumes of saturated steam corresponding to the temperature t_1, t_2. Then the initial dryness fraction x of the steam is $x = v_2 \div v_1$. The method is correct in principle, and there does not seem to be any insuperable difficulty in using it; but it does not appear that it has been tried.

9. *Chemical Methods*—Let a soluble salt be added to the boiler water, so as to form a solution of known strength at any given time; and let the boiler be afterwards fed with pure water. If the steam leaving the boiler is dry, saturated steam, the boiler solution should remain of constant strength. But if there is priming, part of the boiler water will be removed with its percentage of salt, and the solution in the boiler will diminish in strength. This method has been often used from the date of the Mulhouse experiments in 1859 to the present time. There are three variations of the mode of procedure.

(*a*.) The decrease of saltness of the boiler water in a given time can be determined by taking samples from a gauge cock and analyzing them. The sample should be drawn off through a worm cooled so that the water is below 212 degrees at the point of discharge; otherwise there will be a loss by evaporation, which will alter the saltness of the sample. Care should be taken that the level in the boiler is the same when the initial and final samples are taken.

(*b*.) A sample of the steam may be condensed in a small surface condenser, and the amount of salt present in the condensed steam can be determined. Numerous samples should be taken during a trial, so as to obtain an average value of the dryness fraction of the steam.

(*c*.) Mr. Escher, of Zurich, has suggested another mode. The boiler is fed with water containing a constant percentage of soluble salt. During working the solution in the boiler steadily concentrates. If the boiler primes, the concentration will reach a fixed limit, when the amount of salt in the concentrated solution removed by the priming water is as great as the amount of salt introduced in the same time by the weaker feed water. If the limit of concentration and the quantity of feed supplied are known, the dryness of the steam can be exactly determined, at least so far as the moisture in it is due directly to priming. Mr. Escher has shown how the dryness can be approximately determined from the concentration in a given time, when the limit is not reached. This appears to be accurate in principle, as a means of determining the amount of mechanical priming; but no record has been found of its having been tried.

The author has examined the results obtained by the salt methods (*a*) and (*b*) in a number of boiler trials, and he believes that these justify the following general conclusions: 1. According to the salt test there is usually less than $\frac{1}{8}$ per cent. of moisture in the steam produced; whereas in tests of the same steam by other methods a considerably greater amount of moisture is indicated. No doubt this arises partly, perhaps principally, from the fact that the salt test can show only that part of the moisture in the steam which is due to mechanical priming. It may be inferred that in ordinary cases a sensible proportion of the moisture in steam is due, not to mechanical priming, but to condensation in consequence of radiation occurring after the steam is formed. 2. The results obtained by salt tests during any one boiler trial are not closely accordant, and results by method (*a*) do not well agree with results by method (*b*). This throws some doubt on the accuracy of the methods. 3. In cases where there was obviously a good deal of mechanical priming, the wetness shown by salt tests in successive samples of the steam is extremely variable. In a trial by Dr. Bunte, for instance, tests by method (*b*) showed from no wetness up to 13 per cent. of moisture, the mean being $3\frac{1}{4}$ per cent. At the same time method (*a*) gave 1.7 per cent. of moisture. It is obvious that in method (*a*) there must be great difficulty in securing a uniform distribution of salt in the boiler, and if this is not obtained it is impossible to get average samples of the boiler water. The fact that the feed is supplied at one definite place tends to prevent a uniform distribution of saltness. In method (*b*) it would seem that the amount of steam which can conveniently be condensed is not large enough to be an average sample of the steam. A subordinate question is this. Some engineers have thought that the salt method was most suitable for boiler trials, because it gives directly the mechanical priming; while other methods were more suitable for engine trials, where a knowledge of the absolute dryness of the steam was required. It seems doubtful if the salt test does give the mechanical priming accurately; but also the view seems to be founded on a misapprehension. In determining the evaporative efficiency of a boiler it is necessary to know how much of the feed leaves the boiler as steam and how much as water. The total heat utilized depends on the dryness of the steam leaving the boiler. It does not matter how moisture originates in the steam, provided it is there. Moisture produced by radiation from the boiler roof is as much a deduction from the efficiency of the boiler as moisture projected into the steam mechanically. It is important in a boiler trial that the steam tested should be taken very near the boiler, and not from a steam pipe in which heat may have been lost by radiation. On the other hand, in an engine trial it is desirable that the sample of steam should be taken very near the engine.

PRACTICAL CONCLUSIONS AS TO THE MOST CONVENIENT AND ACCURATE METHODS.

The chemical method, the author thinks, may be put aside as both inconvenient and untrustworthy, except, perhaps, in the single case of a boiler subject to marked priming action. In that case the use of the salt test according to method (*a*) might be useful, because, virtually, it integrates the loss of boiler water by mechanical priming over any desired length of trial, and because, where the wetness of the steam is large, the defects of the method, especially the difficulty of securing average samples of the boiler water, are proportionately less serious.

Of the other methods, the condensing or total-heat method, accurate as it is in principle, must be rejected on the ground of the difficulty of making the observations with the necessary accuracy.

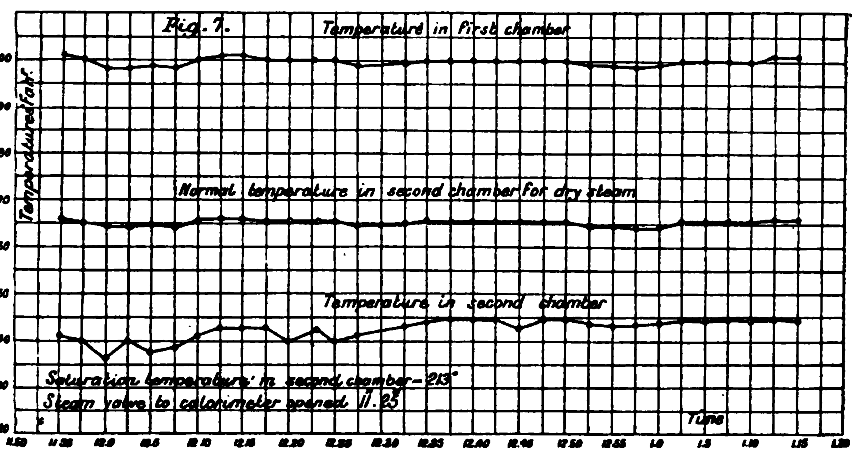
Putting aside some other methods which are almost untried, and which hardly promise to be convenient, there remain two methods only of determining the dryness of steam, which seem to fulfil the necessary conditions. These two methods are the wiredrawing method and the separating method. For either of them very convenient apparatus has been arranged, and the observations to be taken are simple.

Tests of the Wiredrawing Calorimeter.—This apparatus is so easily used, and gives indications of such great delicacy, that it seemed desirable to get a direct test of its trustworthiness by using a sample of steam, about the quality of which there could be no doubt. Especially was it desirable to ascertain whether the small loss of heat by radiation caused any appreciable loss of temperature in the steam in the second or superheating chamber. It occurred to the author to superheat a sample of steam on its way to the wiredrawing calorimeter, and to observe whether the change of temperature in the instrument corresponded with that which should occur according to calculation from the quantities of heat concerned. A small superheater was constructed, heated with gas jets. The steam being passed through this, there was superheated steam in both chambers of the instrument.

Let p_1 be the pressure in the first chamber A, Fig. 5, before wire drawing; t_1, the corresponding temperature of saturated steam; t'_1, the actual temperature of the steam. Then the steam entered the instrument with $t'_1 - t_1$ degrees of superheat. Let p_2, t_2, t'_2 be the corresponding quantities for the second chamber B. Then, after wire drawing, the steam has $t'_2 - t_2$ degrees of superheat. Since the total heat per pound is the same for the steam passing through both chambers, if radiation is neglected, and if the frictional eddies are destroyed,

$$1{,}082 + 0.305\, t_1 + 0.48\,(t'_1 - t_1) = 1{,}082 + 0.305\, t_2 + 0.48\,(t'_2 - t_2).$$
$$\therefore\ t'_1 - t'_2 = 0.3646\,(t_1 - t_2).$$

The quantity $t_1 - t_2$ can be found from the observed gauge pressures, and the observed $t'_1 - t'_2$ can then be compared with the value here calculated. Several tests were made in the laboratory of the Central Technical College, in all of which the observed and calculated values of $t'_1 - t'_2$ agreed very closely. This shows that the effect of radiation in reducing the temperature in the second chamber *B* is very small. Probably this is due to the fact that the heat lost by radiation is small, compared with the amount of heat passing through the apparatus. In Fig. 7 are shown curves drawn for one of these tests. The steam was taken from a steam pipe supplying an engine from a Babcock and Wilcox boiler. The engine was running, and the steam pressure was taken by a Schaeffer and Budenburg gauge,



and can, therefore, be approximately accurate only. The mean superheat in the first chamber *A* was 24 degrees; that in the second chamber *B* was 80.1 degrees. The mean observed difference of temperature in the first and second chambers was 30.78 degrees, and the value calculated from the above formula was 31.45 degrees, showing a loss, if the pressure observations are assumed to be accurate, of only 0.67 degrees, possibly due to radiation. But 1 per cent. of the moisture in the steam would have caused a lowering of temperature in the second chamber amounting to about 20 degrees. Even, therefore, when used without any correction for radiation, it would appear that the wiredrawing calorimeter gives results accurate within about 0.1 per cent. of moisture, provided that a fair sample of steam is obtained. Hence it appears that practically radiation may be neglected, and that for steam initially wet the equation in section 6 may be used.

Test of the Efficiency of a Separator.—The Barrus calorimeter, which the author obtained from America, has a separator *C*, Fig. 5, which can be used in conjunction with the wiredrawing part of the apparatus. This separator does not seem to be quite so well arranged as that of the Carpenter colorimeter; but it occurred to the author that it might be useful to observe how far the separator trapped the moisture of the steam, and what fraction passed on to the wiredrawing aperture. In three tests made at the Central Technical College the separator trapped from 4.4 to 9 per cent. of moisture, and the steam passing through the wiredrawing aperture showed only from 0.4 to 0.2 per cent. of moisture. It would appear, therefore, that even with very moist steam the separator alone will give results not erring by 0.5 per cent. of moisture. In the Carpenter calorimeter, Fig. 1, the current of steam is slower, and the separator is steam-jacketed, and the author thinks its action is more perfect. According to Professor Carpenter's results already mentioned, the action of the separator is practically so perfect that it traps all the moisture.

Tests of a Wiredrawing and Separating Calorimeter Side by Side.—The author has tried the two calorimeters side by side, the steam current dividing at a T-piece to flow to them both alike. In these tests the results by the two methods agreed fairly well, but the wiredrawing calorimeter showed rather more moisture than the separating calorimeter. The former used much more steam than the latter, and the author thinks it possible that a rather larger percentage of moisture was carried away by the stronger current at the T-piece. An incidental result in making these tests was interesting. The steam was taken from the engine steam pipe to the calorimeters through a branch pipe about 30 feet long, which was covered with Keenan's composition. When the separating calorimeter was used alone, the steam showed 13.82 per cent. of moisture. When both calorimeters were in use together, the steam showed only 3.93 per cent. of moisture. The difference appears to be due to radiation from the 30-foot length of steam pipe; with the very small current required for the separating calorimeter, the condensation due to radiation produced a considerable effect; with the much faster current required for the two calorimeters used together, the effect of radiation was much less. So must it be in the working of steam stations: When the engines are working at full power, the effect of radiation in producing moisture in the steam is not serious; but when the engines are working with a small load, the amount of moisture produced by radiation is much more considerable in proportion to the weight of steam used. This is no doubt one cause of inefficiency when engines are worked with small loads.

Conclusion.—Generally the author thinks that the wiredrawing calorimeter without separator is the most convenient and accurate for steam with less than about 2 per cent. of moisture. For steam containing more moisture, the separating calorimeter without wiredrawing apparatus is accurate enough and convenient. The use of the separator and wiredrawing calorimeter combined is more troublesome, especially if, as is desirable, a condenser is also used to determine the amount of steam passing through the separator. In cases where there is much priming, it would seem best to take the whole of the steam through an ordinary steam separator, measuring the amount of water trapped; and then to test by a wiredrawing or separating calorimeter the dryness of the steam after passing the separator. In priming, much of the water probably flows along the bottom of the pipe, and it appears impossible that a sample can be obtained containing an average proportion of steam and water. It is recommended by Professor Carpenter that the sample of steam to be tested should always be taken from a vertical, not from a horizontal steam pipe. No doubt there is rather more tendeney for water to flow along the bottom of a horizontal pipe than down the sides of a vertical pipe; but merely taking steam from a vertical pipe does not insure freedom from error, especially if the amount of moisture in the steam is considerable. Variations in tests for wetness are doubtless often due to the difficulty of getting a true average sample of steam ; and it would seem that errors are generally in the direction of under-estimating the amount of moisture.

Discussion.

Mr. Michael Longridge was the first speaker. He said he was glad to see the paper, for he had suggested many years before, at a meeting of the Institution of Civil Engineers, that a prize should be offered upon the subject. The British Association Committee had done but half the work required. Indeed, the most difficult part of the business was to get a fair sample of the steam. Under these conditions he thought that a small apparatus should not be used, but one which would treat all the steam supplied to a steam engine. Referring to the question of velocity of steam and its effect on carrying forward particles of water, he quoted a case of a large boiler having two openings. Steam was being generated at atmospheric pressure; when one opening was uncovered, water was carried with the steam to a considerable height; when both openings were uncovered, steam only issued forth. He had found that with a velocity of 30 feet per second of steam, water was carried over, but at 8 feet per second there was no water carried forward. This was at atmospheric pressure, but he could not say whether it would hold good at higher pressures. Another experiment bearing on the same subject was one made in supplying steam to a cylinder jacket. It was desirable for a certain purpose to supply the steam and drain the water of condensation by the same pipe, which was 1½ inches in diameter. With a velocity of 5 feet per second at 90 pounds pressure, it was found possible to do this, the steam running up and the water coming down; but if the velocity of the steam were increased above 5 feet, the water would not come down past the steam. On the whole, it seemed to the speaker that it was possible to have a calorimeter to act as separator for an engine, and yet not be of extraordinary size.

Mr. Bryan Donkin spoke as to the value of the paper, and suggested that the Institution should appoint a Research Committee to inquire into the question. He made reference to some French experiments of this nature made on locomotive boilers for the Paris, Lyons and Mediterranean Railway Company. A continuous condensing calorimeter, devised by M. Henri, was used for determining the priming water. This method of working is based on the following principle: A certain quantity of steam is passed into a small surface condenser arranged as a calorimeter, and the increase of heat in the condenser is measured in the circulating water. The greater the quantity of water in the steam the less the heat in the circulating water. From the heat coming from the condenser the percentage of water in the steam is calculated. The steam in the condenser is at atmospheric pressure. The steam to be tested is passed inside the tubes and the circulating water outside, the quantity of the latter being arranged to be constant, as is also the quantity of steam, the pressure of steam being kept uniform in the boiler. The steam is completely condensed in the condenser. The temperatures are taken of the steam before entering the condenser, of the water condensed, and of the circulating water in and out. The quantity of circulating water is also measured. The quantity of heat entering is the same as that leaving the condenser. From an equation it is therefore easy to determine the percentage of water brought over by the steam. In the original paper describing the apparatus, which had appeared in the "Annales des Mines," 1894, vol. vi, full details are given, together with a drawing of the apparatus. The method as used by M. Henri was not, the speaker said, probably new, but he considered it better than many others then known to him. When working the locomotive stationary, M. Henri found the steam practically dry, but he is of opinion that, in running locomotives, the steam always contains a certain amount of moisture.

Some German experiments had also been made to which the speaker referred. He placed on the wall a drawing of Gehre's apparatus, in which a sample of steam, after passing through a pipe, is shut in between two valves. Below there is a means of heating the pipe by a flame. As long as the steam remains saturated, the pressure and temperature will be according to the steam tables. When the steam is heated from below, an evaporation of all water in the steam takes place, the pressure rises, and the steam commences to be superheated. The volume is constant during the operation. Mr. Donkin described the experiment as follows: "The valves are closed and sample of steam obtained, and the pressure of steam read off by the gauge. The lamp is then placed under the pipe, and as soon as the temperature begins to rise, the steam pressure is again noted. From the weights of these equal volumes at the two unequal pressures, the percentage of moisture in the steam can be calculated. If no moisture is present, the pressure will not rise after flames are applied. The greater the percentage of water present, the greater the difference after heating. The valve must be perfectly steam-tight."

Mr. Druitt Halpin said that the Paris, Lyons, and Mediterranean experiments, he had always understood, gave no certain data, and it was concluded that their results were of no value. Mr. Donkin, in replying to this, said that he understood that practical results were obtained. Mr. Halpin continued that he had been told the experiments were on so large a scale as to be unmanageable, and it was said that the whole of the results had been rejected. The author had described a separating method of determining the wetness of steam. Mr. Halpin would suggest another way. In dealing with two fluids of different specific gravity, it might be possible to throw the whole of the water out by a centrifugal method, using mechanical means, such as a fan, for the purpose; in this way the steam and water would be separated.

Professor T. Hudson Beare said he would like to say something in mitigation of the severity with which the author had treated the salt test. It certainly only showed the mean of mechanical priming, and was not influenced by the condensation; but if moisture were present in the steam, the engineer wanted to know whether it was due to mechanical defects in the boiler or to radiation of heat, and the salt test might still be used for that purpose. In the continuous condensing method described by the author, he would like to know if the gauges were calibrated, as the results depended on their accuracy. Again, in the combined separating and wiredrawing methods, in which the author said no weighing was required, he would like to know whether there was a gauge on the second chamber. Professor Unwin said he would like to answer these two questions at once. It was strictly necessary that there should be a gauge on the second chamber in the last apparatus referred to, unless the opening were very large. The gauges referred to by Mr. Beare were tested, but he would confess that he did not trust to them very largely. Professor Beare, continuing, said he had grave doubts whether a true sample of the steam was obtained by drawing it out in the present method.

He would give a practical example of the fact by the way in which steam was taken from a chamber in the case of the experimental boiler at the University College. This was a locomotive boiler with a wet bottom, and the steam was taken from a perforated pipe bent upwards. They found on a trial that a large quantity of water was being brought over, and on investigation it was discovered that the pipe had been accidentally shifted downwards, so that though the orifice was still above water, it was very near the water level. With the pipe in this position there were 378 pounds of water brought over with the steam per hour; with the pipe in the normal condition the quantity was 154 pounds per hour, the conditions of working in all other respects being the same in both cases.

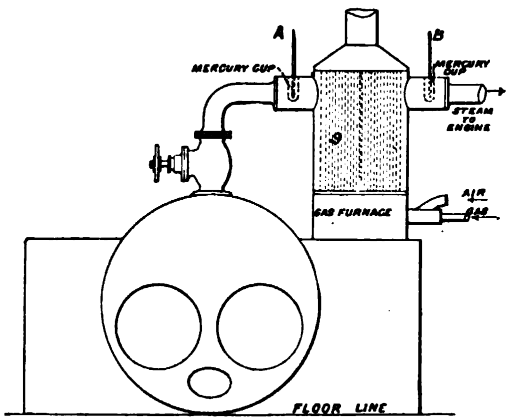
Mr. Clarkson said that a suggestion might be taken from the practice of taking sample minerals, in getting a true sample of the steam. A rotating hollow cylinder was used, through which the stream of minerals poured, and this was projected on to the point of a cone. In this way a uniform stream of mineral was obtained, and a thorough admixture was therefore secured. He thought some such apparatus could be introduced into a steam pipe, and by inserting a sector the steam could be diverted and led off to be tested.

Captain Sankey, who was the next speaker, said that the specific heat of steam was generally accepted as .48, and Professor Unwin had so taken it; but he would point out that Mr. Macfarlane Gray had questioned the accuracy of that figure, and, in a correspondence with the late Mr. Willans had given a formula for the specific heat of steam. This showed the specific heat to be not a constant, but to vary with the temperature of the steam. The speaker proceeded to illustrate this by use of the theta-phi diagram by aid of the blackboard. It was important to get rid of this question of the specific heat of the steam, and Mr. Macfarlane Gray and the late Mr. Willans had devised a superheater in which the steam was reduced to a lower pressure than in the Barrus calorimeter, and so the difficulty of the specific heat was got over, but it was not possible to use it, as the true temperature of superheated steam could not be ascertained.

Professor Barr was pleased that the author had treated the salt test so severely, as it was not in any way trustworthy. He had occasion to look into this matter in connection with applying the salt test to a water tube boiler, but he could not tell from what part of the boiler the water came, and the salt would be more in one part than in another. He had suggested the same method of obtaining a true sample of steam as that sketched by the author on the blackboard. His ideas were embodied in the transactions of a scientific society. The difficulty was that the water had greater inertia than the steam, so that the amount of moisture varied with the velocity of the flow. But though he had suggested this method, he was afraid that it would not be of any use, as the water would get to the side of the steam pipe and stay there, and as the nozzle took steam from the center of the pipe, it would not give a fair sample. It would, therefore, be necessary to mix the steam and water, as the previous speaker had suggested; but the best way would be to separate the whole of the water from the steam. He would suggest the use of a spiral pipe taking the water off at the smaller radius.

Mr. Crompton said that when engineers found water in steam pipes, they wanted to know whether it was due to the boilers or to condensation in the pipes, and he had met with no satisfactory method of determining the problem yet. When they had to deal with a long system of piping they also wanted to know the quantity of water in the steam at various points of the pipe system. If a way could be shown of getting samples of steam, he felt sure that the mean water might be determined by temperature methods, and the electrical engineer would supply means of reading these temperatures accurately. Of late the pyrometer had been so perfected that very trustworthy readings could be obtained by the platinum pyrometer.

Mr. Cawley remarked that Mr. Bryan Donkin had suggested the appointment of a special committee to inquire into and report on the subject of the paper; he would propose another, to deal with the question of the advantages to be derived from moderate superheating of steam supplied to steam engines. He felt so satisfied of the value of these advantages that he predicted that the proposed committee for dealing with the determination of the dryness of steam, and also the one now dealing with the value of steam jackets, would have little work left to do if moderate superheating were generally adopted. However, as such was not yet the case, he would, like other members who had spoken, thank Professor Unwin for his extremely interesting paper. This paper showed that of all the methods mentioned only two could be relied upon. But even these had to deal with only a minute sample of the body of steam taken from the steam pipe, in some way which the experimenter might think best. But it seemed to be generally admitted that this sampling would probably lead to very erroneous results, and he thought it might be easily practicable to apply an apparatus to a medium sized boiler, capable of dealing with the whole of the steam produced, instead of with a minute sample. The arrangement shown by the annexed diagram, which he sketched on the blackboard, would be suggestive of what he meant. The vessel *S* is a superheater with a gas furnace placed in a suitable position near the boiler to be tested. The superheater is fitted with a central baffle plate, reaching from the top to nearly the bottom, and with a number of vertical tubes. The more or less wet steam from the boiler would pass through the superheater, and the gas supply would be adjusted so that the steam escaping from the superheater was very slightly superheated. This would be shown by the mercury in the thermometer *B* standing slightly higher than in *A*. Then, supposing the evaporative efficiency of the superheater—as a boiler—were known from previous experiment, and also the efficiency of the boiler alone, the relative values of the heat supplied to the boiler furnaces, and the superheater, would supply data for de-



termining the wetness of the steam—after making an allowance for the slight amount of superheat in the steam leaving the superheater. There might be objections, he said, on the score of economy, to the use of coal gas for the superheater, but he pointed out that for a brief experiment this would not be serious. For, taking coal gas at 2s. 8d. per 1,000 cubic feet, the cost per pound would be about 1d., and, having regard to the higher calorific value of coal gas, the cost of gas per thermal unit would only be about seven times that of coal, which was not a serious matter in a short experiment.

Mr. William S. Lockhart referred to the device for sampling steam illustrated by Professor Unwin. The speaker pointed out that if the orifice of the connecting nozzle were secured and placed in the middle of the steam pipe, as shown, the sample would not be a fair one, as it would take steam only from the middle of the pipe, whereas the moisture traveled along the walls of the pipe. He suggested, therefore, that the end of the nozzle should be flattened so that the orifice would take the form of a long slit extending across the pipe, and in that way the steam would be taken from the entire diameter.

Mr. Jeremiah Head remarked that he was a member of the committee of the British Association already referred to, and he would like to point out that although there were several members on the committee, the actual work was done by the author of the paper now being discussed, and that the whole credit of the investigation was therefore due to Professor Unwin. The question of separating water and steam, not for the purposes of measurement, but in order to extract the water from the steam, was an old problem. It had been a custom, where long ranges of steam piping were used, to take the main steam pipe into a receiver into which the water would fall. He had known cases where fire had been made at the bottom of this receiver for the re-evaporation of the water. This was a questionable proceeding, and was rarely followed out. What was wanted in an engine was that when the steam passed to the condenser, it should be just saturated steam. That was an ideal case, and in practice it could only be attained by using superheated steam in the high pressure cylinder. He had known cases in which the attempt had been made to get this result by wiredrawing, but he was not aware whether it could be done with advantage. With regard to the question Mr. Lockhart had raised, the speaker questioned whether the water would be present in steam pipes at all parts in equal quantity. It was assumed that in a horizontal pipe water would be at the bottom of the pipe, and for this reason a vertical pipe was used for the purposes of collecting samples, but in this case he doubted whether the proper end was attained. He would, therefore, suggest a telescopic collecting nozzle, which could be pushed in and out so that the collecting orifice could be put in different positions of the pipe, and in this way the sample collected would be a fairer average.

Mr. J. Mair Rumley said he would like to impress upon the meeting the importance of taking water out of the steam that was to be used in an engine. He would give an instance. In the case of a large compound engine using chalky water in the boiler, they found a very low efficiency in the engine, 26 pounds of steam being required per indicated horse-power, and the indicator cocks being full of watter. They put drains on their high pressure valve chest, and extracted 1,200 pounds of water out of 14,000 pounds that were passed from the boiler in the shape of water or steam; this would be an average of about 8 per cent. of water. After this the steam required per indicated horse-power fell to 17 pounds. The fact showed the necessity of a steam separator. Mr. Longridge appeared to think that a very large separator would be required for the purpose of dealing with all the steam passed to an engine, but, as a matter of practice, he (the speaker) was now putting on separators that were no more than five or six times the diameter of the steam pipe. In regard to pipe condensation, he would give an instance showing its importance, and the necessity of keeping the steam pipe as small as possible in order to reduce radiation. A friend of his wished to work a pump at the bottom of a well, and had put on a 2-inch steam pipe, but found that the engine could not be made to revolve at all in consequence of being choked with water. The 2-inch pipe was then taken off and 1¼-inch pipe substituted for it, after which, to use his friend's expression, "all went merrily." The steam separator was an important adjunct, and he considered that any one who improved the design would be rendering a service to all steam users.

Mr. Clark said that the subject under discussion was extremely interesting, both from a mechanical and physical point of view. He described Regnault's experiments and the apparatus used in them, and proceeded to remark that since Regnault's day further discoveries had been made. Regnault assumed that all the water in steam would run down into the boiler and not into the calorimeter, and thus may have vitiated the results. The principal sources of error in calorimeter work were temperature errors, the determination of the latent and specific heat of water and steam, and the capacity of the calorimeter for heat and radiation. The first two might be relegated to the physicist, the other two were common to all apparatus, but they might be eliminated in many cases, and a proper balance maintained between loss and gain. This supposed an ideal calorimeter, but that was a standard that should be aimed at. What was required to be known was the wetness of the steam in the steam pipe, and not that at the end of the tube attached to the pipe, therefore the calorimeter should be in the steam pipe itself. This would give two of the necessary properties of an ideal calorimeter, for the steam as used would be tested, and the calorimeter would always remain at the temperature of the steam. He had designed an instrument of this nature, but one had not yet been made, and he therefore brought forward the suggestion with diffidence. He placed a coil of wire in the steam pipe, and through this passed an electric current; this formed the calorimeter. If such an apparatus were used in air, any fall in temperature would be due to conduction or convection and radiation; whilst if used in dry steam the same conditions would apply. If, on the other hand, the coil were placed in a current of wet steam, the temperature due to the passage of the current could not rise until the water was evaporated. If, therefore, means were supplied for measuring the resistance and the current passing through, there would be a possibility of forming an estimate of the wetness of the steam, for the point at which the temperature began to rise would show that the steam had then reached the saturated condition. To use this apparatus it would be necessary to know the total quantity of steam passing through the pipe. Mr. Clark hoped to carry out the experiments with the apparatus he described, and had already made certain tests, the results obtained being of an encouraging nature.

Professor Unwin, in replying to the discussion, referred to Mr. Longridge's remarks, in which he advocated abandoning small apparatus, and taking the mean of steam passed to the engine for the purpose of examination. It might be, the speaker said, that this course would have to be followed, but in the meantime he would like to know if Mr. Longridge himself had carried out any experiments in this direction, and if so, whether he found he could approach as closely to accuracy as with the sampling method. He concluded that if Mr. Longridge, for the purposes of a boiler trial, wished to analyze coal, he would take a few grains and draw conclusions as to the whole from analyses made with the small quantity. In like manner, if he wished to gain information as to the composition of chimney gases, he would withdraw small samples and analyze them, and the speaker failed to see why the same course should not be followed with the steam also. Professors Beare and Capper thought he had treated the salt test with scant courtesy, but he had reason to doubt its trustworthiness. He had made salt tests with a boiler without changing the conditions of working in any way, and had found the results vary from 500 to 1,000 per cent. With regard to withdrawing the sample, he feared he had not made himself understood, and had used a word which had led speakers astray. When he spoke of a sample, no doubt he had not chosen the expression well. What he meant was, that in withdrawing a quantity of steam from the pipe for the purpose of testing, there was a liability of the percentage of moisture also taken not being that normal to the steam at the point from which the sample was withdrawn; that is to say, water would accumulate on the withdrawing pipe, and thus give untrue results. He did not fear that the steam in any one part of the steam pipe would be greatly different in humidity to that in any other part; when it was considered that the steam would be rushing through the pipe at 100 feet per second, it would be evident that eddies would be caused and there would be a general mixing up. Under these conditions it was impossible for him to conceive that it was not a homogeneous mixture. It was not, therefore, that the steam in any one part of the pipe differed from that in any other part, so much as the extracting apparatus itself disturbed the current, and thus caused more water to be collected than that properly due to the steam. What he aimed at in designing the extracting nozzle, therefore, was to withdraw the steam without changing the velocity of flow, and he thought it immaterial in what part of the steam pipe the collecting orifice might be placed. Mr. Cawley had great faith in the future of superheating steam, and Professor Unwin himself thought that it would be largely used in the future. But the application would not come all at once, and, even if it were universal, engineers would want to know what the boiler was doing, and so the test would be with us always. Captain Sankey had spoken of the inaccuracy of thermometers. There were two calorimeters to which he gave preference. In the separating calorimeters, thermometers were not required, so that it was not so much a question of actual temperatures, but agreement between two instruments. At the same time he admitted that there were considerable errors, but these could be got over by calibrating by means of Regnault's tables, if the pressures could be accurately recorded. Mr. McFarlane Gray had carried out some interesting researches to determine the specific heat of superheated steam. Even if these had not an economic value, they were highly interesting and suggestive.

The value he had taken in his paper, viz., .48, was, he maintained, more useful, even if wrong, than Mr. Gray's variable value. It was considered that he had not treated Mr. Willans' experiments, referred to in the paper, with sufficient respect, but that he wished to disclaim. What he had said with regard to the apparatus used by Mr. Willans being the same as the barrel calorimeter was true, although, as explained in the paper, the size was very much greater than that usual. This fact brought him to the subject of what should be the scale of such experiments. Mr. Willans had made them very large in order to eliminate error by using big quantities, but the speaker thought he might have been wrong in his supposition, and in support of this instanced Joule's experiments made with two gallons of water, which were as accurate as those of Mr. Willans with his three tons. Again, the question of convenience came in. With the large apparatus and great volumes of water dealt with by Mr. Willans, one experiment only would be possible under ordinary circumstances; whilst with Hirn's apparatus it would be possible to make half-a-dozen experiments at the same cost, and he thought the mean of these would be nearer true than the single large trial. Professor Barr had stated that difficulty arose from water traveling in contact with the interior of the steam pipe, and in order to overcome this, he had devised the same apparatus as the speaker had illustrated on the blackboard.

Professor Barr immediately proceeded to knock down the suggestion he had made, by stating that the water traveled at the side of the pipe, and, therefore, the sample taken was not a fair one. His (Professor Unwin's) device, however, was made not with a view of taking steam from any one part of the pipe, but was designed to secure a fair sample by proportioning the nozzle so as to maintain in it a velocity of flow uniform with that maintained in the pipe. Some of the American newspapers had referred to this effect of water in contact with the pipe, but Professor Unwin looked on it simply as a great bugbear. With regard to the position of the calorimeter, it should be put near the boiler if tests for evaporative efficiency were to be made; whilst if tests for engine efficiency were to be carried out it should be placed near the engine. No doubt for engine trials the right thing was to put in a separator, but even then something more was required; and if a calorimeter were placed beyond the separator, then all had been done that was necessary.

[The discussion on this paper is from "Engineering." The nozzle suggested by Professor Unwin for obtaining a sample of the steam is one with its opening turned towards the flowing steam, and so proportioned that the velocity of steam in the nozzle shall be the same as that in the pipe.]

EXPERIMENT TO DETERMINE THE ECONOMIC VAPORIZATION OF GEORGE'S CREEK CUMBERLAND COAL, UNDER CONDITIONS OF ACTUAL PRACTICE ON BOARD THE *DOLPHIN* IN PORT.

By Chief Engineer G. W. Baird, U. S. Navy.

The purpose of the experiment was to determine the economic vaporization of the coal, not alone to estimate its deterioration due to five months' exposure to the weather, but also to determine the efficiency of the boiler.

For this purpose one of the small boilers was used, on its ordinary service in port, *i. e.*, while driving the dynamo, pumping bilges, washing decks, flushing closets, running the distiller and warming and ventilating the ship.

The small condenser with its air and circulating pumps was used; the additional feed water needed was made up from the hydrant on the wharf, but it passed through the feed tank where it was mixed with the warmer water.

The length of stroke of the feed pumps was measured every half hour, and the total number of its double strokes was recorded, from which the piston displacement was calculated for comparison with the feed water delivered, which was actually weighed.

THE BOILER.

The boiler is cylindrical, has two internal cylindrical furnaces, and return tubes above the furnaces; the tubes are of iron, the shell and furnaces of steel. The boiler was built at the Morgan Iron Works in 1883–'84, and has been in use since that time.

Diameter of the boiler, feet	11
Length of boiler, feet and inches	9–7½
Number of furnaces	2
Internal diameter of the furnaces, inches	40
Total number of tubes	216
External diameter of the tubes, inches	2¾
Length of the tubes, feet and inches	6–4
grates, feet and inches	6–9
Width of grates, feet and inches	3–4
Aggregate square feet of grate in both furnaces	45

Aggregate area through the tubes, square feet	7.54
over bridge wall, square feet	9.30
Area through the chimney, square feet	41
Aggregate water heating surface, square feet	1,092
Ratio of heating to grate surface	26 to 1
grate surface to area over bridge wall	4 84 to 1
through tubes for draft	6 to 1
Height of chimney above grates, feet	56.83
Width of top edge of grate bars, inch	1
Width of air space between bars, inch	$\frac{5}{8}$

Feed Pump.—The feed pump is a number 7 Blake pump, having 10 inches diameter of steam end, 6 inches water end, and a nominal stroke of 10 inches.

Feed Tank.—The feed tank is a rectangular iron vessel, well covered with hair felt, and into this tank the air pump, the steam heaters and evaporator drains are led; the feed tank delivers into a filter, but, in these experiments, the filter was not used, as it was not high enough to deliver into the weighing tubs; the feed water was taken directly from the feed tank.

MANNER OF MAKING THE EXPERIMENT.

The coal was all weighed in the fire room as it was brought from the bunker, the height of the water noted in the glass gauge, and the thickness and the quality of the fires noted at the beginning of the experiment; and these were brought to the same condition at the end, as nearly as possible. The feed water was weighed as it flowed from the feed tank into a tub; as each tub became full, and was balanced on the scale, it was emptied into a second tub, from which the feed pump took it. The temperature of each tub of water was noted. The experiment commenced at 1 P. M. on the 26th, and terminated at 1 P. M. on the 28th of March, 1895.

Duration of the experiment in hours	48.

COAL.

Total pounds consumed	8,000.
of refuse	874.5
combustible	7,125.5
Pounds of coal per hour	166.67
combustible per hour	148.45
coal per square foot of grate surface per hour	3.7

Pounds of combustible per square foot of grate surface per hour.........	3.09
Percentage of ashes in the coal..	10.93
FEED WATER.	
Total pounds pumped into the boiler..	71,280.
Mean temperature of the feed water..	156.7
steam pressure in the boiler..	39.2
ECONOMIC.	
Mean number of pounds of water vaporized per pound of coal...........	8.91
vaporized per pound of combustible..	10.004
vaporized per pound of coal had the feed water been delivered at 212 degrees..	9.44
Mean number of pounds of water vaporized per pound of combustible had the feed been delivered at 212 degrees...........................	10.604

REMARKS.

The relatively high economic vaporization is due, largely, to the very low mean rate of combustion. Even when carrying the heaviest load, *i. e.*, the dynamo and ventilating fans, the rate of combustion barely exceeded 5 pounds per square foot of grate surface per hour. The combustion was reduced by closing the ash pit and furnace doors and opening the uptake doors.

The difference between the number of cubic feet of water actually fed to the boiler and the actual piston displacement of the feed pump, even after deducting the slip, was about 9 per cent. The pump had to lift the water about 2 feet, drawing it through a 1-inch pipe for a distance of about 36 inches, though at a mean speed of about four strokes a minute; the high temperature of the feed water caused some vaporization and consequent apparent loss of action. The actual mean stroke of the pump was 8.683 inches. This loss of action, if it may be so called, is not peculiar to any particular make of pump; indeed, there is no essential difference between the water end of steam pumps as now made, but it is due to handling hot water, slip, etc., and must be allowed for in the design. In this test, I find 10 per cent. loss in shortening of stroke due to slowing the pump down, and 9 per cent. loss in addition, as above described. The former of these two losses (the shortening of the stroke) diminishes as the speed of the pump is increased; this variation of speed is much greater in a duplex than a single pump. This uncertainty of the feed pump factor makes it impossible for me to rely upon it as any sort of a meter.

MACHINERY OF BRITISH WAR SHIPS.

By Albert J. Durston, Engineer-in-Chief, British Navy.

[From "Minutes of the Proceedings of the Institution of Civil Engineers."]

The accompanying tables and illustrations, with description of the machinery, are from a paper entitled "The Machinery of War Ships," read before the Institution of Civil Engineers, by Mr. Albert J. Durston, Engineer-in-Chief of the British Navy, the arrangement of the subject-matter being slightly changed; and refer to sixty-four vessels built previously to the Naval Defence Act of 1889, and to seventy built under that act. The latter vessels comprise ten first class battleships, nine first class cruisers, twenty-nine second class cruisers, four third class cruisers, and eighteen torpedo gunboats. Of the hulls, thirty-two were built by contract, and thirty-eight in the Royal dockyards. Of the machinery, that for sixty-three vessels was supplied by contract, and that for seven, consisting of three second class cruisers, one third class cruiser, and three torpedo gunboats, was built in the Royal dockyards.

In Table A are given the particulars of the machinery of nine battleships built before the Naval Defence Act, and of ten others built under that Act. The first six first class, and the *Hero*, a third class battleship, were tried in 1884–'87; the remaining ones in 1893–'94.

First in order (Table A) come seven battleships, six of the first class and the *Hero* of the third class. The trials of these vessels were made in 1884–'87. The engines are vertical in each case, and the boilers are placed back to back against a middle-line bulkhead, and are fired athwartships.

The six first class battleships are fitted with vertical three-cylinder compound twin-screw engines, with one high-pressure and two low-pressure cylinders in each set, all of which* run at about 100 revolutions per minute with a stroke of 3 feet 9 inches, giving a piston speed of about 750 feet per minute. All, except the *Anson*, are fitted with twelve single-ended three-furnace boilers, with separate combustion chambers, loaded to 90 pounds per square inch. The *Anson* has eight single-ended four-furnace boilers, each fitted with two combustion chambers and loaded to 100 pounds per square inch.

The *Hero* is fitted with vertical two-cylinder compound twin-screw engines, running at 109 revolutions with a stroke of 3 feet, giving a piston speed of 654 feet per minute. This vessel has eight single-ended three-furnace boilers, loaded to 90 pounds per square inch, with separate combustion chambers. The ratio of high- to low-pressure cylinder volumes in all these seven battleships is 1 : 4. The boiler tubes are of iron, with the exception of those of the *Collingwood*, which are of brass. It may be said that since 1881 the use of brass tubes in the Royal Navy for the boilers of large vessels has been practically abandoned.

In 1889–'90 the first-class battleships *Nile* and *Trafalgar* were tried. They have vertical twin-screw triple-expansion engines, running at about 95 revolutions per minute, with a stroke of 4 feet 3 inches, giving a piston speed of about 800 feet per minute. They have six single-ended four-furnace boilers, loaded to 135 pounds per square inch. Each boiler of the *Nile* has one combustion chamber, common to the four furnaces, and steel tubes, while each boiler of the *Trafalgar* has two combustion chambers, two furnaces in each, and iron tubes.

The battleships of the Naval Defence Act (Figs. 1 and 2 and Table A, vessels bracketed *A*) have engines of the vertical three-cylinder triple-expansion type, the ratio of the volumes of the high to the low-pressure cylinders being 1 : 4.84. The revolutions at the full power for which the engines are designed, viz: 13,000 I.H.P., are 108 per minute, the stroke being 4 feet 3 inches, giving a maximum piston speed of 918 feet per minute. Having in view, however, the ordinary rates of steaming, when only a small por-

* Except those of the *Collingwood*, which run at 95 revolutions per minute with a stroke of 3 feet 6 inches, giving a piston speed of 665 feet per minute.

tion of the full power is developed, it was deemed advisable to arrange the valve gear for a maximum of 11,000 I.H.P. while keeping up the maximum speeds for which the engines were designed; and most of the vessels, as will be seen from the table, carried out their full power trials arranged in this manner. The *Royal Sovereign*, however, was tried as originally designed, and developed the 13,000 I.H.P. specified. The natural draft power is 9,000 I.H.P. The boilers in these vessels are eight in number, of the single-ended return-tube type, having four furnaces in each, uniting in two, three, or four separate combustion chambers.* These boilers, two in each water-tight compartment, are placed with their backs towards the longitudinal division, and are stoked from the wings.

In the two battleships bracketed *B* the cylinder ratio is 1 : 5.37, while the piston speed at full power—13,000 I.H.P.—is reduced to 840 feet per minute. The natural draft power is 9,000 I.H.P. The boilers are generally of the same description, and are similarly arranged. In the *Barfleur* and *Centurion* each pair of furnaces is led into a common combustion chamber.

Table B gives the particulars of the machinery of seven first class belted cruisers of the *Australia* class, tried in 1887–'88, of the *Blake* and *Blenheim*, tried in 1891–'92, of the first class cruisers of the *Edgar* type, built under the Naval Defence Act, and of the *Vulcan*, a torpedo depot ship designed about the same time as the *Blake*.

The vessels of the *Australia* class are fitted with horizontal twin-screw triple-expansion engines, running at 110 to 115 revolutions per minute, with strokes between 3 feet 6 inches and 3 feet 8 inches, giving piston speeds of between 770 feet and 840 feet per minute. The ratio of the high- to the low-pressure cylinder is 1 : 4.8. The boilers are cylindrical, double ended, with three furnaces at each end. The *Australia* and *Galatea* have one combustion chamber

* The *Hood*, *Empress of India*, *Repulse*, *Royal Sovereign* and *Ramillies* have one combustion chamber to each pair of furnaces. The *Royal Oak* has a separate combustion chamber to each wing furnace, the two middle furnaces uniting in a common combustion chamber. In the *Resolution* and the *Revenge* each furnace has a separate combustion chamber.

common to the six furnaces ; the remainder have three combustion chambers, a furnace from each end leading into each chamber. The steam pressures employed vary between 130 pounds and 137 pounds per square inch. These were the first triple-expansion engines fitted in the navy, and were adopted chiefly at the suggestion of the late Dr. Kirk ; although the *Victoria* and *Sans Pareil* had been specified to have triple-expansion engines, but the orders had not been placed. It will be seen from the table that at this period steel boiler tubes were becoming more general, and their adoption instead of iron tubes may be dated 1885–'86.

In the heavily-powered cruizers *Blake* and *Blenheim*, tested in 1891–'92, four sets of engines of the vertical twin-screw triple-expansion type are fitted ; two sets driving each shaft, every set being placed in a separate water-tight compartment. The revolutions at full power are 105 per minute; the stroke being 4 feet and the piston speed 840 feet per minute. The main boilers, six in number, are double-ended with four furnaces at each end. Those of the *Blake* have one combustion chamber common to the eight furnaces, divided by brickwork into six compartments, the two center furnaces from the same end leading into one compartment, and the wing furnaces leading separately into the others. The boilers of the *Blenheim* have four combustion chambers, two contiguous furnaces uniting in each.

In the first class cruisers built under the Naval Defence Act, the engines, of the three-cylinder vertical triple-expansion type, are arranged abreast in separate water-tight compartments, divided longitudinally by a bulkhead (Figs. 5 and 6). The boilers are arranged with stokeholds athwartships, separated from each other and from the engine rooms by transverse coal blocks. The dimensions of the cylinders are identical with those of the battleships (except the *Barfleur* and *Centurion*), so that the ratio of cylinder volumes, high to low pressure, is 1 : 4.84 ; but the revolutions at the full power, 12,000 I.H.P., are only 100 per minute. This, with a stroke of 4 feet 3 inches, gives a piston speed of 850 feet per minute. As in the battleships, the propellers and valve gear, in all except the *Edgar*, *Hawke* and *Grafton*, were subsequently arranged for a maximum power of 10,000 I.H.P.—the natural draft power in this instance—so as to enable them to steam more economically at the low powers usual when cruising. The *Edgar*, *Hawke* and *Grafton* made their full power trials at the powers for which they were originally designed, and satisfactorily developed these powers. In the vessels tried at the lower powers, as well as in the battleships similarly dealt with in this respect, the higher power could at any time be developed by suitable modifications in the valve gearing and propellers. The vessels bracketed *C* have four double-ended eight-furnace boilers, and one single-ended boiler for auxiliary purposes, placed in a recess at the forward end of the forward stokehold. Those bracketed *D* have eight single-ended four-furnace boilers. The furnaces are similarly arranged with respect to the combustion chambers in all the main boilers of these vessels, *i. e.*, two contiguous furnaces unite in a common combustion chamber.

The *Vulcan*, torpedo depot-ship, is also fitted with two sets of vertical triple-expansion engines, running at 100 revolutions per minute, with a stroke of 4 feet 3 inches, giving a piston speed of 850 feet per minute. The boilers, loaded to 155 lbs. per square inch, are similar to those of the *Blake*, except that they have three furnaces at each end. A single-ended auxiliary boiler is also fitted as in the *Blake* and *Blenheim*, but of larger size, to meet the requirements of the hydraulic boat-lifting appliances.

Table C gives the data for second class cruisers, the four of the *Mersey* type having been tried in 1885–86, and the others built under the Naval Defence Act.

The *Mersey* and *Severn*, *Thames* and *Forth*, are fitted with horizontal two-cylinder compound twin-screw engines, running at about 120 revolutions per minute with a stroke of 3 feet 3 inches, giving a piston-speed of 780 feet per minute. They have six three-furnace boilers, of the cylindrical direct-tube type, fitted in a fore-and-aft line, and loaded to 110 lbs. per square inch. With the single exception of those of the *Thames*, which have steel tubes, all these boilers have iron tubes. The ratio of cylinders is 1 : 2.8 and 2.9, the size of the low pressure cylinders being small for the full power. Thus, although not economical at full power, yet at the reduced powers developed on ordinary service a fair ratio of expansion can be used, and in addition there is a certain amount of weight saved—an important item in vessels of this class.

In the succeeding twenty-nine second-class cruisers, which were built under the Naval Defence Act, the machinery and armor-protection is arranged similarly to that in the first-class cruisers (Figs. 7 and 8). The engines are of the vertical three-cylinder triple-expansion type, the ratio of cylinder volumes being 1 : 4.88 in those bracketed *E*, and 1 : 5.03 in the remainder. The revolutions at the full power for which these engines are designed—viz., 9,000 I.H.P.—are 140 per minute, the stroke being 3 feet 3 inches, giving a piston speed of 910 feet per minute. The natural draft power of these vessels is 7,000 I.HP. The vessels bracketed *E*, as also the *Æolus* and the *Brilliant*, have three double-ended boilers and two single-ended boilers, with six and three furnaces in each respectively. The object of substituting two single-ended boilers for one double-ended is to provide boilers of suitable dimensions for auxiliary purposes. In the remaining vessels of this class eight single-ended three-furnace boilers are fitted. This subdivision of the boilers has certain advantages, which are considered to more than compensate for the additional weight involved, viz., absence of leaky shell joints, which occur in the long boilers by the racking strains set up; the ability to divide the boilers more nearly in the proportion of the power required to be developed; and, further, the spreading of the wear due to steaming for auxiliary purposes over the whole of the boilers rather than confining it to one or two of them.

In table D, which comprises third class cruisers, the last four are the only ones built under the Naval Defence Act. The *Scout* and *Fearless* have horizontal twin-screw two-cylinder compound engines running at 150 revolutions per minute at full power. The boilers are four in number, of the cylindrical direct-tube type, arranged in two compartments. The working pressure is 120 pounds per square inch, and the ratio of the cylinders 1 : 3.1.

Next in order are the six twin-screw cruisers of the *Archer* class tried in 1886–'87. These also are fitted with horizontal compound engines and with four three-furnace boilers of the cylindrical direct-tube type. The pressure was here increased to 130 pounds per square inch, with a consequent change of cylinder ratio of 1 : 3.4. The revolutions are 150 per minute, the stroke is 2 feet 9 inches, and the piston speed 825 feet per minute. The *Racoon*, tried in 1888–'89, has similar boilers, usually described as of the "Navy" type, but is fitted with horizontal triple-expansion engines, the boiler pressure being 140 pounds per square inch. These boilers have steel tubes.

The *Medea* and *Medusa* were ordered in 1887, and tried in 1888–'89. They have vertical twin-screw triple-expansion engines running at 140 revolutions per minute at full power; the stroke is 3 feet 3 inches, and the piston speed is 910 feet per minute. The boilers are four in number, double-ended, with three furnaces at each end, and one combustion chamber common to the six furnaces. They were fitted with iron tubes, and work at a pressure of 155 pounds per square inch. The combustion chambers are divided by brickwork into six separate parts.

These were followed in the same year by the *Marathon*, *Magicienne* and *Melpomene*, tested in 1889, which have the last horizontal engines of importance fitted in the Navy. They have twin-screw, triple-expansion engines and four double-ended boilers with three furnaces at each end. There are three combustion chambers to each boiler, one furnace from each end leading into the same chamber. The revolutions are about 140 per minute, the stroke is 3 feet, and the piston speed is 840 feet per minute. The steam-pressure is 155 lbs. per square inch.

About a year later the five cruisers of the *Katoomba* class were ordered for the protection of the floating trade in Australian waters, and were tried in 1890. In these vessels vertical engines are fitted as in all subsequent ships. The piston speed is lower than that in the preceding vessels, ranging from 800 to 815 feet per minute, the stroke being 2 feet 9 inches. There are four double-ended boilers with two furnaces at each end, and with one combustion chamber common to all four furnaces. In 1890 the four smaller cruisers, *Barrosa*, &c., were tested, having engines and boilers of the same type, but with only two instead of four boilers.

In 1888, the third class special-service cruisers, *Barham* and *Bellona*, were ordered. In these vessels, to obtain the high power required with a limited weight of machinery, a modified type of torpedo-boat engine with locomotive-boilers was employed. The engines are of the triple-expansion type, have a stroke of 2 feet 3 inches and were designed to run at 220 revolutions per minute at full power, the piston speed being 990 feet per minute. The boilers are six in number, and are wet-bottomed with a single fire-box; the working pressure is 155 pounds.

[This machinery was designed to develop 6,000 I.H.P. at the above mentioned piston speed.—Ed.]

In the four third class cruisers of the Naval Defence Act (end of Table D) a similar arrangement of machinery is preserved to that in the first and second class cruisers, except that, for the transverse coal-blocks separating the compartments, watertight divisional bulkheads are substituted. The engines are of the vertical twin-screw three-cylinder triple-expansion type, having a ratio of cylinders, high-to-low-pressure, of 1 : 4.97. At the full power for which the engines are designed—7,500 I.H.P.—the revolutions are 160 per minute, the stroke being 2 feet 9 inches, giving a piston speed of 880 feet per minute. The natural draft power is 4,500 I.H.P. They are fitted with four double-ended boilers, having two furnaces at each end, and a separate combustion chamber to each furnace. The boiler pressure is 155 pounds.

Table E relates to the type known as torpedo gunboats, the first of which was the *Rattlesnake*, tried in 1887. These vessels are fitted with vertical triple-expansion engines of torpedo-boat type, and with four wet-bottomed locomotive boilers. The fire box of the *Rattlesnake* is almost completely divided by flat water legs into two fire boxes. The other three vessels of this class are the *Grasshopper*, the *Sandfly* and the *Spider*, which were tested in 1889. The boilers of the latter two are like those of the *Rattlesnake*, but have an undivided fire box, whilst those of the *Grasshopper* are a modification of the type known as "pinnace" boilers; that is, the fire boxes are circular instead of the usual locomotive form. The engines have the same stroke as those of the *Rattlesnake*, viz: 1 foot 6 inches, but they make 300 revolutions, those of the latter being 310 per minute. The piston speed is thus 900 feet against 930 feet per minute in the *Rattlesnake*. The steam pressures employed are: *Rattlesnake*, 140 pounds; *Sandfly* and *Spider*, 145 pounds, and *Grasshopper* 150 pounds per square inch.

The *Sharpshooter* class, tested in 1889–'90, are larger and more powerful, the stroke being increased to 1 foot 9 inches, but the revolutions are only 250 per minute; giving a piston speed of 875 feet per minute. The wet-bottomed locomotive boiler is used in all of the eleven vessels of this class. The number of boilers is four and each fire box is undivided.

[The original design for this machinery contemplated 4,500 I.H.P.—Ed.]

In the torpedo gunboats of the Naval Defence Act, Fig. 3, the engines are arranged as in the cruisers, viz., abreast in watertight compartments divided by a middle-line bulkhead, while the boilers are arranged with stokeholds athwartships in two watertight compartments, which in those bracketed *F* are situated forward of the engines. In those bracketed *G*, the two stokehold compartments are placed one forward and one aft of the engines, an arrangement which facilitates supervision and reduces vibration. The engines are of the three-cylinder triple-expansion type, with a cylinder ratio of 1 : 5.37. The revolutions at full power, 3,500 I.H.P. (*Speedy*, 4,500 I.H.P.), are 250 per minute, and the stroke is 1 foot 9 inches, the piston speed being 875 feet per minute. The natural draft power is 2,500 I.H.P. The boilers in all these vessels, except the *Speedy*, are of the locomotive wet-bottomed type, four in number, having (except in the *Gossamer*) the furnace divided in the middle by a water division. In the *Gossamer* no such water division exists, the boilers being similar to those of this class built prior to the Naval Defence Act. The tubes in the boilers of the *Gossamer* and *Gleaner* are smaller than those in the later vessels. In the *Speedy*, Fig. 4, eight Thornycroft water-tube boilers are fitted, four in each compartment, arranged two abreast, with the stokehold dividing them.

The steam pressure is 155 pounds in all except the *Speedy*, when the working pressure is 210 pounds.

The general characteristics of the machinery of the vessels built under the Naval Defence Act having been briefly described, a few comparative remarks may be of interest. As regards steam pressure, it was not considered advantageous to exceed 155 pounds per square inch, as employed in the *Blake*, the *Blenheim*, and in several other vessels ordered prior to the date of the Act; and this pressure is now general in the naval service for boilers of the water-tank type. In the water-tube boilers of the *Speedy* a boiler pressure of 210 pounds per square inch is employed.

An analysis of the weights of machinery and boilers shows that in the eight battleships bracketed *A* the machinery as a whole is lighter per horse power than in the six battleships of the *Admiral* class built prior to the Naval Defence Act, and this increase in horse power per ton is slightly greater when comparing the boiler weights alone. The auxiliary machinery is considerably more powerful in the battleships last constructed than in the vessels of the *Admiral* class, and is therefore heavier; consequently the saving in weight, arising from the employment of triple-expansion engines and a higher steam pressure, is even greater than the figures appear to show. In addition to this saving in weight, there is considerable economy in coal consumption in the later vessels as compared with the earlier type, which had compound engines.

Comparing the *Barfleur* and *Centurion* with the earlier vessels, it will be observed that the saving in weight is less pronounced. This arises particularly from the nature of the service required of these vessels, which are intended for employment on distant stations, where the duration of steaming will be greater and the facilities for repairs less.

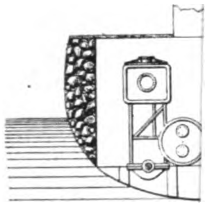
In comparison with the weights of that of the *Nile* and of the *Trafalgar*, the machinery of the battleships built under the Naval Defence Act is seen to be heavier. Some of this difference is explained by the heavier auxiliary machinery fitted in the latter vessels, but it must be mainly attributed to the increased weights of the boilers provided, to secure greater subdivision of the boiler power, increased facilities for access and repair, and greater durability.

Comparing the first class cruisers built under the Naval Defence Act with the seven previously referred to, tried in 1887–'88, it will be observed that a slight increase in power for tonnage is shown at the natural draft powers, which is not maintained when the forced draft powers are compared. This arises chiefly from the altered ratio which exists between the natural draft and forced draft powers in the two instances. The object aimed at in the design of the first class cruisers built under the Naval Defence Act, was to maintain a high continuous steaming power, less regard being paid to the possible performances for short periods under forced draft.

A comparison of the weights of the second class cruisers (Table C) built under the Naval Defence Act with the five third class cruisers bracketed H, Table D, which are the type from which these vessels were developed, exhibits the same general features as the first class cruisers, though somewhat more marked, the horse power at forced draft per ton of machinery, as well as of boilers, being considerably less in the later vessels than in the earlier. This arises from the causes already mentioned in regard to the first class cruisers. It is not proposed to carry this comparison further, as what has been mentioned will serve to show the general principles kept in view in determining the weights of machinery of these later vessels.

The machinery of all the battleships built under the Naval Defence Act is arranged in a similar manner, viz., in six separate water-tight compartments, the twin engines being abreast, and the boilers stoked being athwartships. This is illustrated in Figs. 1 and 2. In all the cruisers, the engines are arranged on a similar plan, but the boilers are in two compartments, stoked in the fore-and-aft direction as illustrated in Figs. 5 to 8. It is, of course, well understood that in the design of the machinery for war ships, special attention has to be paid to requirements arising from the necessity of its protection from damage in action. This generally limits the stroke that can be employed.

As regards the details of the machinery of the Naval Defence Act vessels, space only permits of brief reference to them. The barrels of the cylinders in all except the torpedo gunboats, are



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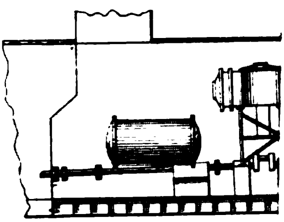

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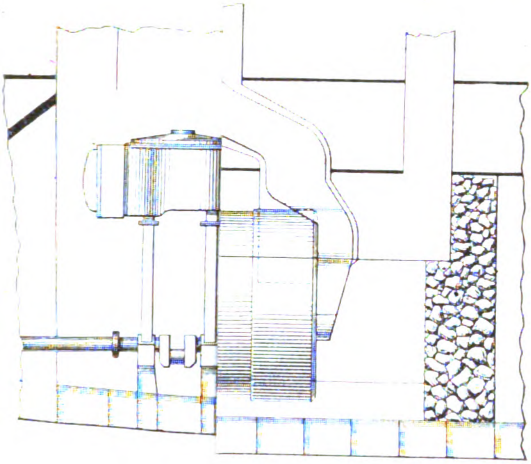

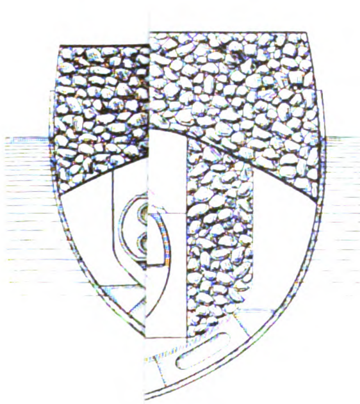

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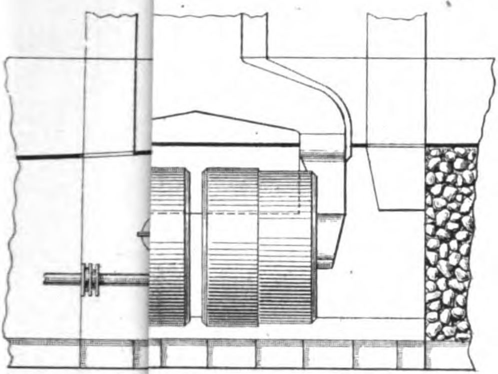

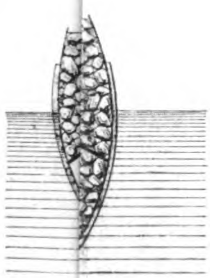


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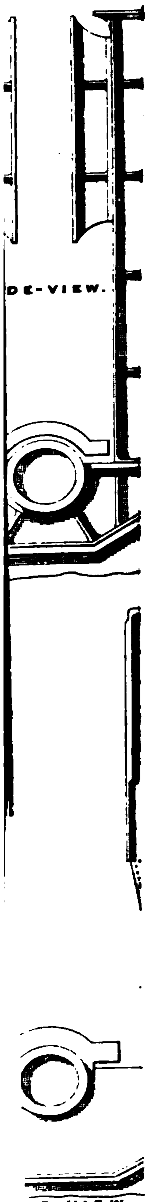

DE-VIEW.
DE-VIEW.

jacketed and fitted generally with forged steel liners in the high pressure cylinders, and either forged steel or hard close grained cast iron liners in the intermediate and low pressure cylinders. The engine standards, in all except the torpedo gunboats, consist of one cast steel or iron back column, and two forged steel front columns for each cylinder. There are occasional deviations from this practice, as will be observed by reference to the illustrations of the standards fitted in several of the battleships and first class cruisers, where it is seen that the back and front columns of the *Royal Arthur* are of cast-steel of I section, four to each cylinder, whilst those of the *Gibraltar* and *Royal Oak* are of the forged-steel pillar type with bracing. Table F, column 3, gives the weights of these, including the guide-faces. Although there is nothing in the table to indicate any saving in weight by employing forged steel rather than cast steel for the columns, it is interesting as showing the variation in the weights of these parts, and where a saving in weight might occasionally be effected. The main bearing frames are generally of cast steel, and are in most cases united by distance pieces between consecutive frames. The weights of these are given in column 4, Table F. The pistons are of the steel conical type, having generally in the larger vessels wrought steel junk rings, and for the most part wide single packing rings of either phosphor-bronze or cast iron held out by tempered steel springs. In the torpedo gunboats, Ramsbottom rings of Perkins metal are generally fitted. The crank shafts and propeller shafting are hollow and of forged steel. The condenser cases are of rolled or cast brass. In all, except the torpedo gunboats, separate auxiliary condensers are fitted for taking the auxiliary machinery exhaust. For providing fresh water for "make-up" purposes, reserve fresh water tanks are fitted, in addition to evaporators and distilling plant.

The valve gear in all the seventy vessels consists of the ordinary link motion, working in most cases piston slide valves in the high pressure, either piston or flat slide valves for the intermediate pressure, and usually flat slide valves for the low pressure engines. The air pumps are in all cases worked off the main engines, but separate circulating engines and pumps of the centrifugal type are fitted for the condensers. For the purpose of controlling the boilers more readily, especially under forced draft, separate uptakes are fitted to each combustion chamber, with hinged dampers workable from the stokehold floor in each uptake.

For the various auxiliary engines fitted in these vessels, open engines have been generally fitted, instead of the closed type formerly used for the same purposes, also a lower speed of revolution has been adopted. Extra weight has, as already mentioned, been incurred on this account, but it is more than compensated by the greater durability of the machinery. With regard to the boilers of these later vessels, it will be observed that those of the single-ended rather than of the double-ended type have been given increased plate heating surfaces, due to subdividing the combustion chamber, which has the further effect of subdividing the tube plate area. It is considered that these modifications, though increasing the weight of the boilers, ensures stronger and better steaming boilers of a kind more suitable to the varied requirements of Naval service, as previously explained in detail. Representations from the service afloat have been strongly in favor of this change.

As regards the question of leaky boiler tubes, its great importance may make a few remarks excusable. Experience has shown that this defect primarily arises from overheating, due either to forced combustion or to the presence of oily or other deposits on the surfaces exposed to heat; and that this may be mitigated (1) by interposing plate heating surface to absorb the heat before the flames impinge on the tube plate and the tube ends; (2) by the employment of a tube ferrule so constructed as to prevent the flame from impinging on the tube ends and tube plates, and also to prevent conduction of heat to those parts by means of the air space between them and the protecting ferrule; (3) by reducing to a minimum the oil employed for internal lubrication, and by the employment of filters or other processes for its extraction. The employment of all these means has reduced the leaky tube question to one of insignificant character compared with that which it at one time assumed, so that one of the evils consequent on the use of forced draft has been to a large extent successfully combated. In the smaller vessels a less objectionable difficulty has arisen, viz., the gradual closing up of the ferrules at the tube ends by scoriæ. This appears to depend on the description of coal used, and considerable variation in its amount has been observed. In the return-tube boilers which are fitted in most vessels no trouble arises from this cause, since the tubes are of fairly large diameter. In the locomotive boiler, however, where the tubes are small, some trouble has been experienced; but experiments are being made with the view of minimising it. A different type of tube ferrule, more costly than that mentioned, has also been tried satisfactorily in two boilers of the *Medusa*, and will be fitted in one of the new battleships.

As already mentioned, water-tube boilers for vessels other than torpedo boats have been introduced in the *Speedy*, one of the torpedo gunboats built under the Naval Defence Act. Table E gives the particulars of the performance of this vessel, and the corresponding figures for vessels of the same class will enable a comparison to be instituted. There is seen to be a material increase in the horse power per ton of machinery and boilers. As regards the working capabilities of this type of boiler, immunity from leaky tube ends, the readiness with which steam can be raised, and the absence of all special precautions in their stoking, are points in their favor. On the other hand, the small quantity of water in them, and the rapid evaporation entail considerable attention in feeding; further, their steam space is not great, and care has to be exercised to avoid priming. The small diameter of the tubes precludes the use of salt water for feed, and, further, these boilers exhibit a greater disposition than the water-tank boilers to prime if any cause gives rise to it.

Although not strictly within the range of this paper, possibly a few words on what is now being done in respect of other boilers of the water-tube type may be of interest. In the *Sharpshooter* (Table E), the boilers of the locomotive type have been removed and replaced by eight water-tube boilers of the Belleville type. It cannot be said that any increase in horse power per ton has accrued on this account, but an advantage as regards ability to continuously maintain a high power is shown, arising more particularly from the fact that there are no tube ends to choke up as in the other type of boiler, and that the whole of the fire side of the heating surfaces is readily cleaned when under way. Particulars of the performances of the *Sharpshooter* fitted with Belleville boilers are given in Table E. It is seen that an increase in weight is involved by their installation above that of the boilers at first fitted, but these latter never generated satisfactorily the required power, even on trials when new. A more just comparison might be instituted between these figures and those of the later vessels of the class in which the boilers have been increased in size and modified in other ways, in order to enable them to attain their intended power satisfactorily. Compared in this way, the boiler weights do not exceed those of the locomotive type. It is to be observed from the air pressures employed, that little or no forcing was resorted to in obtaining the power recorded. In view of the ability of these boilers to maintain a high rate of steaming for considerable periods, and their tactical and other advantages, it has been decided to fit them in the two first class cruisers *Powerful* and *Terrible* now building.

An extended use of the water-tube type of boiler is also being made in the torpedo boat destroyers built and under construction. The table below gives a few particulars of what has been accomplished with these boilers. These figures exhibit the great capability of the boilers to produce steam, but the question of their durability is one that can only be decided after longer experience.

Ship.	Description of boiler.	I.H.P.	Grate area.	Heating surface.	Weight of boiler, mountings, furnace fittings, brickwork, and water to working level.	I.H.P. per ton.
			Sq. feet.	*Sq. feet.*	*Tons.*	
Speedy...	Thornycroft...	4,704	205	17,700	87.45	53.7
Daring..	" ...	4,409	189	8,892	48.5	90.9
Ferret...	Normand......	4,774	154	8,112	50.7	94.1
Hornet...	Yarrow.........	3,884	172.8	8,216	44.8	86.7

An experiment has been made in another of the vessels built under the Naval Defence Act, viz., in the *Gossamer*, which has had the Martin system of induced draft fitted to the two forward boilers, the two after boilers retaining their forced draft fittings, thus enabling a comparison to be made between the two systems. The trials have been numerous and prolonged, and experience at sea has also been obtained during the manœuvres of 1893 and 1894. A brief summary of the most important conclusions arrived at may enable an idea to be formed of the merits of the system. The draft can be accelerated equally by either system, but a fan of considerably larger dimensions is required for the induced draft, and this occupies a disadvantageous position by being placed in the uptake. As regards absence of leaky tube ends, no superiority can be claimed for induced draft. The formation of scoriæ at the tube ends occurs apparently to the same extent with both systems. With induced draft, the fitting of a separate fan in the uptake of each boiler places the boilers under better control for cleaning fires, etc. The open stokehold, consequent upon induced draft, enables much freer communication to be kept up with the other machinery spaces. The temperature of the stokeholds is lower, and the stokers work generally in greater comfort; as a consequence, the stoking is better, and this, combined with the maintenance of more perfect control over the fires, helps to reduce the coal consumption, which the trials show to be lower. This system of draft is being fitted to one of the new first-class battleships now under construction, and to another vessel of the gunboat class.

Several of the vessels forming the subject of this paper have been sufficiently long in commission to have made passages at powers approaching their natural draft; and these indicate that the vessels are capable of maintaining, without any special effort and with their own complement of stokers, a high percentage of their natural draft powers. A few of these trials may be cited: The *Royal Sovereign*, on a passage from Plymouth to Gibraltar, maintained 8,180 I.H.P. for seventy-two hours, the coal consumed being 1.84 pounds per hour. The *Royal Arthur*, on a passage from Callao to Coquimbo, maintained 8,821 I.H.P. for seventy-two hours with a coal consumption of 1.85 pounds per I.H.P. per hour. The *Sans Pareil*, on a passage from Malta to Volo, de-

TABLE A.—

Ship.	I.H.P. on trial, natural draft.	Air-pressure.	I.H.P. on trial, forced draft.	Air pressure.	Weights. Machinery complete.	Weights. Boilers	Surfaces. Grate.	Surfaces. Total heating.
		Inch.		*Ins.*	*Tons.*	*Tons*	*Sq. ft.*	*Sq. ft.*
Benbow	8,662	..	10,853	1.3	1,274	717.2	798	20.500
Howe	7,730	..	11,725	2.4	1,151	608.4	756	20.726
Rodney	8,259	..	11.158	1 4	1.159	636 5	756	20.726
Camperdown	8,605	..	11,739	2.4	1,276	695 5	826	20,500
Collingwood	8,100	..	9,570	1.1	1,244	736 1	810	20,776
Anson	8 305	0 2	12,585	1 9	1,149	612.1	797	20,296
Average	8,277	..	11,271	1.7	1,209	667 6	790	20.587
Nile	9,106	0.5	12,109	1.7	1,017	537.7	600	19 560
Trafalgar	8.520	0 5	12,822	2.1	1 013	501.2	659	18.300
Average	8,813	0.5	12,465	1.9	1,015	519.4	629	18.930
Hero	4.351	..	6,162	1 0	817	483.9	507	14.377
A *Hood*	9,539	0 4	11,446	1.0	1,155	583.4	734	20,034
A *Empress of India.*	9,508	0.5	11,625	1.0	1,149	581.1	728	20 034
A *Repulse*	9,588	0.4	11,314	0 9	1,149	586.6	718	20,034
A *Royal Sovereign*	9,661	0.4	13 363*	1.6	1,159	597.9	718	20,034
A *Ramillies*	9,443	0 2	11.571	0 3	1,159	587.7	711	20,132
A *Resolution*	9,248	0 2	11,402	0.6	1,161	608 1	765	21,178
A *Revenge*	9 220	0.2	11,536	0 4	1,158	607.2	765	21,178
A *Royal Oak*	9,235	0.2	11,608	0.9	1,216	610.3	710	20,160
Average	9,430	0.3	11,500	0.8	1,163	595 3	731	20,348
B *Barfleur*	9,934	..	13 163	1.7	1,302	668.4	774	22,317
B *Centurion*	9.711	0 18	13.214	1 5	1,307	660.6	774	22.317
Average	9,822	0.09	13,188	1.6	1,304	664.5	774	22.317

* Omitted from average.

BATTLESHIPS.

I.H.P. per ton.				I.H P. per square foot of grate.		Heating surface per I.H.P.		Boiler-tubes material.
Machinery complete.		Boilers.		Natural draft.	Forced draft.	Natural draft,	Forced draft.	
N. D.	F. D.	N. D.	F. D.			*Sq. feet.*	*Sq. feet.*	
6.8	8.5	12.0	15.1	10.8	13.6	2.3	1.8	Iron.
6.6	11 8	11 0	19.2	10.2	15 5	2.6	1.7	"
7.1	9.6	12.9	17.5	10 9	14.7	2.5	1.8	"
6.7	9 2	12.3	16.8	10 4	14 2	2.3	1.7	"
6.5	7.6	11.0	13.0	10.0	11.8	2.5	2.1	Brass.
7.2	10.9	13.5	20.5	10 4	15.7	2.4	1.6	Iron.
6 8	9 3	12 4	16.9	10 4	14.2	2.4	1 8	..
8 9	11.9	16.9	22 5	15.1	20.1	2.1	1.6	Steel.
8 4	12.6	17 0	25.5	12.9	19.4	2.1	1.4	Iron.
8 6	12 2	16.9	24.0	14 0	19.7	2.1	1.5	..
5 3	7 5	8.9	12 7	8.5	12.1	3.3	2.3	Iron.
8.2	9.9	16.3	19.6	13.0	15 6	2.1	1.7	Steel.
8 2	10.1	16 3	20.0	13.0	15.9	2.1	1.7	"
8 3	9 8	16.3	19.3	13.3	15.75	2.0	1.7	"
8.3	11.5	16.1	22.3	13.4	18.6	2.0	1.5	"
8.1	9 9	16.0	19.7	13.2	16 2	2.1	1.7	"
8.0	9.8	15.2	18.7	12 0	14.9	2.2	1.8	"
8.0	9 9	15.1	19.0	12.0	15.0	2.2	1.8	"
7.6	9.5	15 1	19.0	13.0	16.3	2.1	1.7	"
8.1	10.0	15.8	19.7	12.9	16.0	2 1	1.7	..
7.6	10.1	14.8	19 7	12 8	17.0	2 2	1.7	Steel.
7 4	10.1	14.7	20.0	12.5	17.0	2.2	1.7	"
7.5	10 1	14.7	19 8	12.6	17.0	2 2	1.7	..

TABLE B.—

Ship.	I.H.P. on trial, natural draft.	Air pressure.	I.H.P. on trial, forced draft.	Air pressure.	Weights. Machinery complete.	Weights. Boilers.	Surfaces. Grate.	Surfaces. Total heating.
		Inch.		*Ins.*	*Tons.*	*Tons.*	*Sq. ft.*	*Sq. ft.*
Australia	5,810	Nil	8,876	1.7	780	413.2	513	15.191
Orlando	5,628	...	8,739	1.0	795	430.2	548	15.795
Undaunted	5,682	...	8,670	1.8	792	425.6	548	15.795
Narcissus	5,353	...	8,589	2.0	770	434.8	535	15.524
Galatea	5,871	...	9,220	1.1	786	434.3	495	15.191
Immortalite	6,090	...	8,738	2.0	772	440.0	492	15,190
Aurora	5,706	...	9,013	1.2	818	457.5	471	15,832
Average	5,734	...	8,835	1.5	787	433.6	514	15.502
Blake	14,525	0.4	...	...	1,017	787.2	871	27,192
Blenheim	14,924	0.2	21,411	2.0	1,013	754.0	1,135	31.073
Average	14,724	0.3	21,411	2.0	1,015	770.6	1,003	29,132
C { *Edgar*	10,172	0.3	12,550	0.7	1,135	639.8	849	24.879
C { *Hawke*	10,761	0.3	12,521	0.4	1,144	628.5	812	24,879
C { *Endymion*	10,662	0.1	...	...	1,129	654.2	847	25.173
C { *Gibraltar*	10,445	0.1	...	...	1,178	606.9	746	24.754
C { *St. George*	10.585	0.1	...	...	1,155	670.7	847	25,173
D { *Royal Arthur*	10,086	0.4	...	...	1,186	663.1	731	24.828
D { *Crescent*	10,378	...	...	...	1,188	661.1	860	24,784
D { *Grafton*	10,956	0.4	13,483	1.1	1,164	644.7	875	24,880
D { *Theseus*	10,608	0.4	...	...	1,170	650.4	751	24,828
Average	10 517	0.2	12,851	0.7	1,161	646.6	812	24,908
*Vulcan**	8.167	0.4	12.062	1.8	988	495.5	564	15,861

* Torpedo depot ship.

FIRST CLASS CRUISERS.

I.H.P. per ton.				I.H.P. per square foot of grate.		Heating surface per I.H.P.		Boiler tubes, material.
Machinery complete.		Boilers.						
N. D.	F. D.	N. D.	F. D.	Natural draft	Forced draft.	Natural draft.	Forced draft.	
						Sq. ft.	*Sq. ft.*	
7.4	11.3	14.0	21.4	11.3	17.3	2.6	1 7	Steel.
7.0	10.9	13.0	20.3	10.2	15.7	2.8	1.8	"
7.1	10.9	13 3	20.4	10.3	15.8	2.7	1 8	"
6.9	11.1	12 3	19 7	10.3	16.0	2.9	1.8	Steel. Stay, Iron.
7.4	11.7	13.5	21.2	11.9	18.6	2.5	1 6	Iron.
7.8	11.3	13.8	19.8	12.3	17.7	2.5	1.7	Steel. Stay, Iron.
6.9	11.0	12.4	19.7	12.1	19.1	2.7	1.7	Steel.
7.3	11.2	13.2	20.7	11.2	17.2	2.7	1.7	
9.3	...	18.4	...	16.6	...	1.8	...	Steel.
9.6	13.8	19.7	28.3	13.1	18.8	2.0	1.4	"
9.4	13.8	19.0	28.3	14.8	18.8	1.9	1 4	
8.9	11.0	15.8	19.6	12 0	14.7	2.4	1.9	Steel.
9.4	10.9	17 1	19.9	13.2	15 5	2.3	1 9	"
9.4	...	16.3	...	12.5	...	2.3	...	"
8.8	...	17.2	...	13.9	...	2.3	...	"
9.1	...	15.7	...	12 5	...	2.3	...	"
8.4	...	15.2	...	13.7	...	2.4	...	"
8.7	...	15.7	...	12.2	...	2.3	...	"
9.4	11.5	17.0	20 9	12.5	15.4	2.2	1.8	"
9.0	...	16.3	...	14.0	...	2.3	...	"
9.0	11.1	16.2	20.1	12.9	15.2	2.3	1.9	
8.2	12.2	16.4	24.3	14.4	21.3	1.9	1.3	Steel.

TABLE C.—

	Ship.	I.H.P. on trial, natural draft.	Air pressure	I.H.P. on trial, forced draft.	Air pressure.	Weights. Machinery complete	Weights. Boilers	Surfaces. Grate.	Surfaces. Total heating.
			Inch.		*Inches.*	*Tons.*	*Tons.*	*Sq. ft.*	*Sq. ft.*
	Mersey	4,515	Nil	6,628	2.0	552	307.9	399	11,711
	Severn	4,603	"	6,335	2.0	552	306.6	399	11,711
	Thames	4,162	"	5,886	1.4	563	311.4	377	11,444
	Forth	3.590	"	5.756	1.9	568	320.2	380	11,393
	Average	4,217	Nil	6,151	1.8	559	311.0	388	11.565
	Andromache	7,234	0.5	9,044	1.3	714	435.5	560	15.389
	Apollo	7.488	0.3	9,226	0.8	715	432.5	560	15,389
	Indefatigable	7,349	0.4	9,047	0.9	735	422.2	588	15,725
	Intrepid	7,522	0.4	9,489	1.2	739	420.9	588	15.725
	Iphigenia	7,251	0.2	9.337	0.8	736	418.0	546	15,725
	Latona	7,261	0.4	9,455	1.3	728	433.6	584	15.512
	Melampus	7,684	0.4	9,135	1.2	713	431.7	588	15.512
	Naiad	7.547	0.4	9,261	1.2	703	425.2	584	15,512
	Pique	7,515	0.2	9,258	1.0	751	422.8	574	15.704
E	*Rainbow*	7,879	0.3	9.741	0.7	751	422.8	574	15,704
	Retribution	7,645	0.2	9,367	0.6	751	422.8	574	15.704
	Sappho	7,301	0.3	9,618	0.7	727	420.7	593	15.754
	Scylla	7.614	0.2	9,280	0.8	727	421.0	593	15.754
	Sirius	7,491	0.2	9,281	0.8	742	428.0	602	15.918
	Spartan	7,832	0.3	9,254	0.9	.....	428.0	581	15,918
	Sybille	7.598	0.1	9,524	0.5	726	425.7	604	16,039
	Terpsichore	7,133	0.2	8,825	0.9	718	402.3	573	15,470
	Thetis	7,034	0.5	9.496	0.7	718	402.3	553	15.470
	Tribune	7,523	0.1	9,101	0.5	718	402.3	553	15,470
	Æolus	7,504	0.1	9.315	0.7	....	417.0	555	15,947
	Brilliant	7,522	0.1	9,180	1.1	732	439.0	556	15.947
	Bonaventure	7,423	0.4	9,365	0.8	797	469.4	553	15,600
	Cambrian	7,164	0.4	9,259	1.0	776	455.0	567	15,600
	Charybdis	7,109	0.5	9,136	1.6	.....	488.3	574	15,304
	Flora	7.187	0.4	9.008	1.3	.....	458.4	580	15,788
	Astræa	7,603	0.4	9.151	1.4	813	466.9	593	15,287
	Fox	7,034	0.3	9,063	1.3	...	460.0	600	15,655
	Forte	*	...	...	...	...	445.2	584	15,600
	Hermione	7.393	0.4	9,264	0.9	795	481.4	573	15.440
	Average	7.437	0.3	9.274	0.9	740	434.4	575	15,641

* Not yet tried.

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear, and all fittings in boiler rooms; also water in boilers at working level.

SECOND CLASS CRUISERS.

I H.P. per ton.				I.H.P. per square foot of grate.		Heating surface per I.H.P.		Boiler tubes material.
Machinery complete.		Boilers.						
N. D.	F. D.	N. D.	F. D.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	
						Sq. ft.	*Sq. ft.*	
8.1	12.0	14.6	21.5	11.3	16.6	2.5	1.7	Iron.
8.3	11.4	15.0	20.7	11.5	15.8	2.5	1.8	"
7.3	10.4	13.3	18.9	11.0	15.6	2.7	1.9	Steel.
6.3	10.1	11.2	18.0	9.4	15.1	3.1	1.9	Iron.
7.5	11.0	13.5	19.7	10.8	15.8	2.7	1.8	...
10.1	12.6	16.6	20.7	12.9	16.1	2.1	1.7	Steel.
10.4	12.9	17.3	21.3	13.3	16.4	2.0	1.6	"
9.9	12.3	17.3	21.4	12.5	15.3	2.1	1.7	"
10.1	12.8	17.8	22.5	12.8	16.1	2.0	1.6	"
9.8	12.6	17.3	22.3	13.2	17.1	2.1	1.6	"
9.9	13.0	16.7	21.8	12.4	16.1	2.1	1.6	"
10.7	12.8	17.8	21.1	13.0	15.5	2.0	1.7	"
10.7	13.1	17.7	21.7	12.9	15.8	2.0	1.6	"
10.0	12.3	17.7	21.8	13.0	16.1	2.0	1.7	"
10.4	12.9	18.6	23.0	13.7	16.9	2.0	1.6	"
10.1	12.4	18.0	22.1	13.3	16.3	2.0	1.6	"
10.0	13.2	17.3	22.8	12.3	16.2	2.1	1.6	"
10.4	12.7	18.0	22.0	12.8	15.6	2.0	1.7	"
10.0	12.5	17.5	21.7	12.4	15.4	2.1	1.7	"
...	...	18.3	21.6	13.4	15.9	2.0	1.7	"
10.4	13.1	17.8	22.3	12.5	15.7	2.1	1.6	"
9.9	12.2	17.7	21.9	12.4	15.4	2.1	1.7	"
9.8	13.2	17.4	23.6	12.7	17.1	2.1	1.6	"
10.4	12.6	18.7	22.6	13.6	16.4	2.0	1.7	"
...	..	18.0	22.3	13.5	16.7	2.1	1.7	"
10.2	12.5	17.1	20.9	13.5	16.5	2.1	1.7	"
9.3	11.7	15.8	19.5	13.4	16.9	2.1	1.6	"
9.2	11.9	15.7	20.3	12.6	16.3	2.1	1.6	"
...	...	14.5	18.7	12.4	15.9	2.1	1.6	"
...	...	15.6	19.6	12.4	15.5	2.1	1.7	"
9.3	11.2	16.2	21.7	12.8	15.4	2.0	1.6	"
...	...	15.3	19.7	11.7	15.1	2.2	1.7	"
...	...	...	...	...	...	...	...	"
9.0	11.6	15.3	19.2	12.9	16.1	2.0	1.6	"
10.0	12.5	16.5	20.7	12.9	16.1	2.1	1.6	"

TABLE D.—

Ship.	I.H.P. on trial, natural draft.	Air pressure.	I.H.P. on trial, forced draft.	Air pressure.	Weights.		Surfaces.	
					Machinery complete.	Boilers.	Grate.	Total heating.
		Inch.		*Ins.*	*Tons.*	*Tons.*	*Sq. ft.*	*Sq. ft*
Scout	2,162	Nil	3,370	1 5	291	174.1	207	6,362
Fearless	2,241	"	3,360	2.0	302	185 8	217	6,439
Average	2,201	"	3,365	1 7	296	179.9	213	6.400
Archer	2,220	Nil	3,850	1.0	354	206.8	209	6,836
Brisk	2,614	"	3,816	0.9	354	206.2	209	6,836
Cossack	2,335	"	3,700	1.0	354	208.1	228	6,836
Mohawk	2,577	"	3 398	0.9	352	202.1	228	6,836
Porpoise	2,476	"	3,944	1.0	353	206.2	234	6,836
Tartar	2.554	"	3,824	0.9	355	204.9	228	6,836
Average	2,462	"	3,754	0.9	353	205.7	222	6,836
Racoon	2,647	Nil	4,613	1.5	395	226.6	244	7,878
H { *Medea*	6,027	0.5	9,185	2.2	624	373.5	468	12,628
H { *Medusa*	6,144	...	9,435	1.9	614	363 8	525	12,628
H { *Marathon*	6,530	0.4	8,786	2.3	624	360.2	535	13,616
H { *Magicienne*	5.408	0.6	9,280	2.2	627	365.0	535	13 616
H { *Melpomene*	6,215	0.4	9,653	1.7	649	369 0	570	13,830
Average	6,065	0.5	9,268	2.0	627	366.3	526	13,264

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear, and all fittings in boiler rooms; also water in boilers at working level.

THIRD CLASS CRUISERS.

I.H.P. per ton.				I.H.P. per square foot of grate.		Heating surface per I.H.P.		Boiler-tubes material.
Machinery complete.		Boilers.						
N. D.	F. D.	N. D.	F. D.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	
						Sq. ft.	*Sq. ft.*	
7.4	11.6	12.4	19.3	10.4	16.2	2.9	1.9	Iron.
7.4	11.1	12.1	18.1	10.3	15.4	2.8	1.9	"
7.4	11.3	12.2	18.7	10.3	15.8	2.8	1.9	..
6.2	10.8	10.7	18.6	10.6	18.4	3.0	1.7	Iron.
7.3	10.7	12.6	18.5	12.5	18.2	2.6	1.7	"
6.6	10.4	11.2	17.7	10.2	16.2	2.9	1.8	"
7.3	9.6	12.7	16.8	11.3	14.8	2.6	2.0	"
7.0	11.1	12.0	19.0	10.5	16.8	2.7	1.7	"
7.1	10.7	12.4	18.6	11.2	16.7	2.6	1.7	"
6.9	10.6	12.0	18.3	11.1	16.9	2.7	1.8	..
6.7	11.6	11.7	20.4	10.8	18.9	2.9	1.7	Steel.
9.6	14.7	16.1	24.6	12.8	19.6	2.0	1.3	Iron.
10.0	15.3	16.9	26.0	11.7	17.9	2.0	1.3	"
10.4	14.0	18.1	24.4	12.2	16.4	2.0	1.5	Steel.
8.6	14.7	14.8	25.4	10.1	17.3	2.5	1.4	"
7.5	14.8	16.9	26.1	10.9	16.9	2.2	1.4	Iron.
9.2	14.7	16.5	25.3	11.5	17.6	2.2	1.4	..

TABLE D.—

Ship.	I.H.P. on trial, natural draft.	Air-pressure.	I.H.P. on trial, forced draft.	Air pressure.	Weights.		Surfaces.	
					Machinery complete.	Boilers.	Grate.	Total heating.
		Inch.		*Ins.*	*Tons.*	*Tons.*	*Sq. ft.*	*Sq. ft.*
Barrosa	2,133	0.4	3,111	1.4	248	151.3	201	4,529
Barracouta	1,920	0.9	...	...	247	148.3	195	4,529
Blanche	1,832	0.6	2,849	1.4	245	142.1	188	4,650
Blonde	1,918	0.5	2,762	1.7	245	142.3	188	4,650
Average	1,951	0.6	2,907	1.5	246	146.0	193	4,589
Katoomba	4,538	0.5	...	...	497	288.8	377	10,150
Mildura	4,543	0.9	...	...	505	289.0	319	10,150
Wallaroo	4,574	0.5	...	...	505	289.0	376	10,150
Tauranga	4,651	0.6	...	...	541	281.5	378	9,621
Ringarooma	4,771	0.4	...	...	529	281 0	378	9,621
Average	4,615	0.7	...	...	515	285.8	365	9,938
Barham	3,618	1.1	4,561	2.1	273	138.0	244	7,088
Bellona	3,566	1 2	...	..	275	141.3	244	7,088
Average	3,592	1.1	4,561	2.1	274	139.6	244	7,088
Pallas	5 066	0.1	7,333	1.5	516	297.7	425	11,109
Pearl	5,372	0.3	7,227	1.5	543	318.4	400	11,105
Philomel	4,923	0.3	7,735	1 2	539	320 9	416	11,105
Phœbe	4,705	0.2	7,582	1.6	559	317.4	401	10,782
Average	5,016	0.2	7,469	1.4	539	313.6	410	11,025

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear, and all fittings in boiler rooms, also water in boilers at working level.

THIRD CLASS CRUISERS—Continued.

I.H.P. per ton.				I.H.P. per square foot of grate.		Heating surface per I.H.P.		Boiler tubes material.
Machinery complete.		Boilers.						
N. D.	F. D.	N. D.	F. D.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	
						Sq. ft.	*Sq. ft.*	
8.6	12 5	14.1	20.6	10 9	15.4	2.1	1.4	Steel.
7.8	...	13.0	...	9.8	...	2.3	...	"
7.4	11.6	12.8	20.0	9.7	15.1	2.5	1.6	"
7.8	11.2	13.5	19.4	10.1	14.7	2.4	1.6	"
7.9	11.8	13.3	20.0	10.1	15.1	2.3	1.5	..
9.1	...	15.7	...	12.0	...	2.2	...	Steel.
9.0	...	15.7	...	14.2	...	2.2	...	"
9.0	...	15.8	...	12.1	...	2.2	...	"
8.6	...	16.5	...	12.3	...	2.0	...	"
9.0	...	17.0	...	12.6	...	2.0	...	"
8.9	...	16.1	...	12 6	...	2.1	...	..
13.2	16.7	26.2	33.0	14.8	18.7	1.9	1.5	Steel.
13.0	...	25.2	...	14.6	...	1.9	...	"
13.1	16.7	25.7	33.0	14.7	18.7	1.9	1.5	..
9.8	14.2	17.0	24.7	11.9	17.2	2.1	1.5	Steel.
9.9	13.3	16 9	22.7	13.4	18.0	2.0	1.5	"
9.1	14 3	15.3	24.1	11.8	18.5	2.2	1.4	"
8.4	13.5	14.9	23.9	11.7	18.9	2.2	1.4	"
9 3	13.8	16.0	23.8	12.2	18.2	2.1	1.47	..

TABLE E.—

Ship.	I.H.P. on trial, natural draft.	Air pressure	I.H.P. on trial, forced draft.	Air pressure.	Weights. Machinery complete.	Weights. Boilers.	Surfaces. Grate.	Surfaces. Total heating.
		Inch.		*Ins.*	*Tons.*	*Tons.*	*Sq. ft.*	*Sq. ft.*
Rattlesnake	...	...	2,740	2.3	133	85.2	126	4,639
Grasshopper	...	...	2,368	2.8	118	72.4	120	4,396
Sandfly	...	...	3,014	2.8	115	72.4	119	4,334
Spider	...	...	2,664	2.5	115	72.0	119	4,334
Average	...	...	2,696	2.6	120	75.5	121	4,426
Sharpshooter	2,836	0.8	...	...	167	94.3	190	5,330
Spanker	2,524	1.0	...	...	163	98.0	182	5,330
Boomerang	2,612	0.6	3,509	2.0	173	98.0	190	5,330
Karakatta	2,598	0.5	3,840	1.7	171	95.6	190	5,330
Salamander	2,825	0.9	...	...	175	109.2	153	5,319
Seagull	2,792	1.8	...	2.3	176	109.4	144	5,319
Sheldrake	2,659	0.9	...	...	...	109.0	153	5,319
Assaye	2,774	1.1	...	...	174	100.0	153	5,980
Plassy	2,895	0.9	...	...	176	97.6	153	5,980
Skipjack	2,282	0.6	3,931	3.4	170	102.5	192	5,469
Speedwell	2,601	0.5	3,588	2.8	168	102.0	191	5,469
Average	2,672	0.9	3,717	2.4	171	101.4	172	5,470
*Sharpshooter**	2,620	Nil	3,238	0.1	197	124.3	269	7,695

* After being fitted with Belleville boilers.

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear, and all fittings in boiler rooms; also water in boilers at working level.

TORPEDO GUNBOATS.

I.H.P. per ton.				I.H.P. per square foot of grate.		Heating surface per I.H.P.		Boiler tubes, material.
Machinery complete.		Boilers.		Natural draft.	Forced draft.	Natural draft.	Forced draft.	
N. D.	F. D.	N. D.	F. D.					
						Sq. ft.	*Sq. ft.*	
...	...	...	...	...	...	...	...	Steel.
...	20.0	...	32.8	...	19.7	...	1.85	"
...	26.2	...	41.8	...	25.3	...	1.43	"
...	23.1	...	37.0	...	22.3	...	1.62	"
...	23.1	...	37.2	...	22.4	...	1.63	..
17.0	...	30.1	...	15.5	...	1.8	...	Steel.
15.4	...	25.7	...	13.8	...	2.1	...	"
15.1	20.2	26.6	35.8	13.7	18.4	2.0	1.5	"
15.1	22.4	27.3	40.4	13.6	20.2	2.0	1.3	"
16.1	...	25.9	...	18.4	...	1.8	...	"
15.8	...	25.6	...	19.3	...	1.9	...	"
15.1	...	24.4	...	17.3	...	1.9	...	"
15.9	...	27.7	...	18.1	...	2.1	...	"
16.4	...	29.8	...	18.9	...	2.0	...	"
13.4	23.1	22.3	38.5	11.8	20.4	2.3	1.3	"
15.4	20.7	25.5	35.1	13.6	18.7	2.0	1.5	"
15.6	21.6	26.4	37.4	15.5	19.4	2.0	1.4	..
13.3	16.4	21.1	26.1	9.8	12.0	2.9	2.3	..

TABLE E.—

	Ship.	I.H.P. on trial, natural draft.	Air pressure.	I.H.P. on trial, forced draft.	Air pressure.	Weights.		Surfaces.	
						Machinery complete.	Boilers.	Grate.	Total heating.
			Inch.		Ins.	Tons.	Tons.	Sq. Ft.	Sq. Ft.
F	*Alarm*	2,593	0.8	3,886	2.4	220	130.1	156	6,241
F	*Circe*	2,621	0.9	3,508	1.9	219	129.5	156	6,241
F	*Gleaner*	2,606	0.9	3,632	2 7	174	109.8	155	5,578
F	*Gossamer*	2,634	0.9	3,654	2.7	167	103.4	183	5,654
F	*Hebe*	2,702	0.7	3,566	2.0	216	129.1	163	6,241
F	*Leda*	2,696	0.8	3,597	2.2	217	128.8	156	6,241
F	*Antelope*	2,653	0.5	3,597	1.3	211	128.6	179	6,228
F	*Jaseur*	2,546	...	3.711	2.7	207	121.0	182	6,220
F	*Jason*	2,676	0.9	3,552	2.1	208	122.5	180	6,220
F	*Niger*	2,710	0.8	3,785	2.2	209	122.0	182	6,220
F	*Onyx*	2,526	0.8	3,548	2.1	210	125.1	169	6,197
F	*Renard*	2,609	0 8	3,962	2.5	210	123.6	169	6,197
G	*Dryad*	2,696	0.9	3,709	2.2	233	129.5	183	6,301
G	*Halcyon*	2,590	1.0	3,546	2.0	231	129.0	182	6,204
G	*Harrier*	...	...	...	...	...	129.0	182	6,204
G	*Hazard*	2,621	0.8	3,734	2.1	233	134.7	172	7,086
G	*Hussar*	...	...	...	...	...	129.0	...	6,204
	Average	2,631	0.8	3,665	2.2	211	124.4	171	6,204
	Speedy	3,046	0.5	4,703	1.7	212	107.2	204	17,700

NOTE.—The weights given in column 7 comprise boilers, funnels, casings, pipes, spare gear and all fittings in boiler rooms, also water in boilers at working level.

TORPEDO GUNBOATS—Continued.

I.H.P. per ton.				I.H.P. per square foot of grate.		Heating surface per I.H.P.		Boiler tubes material.
Machinery complete.		Boilers.		Natural draft.	Forced draft.	Natural draft.	Forced draft.	
N. D.	F. D.	N. D.	F. D.					
						Sq. ft.	*Sq. ft.*	
11.8	17.6	19.9	29.8	16.6	24.9	2.4	1.6	Steel.
11.9	16.0	20.3	27.1	16.8	22.4	2.3	1.7	"
14.9	20.8	23.9	33.3	16.7	23.4	2.1	1.5	"
15.7	21.8	25.5	35.4	14.3	19.9	2.1	1.5	"
12.5	16.5	20.9	27.6	16.5	21.8	2.3	1.7	"
12.4	16.5	21.0	28.1	17.2	23.0	2.3	1.7	"
12.5	17.0	20.7	28.1	14.8	20.1	2.3	1.7	"
12.3	17.9	21.0	30.6	14.0	20.3	2.4	1.7	"
12.8	17.0	21.9	29.1	14.8	19.7	2.3	1.7	"
12.9	18.1	22.2	31.0	14.3	20.7	2.2	1.6	"
12.0	16.9	20.2	28.3	14.9	20.9	2.4	1.7	"
12.4	18.8	21.2	32.2	15.4	22.2	2.3	1.5	"
11.5	15.9	20.9	28.7	14.7	20.2	2.3	1.7	"
11.2	15.3	20.0	27.4	14.2	19.4	2.3	1.7	"
...	...	...	...	...	...	...	..	"
11.2	16.0	19.5	27.8	15.2	21.7	2.7	1.9	"
...	...	...	...	...	...	...	...	"
12.4	17.3	21.2	29.5	15.3	21.4	2.35	1.7	..
14.3	22.1	28.4	43.9	14.9	23.0	5.8	3.7	Steel.

TABLE F.—COMPARISON OF WEIGHTS OF FRAMING.

Ship.	Bed plates.				Standards and guides.				Total.				Remarks.
	Tons.	*cwt.*	*qrs.*	*lbs.*	*Tons.*	*cwt.*	*qrs.*	*lbs.*	*Tons.*	*cwt.*	*qrs.*	*lbs.*	
Royal Oak....	32	8	3	12	37	6	2	16	69	15	2	0	Forged-steel front and back columns.
Ramillies	37	19	0	16	40	2	2	12	78	1	3	0	Cast-steel back columns; forged-steel front columns.
Crescent........	36	1	0	24	46	0	2	10	82	1	3	6	Cast-iron back columns; forged-steel front columns.
Gibraltar......	40	16	1	16	26	7	3	1	67	4	0	17	Forged-steel back and front columns.
Royal Arthur.	20	5	0	20	27	10	1	17	47	15	2	9	Cast-steel columns, back and front.
Endymion......	32	0	1	12	22	2	1	22	54	2	3	6	Cast-steel back columns; forged-steel front columns.

NOTE.—The engines of all these vessels have cylinders of the same dimensions.

veloped 7,051 I.H.P. for fifty hours, with a coal consumption of 2.23 pounds per I.H.P. per hour. The *Sirius*, on a passage, maintained 4,555 I.H.P. for sixty-four hours, with a coal consumption of 2.03 pounds per I.H.P. per hour. The *Pallas*, on a passage, developed 3,620 I.H.P. for seventy-three hours.

The quarterly passage trials of twenty-four hours' duration made by these vessels furnish further indications of their ability to repeat their trial performances with natural draft. On these occasions the full natural draft power is maintained for four hours, and not less than three-fifths of the natural draft for the remaining twenty hours.

In the discussion, **Mr. Durston** called attention to the different figures given for the weight of the boilers of the *Speedy* in Table E, and in the table on page 346, and stated that the diference was due to the fact that, in one case, all the boiler room weights are included, which are not in the other.

Mr. Thornycroft in speaking of the Belleville boilers in the *Sharpshooter*, and for the *Powerful* and *Terrible*, said he thought he could show that it is too heavy. The information given in the tables was not all comparable on the same terms, because in the paper itself the boilers were compared without the weight of some of the fittings, whereas the ash-hoists and all the engine room fittings connected with the boiler were included in the tables. The boilers of the *Daring* weighed 47.7 tons instead of 48.5, which would make the I.H.P. per ton of boiler 92.5. Considering the different boilers, he found that the weight of the drum boiler with all the fittings amounted to .027 ton per square foot of heating surface, and the locomotive boiler to .020. The weight of the water-tube boilers in the *Speedy* was .007 ton per square foot. In the *Sharpshooter*, with Belleville boilers, the figure was .016.

Mr. J. P. Hall said that the weight now allowed for the machinery of second class cruisers, such as those bracket *E*, in Table C, is 800 tons, or an increase of 10 per cent.

Mr. A. E. Seaton pointed out that the engines of the *Endymion* and *St. George* had not forged steel columns, but steel castings, and were not like those of the *Royal Arthur*, but were on an entirely new design. It had been concluded that the lightest form of engine was that with turned steel columns. On inquiry he had found that a design with back cast columns could be made really lighter than with forged turned columns.

In replying to the discussion, **Mr. Durston** said that since the paper had been written other ships had been tried over long periods with the following results :

	Hrs.	*I.H.P.*	*Coal per I.H.P.*
Spartan, . . .	72	6,777	1.96
Resolution, . . .	48	8,085	2.10
Ramillies, . . .	34	8,111	1.97

The weight of water in the water tube boilers, on page 346, was for cold water, and in the Tables A to E for hot water.

TUBULOUS BOILERS IN THE FRENCH NAVY.

By Assistant Engineer John K. Robison, U. S. Navy.

In what follows, I have endeavored to place before the readers of the Journal the result of my observation of the practical working of tubulous boilers in France, with such data regarding the most important of them as could be obtained.

In nearly every vessel under construction for the French Navy the boilers are of the tubulous type, and cylindrical boilers have almost entirely disappeared from designs for men of-war in favor of the lighter tubulous ones. For torpedo boats and other vessels of small size, the boilers are generally of the Thornycroft or Normand type, and, except for slight differences in detail, are similar to those used in this country. The French seem to get better results from the Normand and Lagrafel than from the Thornycroft that were first used in their navy for torpedo boats; but this is largely due to the fact that the later boilers are of French design and manufacture.

The boilers which are designed to replace the large cylindrical ones that are used in all other countries for large vessels are those that present the most novelty to us, and are the ones which will be considered here. There are only three types which can be said to have any chance of replacing the Scotch boiler: the Belleville, the D'Allest and the Niclausse. Other types essay to fill the places of these boilers, but, so far as I know, the three named are the only types that are used in vessels larger than gunboats. Others have been tried with a view to applying them in large vessels, but so far they have not been a success.

Of the boilers mentioned, the Belleville is the oldest type; it is claimed for it that it is also the oldest tubulous boiler, and it probably is the oldest French one. It is too well known to require description, but some consideration of its working may not be out of place, when it is considered that the results are those reached where the experience has been greater than ours.

The extremely small quantity of water in the boiler has made the use of an automatic feed regulator necessary. This regulator works well when it does work, but fails to work at all, often enough to destroy all confidence in it. Besides, when the regulator fails to work, serious accidents often result. The amount of feed water is so small that any failure of the regulator to act is liable to cause the water to disappear entirely from the boiler. The small quantity of water in the boiler likewise causes large variations in the steam pressure and necessitates a larger pressure in the boiler than at the engines; that is to say, there is a reducing valve between the boilers and the engines.

The slow circulation of the water causes the tubes to deteriorate very rapidly if the water is not pure. The tubes of the lowest row are made very thick, but they wear out very rapidly nevertheless, being bent after fires are lighted under the boilers two or three times.

The system of circulation of the water causes a great deal of "priming," and this cannot be cured even with the use of a complicated set of baffle plates in the steam drum of the boiler, and with the addition of a separator between the boilers and the reducing valve. The reducing valve must also reduce the amount of water in the steam, though, as has been seen, this is not the prime object of its use. It has been estimated by engineers that have worked these boilers for several years that the amount of water in the steam at the cylinders is never less than 10 per cent.

The use of the Belleville boilers was said at the outset to be sure to give a great gain in economy of fuel. In fact, many engineers still seem to think that they are not greatly inferior to the Scotch boilers in this respect. The fact is, however, that the arrangement for the combustion of the coal to take place entirely in one place has made the mixing of the gases of combustion very poor. To ensure their proper mixing all the gas from the grate should be brought together at some point before the combustion is supposed to be completed. This would correct the inequalities in the thickness of the fires in different parts of the grate. So very poor is the mixing of the gases in the Belleville boiler, that it has been found necessary to have a pump for forcing jets of compressed air in the top of the furnace, forcing the gases of combustion down towards the grate, and so promoting their thorough mixing.

The absolute necessity of a sure acting feed pump has led to the use of a specially designed pump that will always be sure to act. This result is obtained at the cost of a large amount of steam for the pumps, but the result is so necessary that it has been said that the pump is what makes the boilers.

The accessories to this boiler are so numerous that they make a considerable addition to the machinery of a vessel. The number of separate machines that are required to make this boiler act in at all a safe way leads to an exaggerated amount of repairs, and the care of the steam producing plant becomes a more difficult matter than that of the engines. The repairs to the boilers are more costly than those for ordinary boilers. Not that any one case of repairs is not cheaper than a similar job would be with Scotch boilers, but the greater number of repairs has led to greater expenses for the government in the repair shops. The repairs can, however, be made in a much shorter time than with the cylindrical boilers, and this must be held to counterbalance in a large degree, the greater frequency of break downs in the boilers. Also the large number of boilers in the steam producing plant of a powerful ship makes the loss due to the putting out of commission of any one boiler a minimum. It is also to be noted that all ships that are fitted with these boilers have more boilers than are necessary to the running of the engines at full power. Thus it is always possible to run at full power even with one or more boilers disabled.

The advantages of the Belleville boiler over the Scotch boiler that are the most appreciated in France are the great gain on the weight of the steam producing plant, even with a reduction in the forcing of the boilers, and the ease of raising steam. The pressure allowed for this boiler is practically unlimited by the boiler, on account of the small diameter of the cylinders that contain the steam. The parts are small and can easily be removed from the boiler rooms without cutting any holes in the decks. In fact, the whole boiler may be removed from the boiler room without troubling the decks at all.

The manufacturers of this boiler claim that it is possible to use salt water in it without any bad effects. Though it has never been intended that they, more than any other working at a high pressure, should be usually fed with salt water, it has been occasionally necessary to use salt water in them. The results have not been of the best. The tubes were found to be eaten away, and the rods of the feed regulator were soon covered with incrustrations that prevented it from acting, and so entirely destroyed the boiler.

As has been said, these were the first French tubulous boilers. While Mr. Belleville has been constantly at work devising methods for making his boiler run with success, other people have been busy devising some way of getting around the difficulties in the Belleville boilers by a change in the system.

The D'Allest boiler, or more properly the Lagrafel-D'Allest, is probably the best of the attempts to secure a substitute for the Scotch boilers. This boiler has been described in the Journal, but some recent changes that have been made may be an excuse for going over the ground again. This description will follow, but the following is the result of observations made on the comparative working of these boilers and the Belleville. Each boiler, it will be remarked, has advantages over the other.

The D'Allest boilers are not quite so heavy as the Belleville, but the floor space occupied is greater for the same area of grate or heating surface. As, however, the D'Allest boilers are much more capable of being forced than the Belleville (which are uneconomical with over fifteen pounds of coal burned per square foot of grate), it may be said that the space occupied by the D'Allest boilers is not greater for the same power than that required by the Belleville. A great advantage for the D'Allest boilers is, that with them it is unnecessary to have more than the ordinary auxiliaries of the Scotch boilers, and the frequency of repairs with the Belleville boilers is thus avoided. The amount of water in the D'Allest boilers is not, of course, so great as in

Scotch boilers, but it is sufficient to make the use of that bugbear of the practical engineer, the automatic feed regulator, unnecessary. The cost of running the D'Allest boiler is far less than that of the Belleville, and, indeed, it may be said that on this point the D'Allest boiler may be compared with the Scotch. It has an independent combustion chamber, and thus the gases are well mixed before entering the uptake. The results of steaming with this boiler are in marked contrast with those from the use of the Belleville. While the D'Allest boilers have not required more coal than Scotch boilers for similar engines, the loss in coal has been with the Belleville boilers as much as 42 per cent., as will be seen later.

The greatest advantage of the Belleville boilers over the D'Allest lies in the comparative freedom of the tubes of the Belleville boiler to expand when heated, they being fastened at only two points in each element while those of the D'Allest are fastened, the same as the tubes of Scotch boilers, at both ends of each tube. This reduces the danger of leaky tubes in the Belleville below what it is in the D'Allest boilers. Another advantage of the Belleville over the D'Allest lies in the fact that the parts of the former are smaller than those of the latter, and that, therefore, there is less difficulty in removing them from the firerooms in case of injury beyond repair. When one considers the fact that the French Government requires reducing valves to be placed between the boilers and the engines whenever tubulous boilers of any type whatever are used, some excuse for the use of the Belleville in preference to the D'Allest boiler may be found. Of course, the question of the advisability of using any type of tubulous boilers is quite apart from the question of the superiority of one tubulous boiler over another.

Of the many other types that have been proposed for replacing the Scotch boilers there is but one, the Niclausse, that has so far been recognized as possessing the points that are requisite for use in men-of-war. These boilers are modifications of the Collet, that have been fully described in the JOURNAL. The differences between the new boiler and the older one lie almost entirely in the details of construction, the main points of the boilers being the same. These boilers are as different from the others as the latter are from each other. They are compared only with the D'Allest, as the latter are so evidently superior to the Belleville that it would be waste of time to include a second comparison.

The weights of the D'Allest and the Niclausse boilers are practically the same for the same area of heating surface, with the same advantage for the Niclausse in regard to the space occupied as for the Belleville boiler. But while the Niclausse boilers are capable of being forced more nearly to the power of the D'Allest than the Belleville boilers are, they are not the equals of the D'Allest in their capacity for high powers. It may, therefore, again be said that the D'Allest boiler takes up less space for the same power than the Niclausse. Both of these boilers give dry steam at the highest powers at which they are run, and, therefore, have a point of advantage over the Belleville. The amount of water in the Niclausse is less than in the D'Allest, but it is still large enough so that the water level may be easily maintained without the use of any other than the ordinary check valves on the boilers. The greater the amount of water in any boiler, however, the better it is for keeping a steady steam pressure; and some difficulty was experienced in maintaining the pressure of steam constant during the forced draft trials of the *Friant* (fitted with Niclausse boilers). The frequency of repairs to one of these boilers is about the same as for the other, and the cost is about the same in each case. The joints in the Niclausse boiler are all metallic and conical, and so require more care in the making, but are less liable to give trouble when once made. The tubes are all free at one end, and therefore the danger of leaky tubes is reduced to a minimum. In fact, during all the trials of the *Friant*, there were no leaks in this boiler. It is another point in its favor that the repairs are all made from the front of the boiler. It must also be remarked that it is easier to mount and dismount a tube in the Niclausse than in any other type of tubulous or other boiler. The complete operation of removing a tube and replacing it with another took, in one instance within my observation, less than two minutes.

The advantages that the D'Allest boilers have are chiefly in the matter of economy. As has been said, they are about as good as the Scotch boilers, while the Niclausse or the Belleville give much poorer results in actual use than have been found from the use of ordinary boilers. Another advantage of the D'Allest boiler lies in the fact that the tubes in the rows next to the fires are all Serve tubes, and thus much less liable to burn out than ordinary tubes. It would be hard to use this type of tubes in the Niclausse boilers, on account of the inner circulating tube in each element. It would seem that tubes of the style used in the Niclausse boiler are the best, however, on account of their freedom to expand when the boiler is being fired. The one great advantage of the D'Allest boilers seems to lie in their great relative economy over any other tubulous boilers. Mr. D'Allest himself says that this advantage is almost if not entirely due to the use of an independent combustion chamber. There would be little difficulty in adding a combustion chamber to the Niclausse boiler, and then it would seem that this boiler would be inferior to the D'Allest in but the detail of the amount of water in the boiler. This defect could be remedied by a change in the size of the tubes to allow for the increased rate of evaporation rendered possible by the addition of the combustion chamber, and by the use of a larger steam drum at the top of the boiler. Perhaps even now it may be said to be a question whether the Niclausse boilers are not the equals of the D'Allest, but the opinion of French engineers seems to be that the D'Allest are the boilers of the future, and that, with a few changes, they can be readily supplied in the place of Scotch boilers. The addition of hydrokineters would reduce the disadvantages of the D'Allest tubes being fixed at both ends. This apparatus has not yet been used in these boilers.

In the use of these boilers in the French Navy it is to be remarked that even with the number of spare boilers (20 per cent. in many cases), and with the small rate of combustion allowed in all cases (never above 31 pounds of coal per square foot of grate), and with engines that are considerably heavier than those used for the same power in this country, the total weight of the machinery is not so great as in our latest ships. In no case of a modern French man-of-war fitted with tubulous boilers, that I now recollect, has the weight been over 200 pounds per I.H.P. of all the machinery; in most cases the weight is down to about 185 pounds. These figures are, of course, for large vessels of the battle-ship or fast cruiser type. This seems to be the greatest if not the only advantage for the tubulous boilers. The pseudo advantage of quickness in raising steam is one that is more than counterbalanced by the always attendant greater difficulty in managing the boilers when under pressure.

The pertinent points that seem to me to need attention in the French boilers are that the tubes are always so arranged so as to be easily removed or cleaned. This seems to be an absolute requisite for any boiler that can entirely replace the Scotch boilers.

Tubulous boilers will always give more trouble to keep in good condition than would Scotch boilers, but they are sure to retain their full efficiency almost indefinitely, as the worn parts are replaced by new ones that are as strong as the old ones were in the first place. There is no shell to deteriorate.

It is also to be remarked that the tubes used in these boilers are invariably of a larger diameter than is generally used in the boilers made in this country. The gain in the weight of the boilers may be said to be about equal to the weight of the water in Scotch boilers that would have to be substituted for the tubulous boilers.

THE BELLEVILLE BOILERS OF THE *AUSTRALIEN.*

The Messageries Maritimes is one of the greatest steamship companies of France, if not the very greatest. This company began the use of Belleville boilers some five or six years ago. The officials of the company seem to be fairly well satisfied with the performance of them, but there is a tendency to obtain something that will give better economical results. Designs were prepared in the last vessel designed (the *Ernest Simon*) for the use of Scotch boilers. There was still a question as to which type of boilers would be adopted when I left France.

Of the vessels that are fitted with Belleville boilers in the fleet of this company the *Australien* is the oldest. She is a vessel about 466 feet in length, and of about 10,000 tons displacement. The mean speed on the trial trip was 17.5 knots. She has a single screw vertical engine of 7,535 I.H.P. on the trials, and developing about 4,100 I.H.P. on the whole trip to Australia, giving a mean speed of about 15 knots. The engine was constructed in 1890, at the company's shops at La Ciotat, and is a triple expansion engine with three cylinders. The evaporating plant is composed of twenty Belleville boilers for the main engines, and of one small cylindrical boiler for the distillers and for the winches on deck. These boilers (Belleville) have five, or for the most part six, elements each, and are twelve rows high. The total grate surface is 581.27 square feet.

The weight of the machinery is as follows:

Engines, tons	750
Boilers and accessories, tons	392
Water in boilers, tons	20
Total for machinery, tons	1,162
Per I H.P. (on 7,535 I.H.P.), pounds	340
Engines per I.H.P., pounds	220
Boilers per I.H.P., pounds	115
with water per I.H.P., pounds	120

The fire room is fore-and-aft.

The watch for four hours consists of one engineer, two chief firemen, three first-class firemen, two Arab leading men of the fire room, eight Arab firemen, six Arab coal passers, two European oilers, two Arab oilers; total, twenty-six men.

There have been some more or less important changes made in the fire room from the original designs. The pipe connecting the feed regulator to the boiler went originally directly to the ejector. It was found that this pipe soon filled with sediment, and caused the feed water to fail in the boiler. The pipe was changed to go directly to the feed-water collector at the base of the boiler. A tube was burned out in finding that this change was necessary.

The lever of each feed regulator has been fitted with a wire handle, so that it may be seen at any time whether the regulator is in working order or not. This is done by opening the regulator wide, and seeing if the valve closes when the handle is loosed.

RUNNING OF THE BOILERS OF THE *AUSTRALIEN.*

Filling with water.—The boilers are always filled with fresh water, and never has any other water been used for this purpose. In the instructions sent to the company by Mr. Belleville, provision is made for the use of salt water for filling the boilers, but the accidental use of salt water in making up feed gave such bad results that the company has never used it for originally filling the boilers.

Raising steam.—The grates are carefully cleaned and put in place. They are entirely covered with coal to a thickness of about four or five inches. At the front of the boiler a wall is built up around the furnace door. This wall of coal and kindling wood is lighted first. Before lighting the fires the safety-valves are opened. The ash-pit doors are closed, and the furnace doors are left slightly open at first. The doors to the tube nest are closed.

When the little wall around the furnace door is well lighted, it is spread over the grate and the furnace doors closed; the ash-pit doors are then opened more or less according to the time allowed to raise steam. This time is generally about 1½ to 2 hours. Steam can be raised in less time, and it has been done in ¾ hour, but the effects on the boiler are not good, and the rules of the company call for 2 hours in raising steam.

When the elbow communicating between the ejector and the collector on the boiler begins to warm up, the blow-off cocks are opened several times, and the boiler freed of the sediment in the base of the tubes. This serves to promote circulation in the boiler during the time that there is no steam drawn off to make the circulation sure. If this is not done, the water hammering in the tubes during the time that steam is being raised will cause trouble and may break any or all joints in the tubing of the boiler.

The feed pumps are kept going from the time the fires are lighted. As soon as the pressure of steam in the main boilers becomes great enough to run these pumps, the steam is taken from the main boilers. (Pressure as much as 60 pounds.)

Getting Under Way.—If there is any delay in getting under way after steam is raised, the ash-pit doors are closed and the furnace doors opened. The feed pumps are kept working as always while the fires are lighted, and the extra steam is condensed. If the fires are properly managed there is no danger of steam blowing off from the safety valves, and it is rarely necessary to send any steam to the condenser.

The stop valves are not opened wide, nor is the pressure in the boilers allowed to exceed 150 pounds, until the engines are well under way.

When the engines are first started, there is great danger of "priming." The water level must be carefully watched and the feed regulators kept closed at this time. The fires are not forced until after the engines are started, nor are the doors opened.

The doors of the tube nest are never opened except to clean tubes.

Working of the Fires.—The firing must be thoroughly regular and methodical. There has been great difficulty in finding European firemen to do the work on these boilers. It is always necessary that the fires should be what would, in Scotch boilers, be considered low, that is to say, they are never more than five or six inches thick. At the same time it is absolutely necessary that there should be no holes in the grate, or the air would rush through at this point alone and leave the gases of combustion incompletely burned. The firemen that have been accustomed to the grates of the Scotch boilers, seemingly cannot learn to properly fire the furnaces of the Belleville boilers, which are so much wider than those of the Scotch boilers.

The grates are fired in rotation, beginning forward and working aft, and putting two or three shovelfuls of coal on the fires at a time. The tendency of the firemen is to fire only on the front of the grates, and care must be taken to prevent this: one grate is always in process of being fired. When those in one fire room have been fired, those of the other fire room are commenced, and so on until all the fires have been fed, when the operation is recommenced.

The safety valves are set at 220 pounds, and the steam at the cylinder is only at 185 pounds pressure. Variations in pressure between those limits have then no effect on the engines; but the limited quantity of water in the boilers makes rapid change of pressure frequent. A man is always at the gauge watching the pressure. The moment the pointer commences to drop the fires are pushed, and again the moment the pressure commences to rise the ash-pit doors must be closed. Failure to observe these precautions may cause the pressure to drop in one or two minutes from 200 pounds to 150 pounds, or it may increase to 250 pounds in as little time. The instant the pressure commences to rise is the one taken for cleaning fires.

Each grate is half cleaned every four hours, making the total time between cleaning fires eight hours, and preventing any part of any grate from ever getting very dirty. Two grates are often cleaned at a time, and the twenty grates are cleaned during each watch (half).

The cleaning of these grates is done in a slightly different way from that used with the grates of Scotch boilers. The part that is to be cleaned is cleared of coal, the burning coal being pushed on the other half of the grate. The clean part of the grate is then covered with fresh coal, and the clinkers, &c., on the dirty part of the grate are removed as soon as possible. The coal on the clean part of the grate is then spread over the whole grate, and the doors fixed as before cleaning fires. While cleaning fires, the valve on the feed pipe to this boiler is partly closed to prevent the boiler from filling with water. The mixer of the gases of combustion is left in operation during the cleaning. If care is taken in choosing the moment for cleaning fires the steam pressure will not fall during the operation.

The mixer of gases admits the air to the furnaces at a pressure about 5 pounds above that of the atmosphere. The air enters the furnaces through little nozzles at the top of the front of the boilers and is so directed as to force the gases of combustion downwards toward the grate. This is calculated to mix the gases and so to ensure the thorough burning of the coal. It is to be noted that the boilers were worked during an entire trip without using the gas mixer, and without any appreciable difference in the amount of coal used.

Feed.—All make-up of waste feed is with fresh water. A distilling plant is placed on the ship for this purpose. The steam is formed in the donkey boiler and is sent to the second receiver on the main engines. A connection is fitted from the donkey boiler to the exhaust pipe which permits the direct condensation of the steam in distillers such as are used in our Navy.

Lime is added to the feed water in a continuous fashion by means of a lime tank fitted above the air pumps and having an exhaust to the bottom of the condenser. This lime tank is fed by a small pipe from the feed pump discharge. Lime is added at the commencement of a voyage in the proportion of one pound for each pound of oil used in the cylinders. At the end of the voyage the ratio between the amount of lime and oil is increased to three.

The feed pumps are so arranged that any one of them can feed any boiler from either of the feed tanks. On the pipe to each boiler there is fitted at the main feed pipe a valve, and there is another graduated valve at the entrance of the feed water to the feed regulator. This graduated valve is much used in running the boiler, for the feed regulator is not entirely depended upon. The graduated valve is kept as far closed as possible, and allows the feed to enter the boiler in an amount slightly exceeding that required for the boiler. The regulator, which is almost always nearly wide open, is thus unable to let much more water in the boiler than is absolutely necessary. During rough weather the graduated valve is more finely fixed still, so that the feed regulator cannot let too much water into the boiler, and so that it is necessary at intervals to open the graduated valve to give the boiler enough water. In some, this graduated valve takes the place of the regular check valve on Scotch boilers, and the feed regulator is only depended on to do the regulating of the feed more finely than would be possible by hand. In this way only can any dependence be placed on the feed regulator. The check valve of the boiler is included in the graduated valve and not in the feed regulator.

On leaving the graduated valve the water enters the feed regulator, and from there enters the cylindrical reservoir at the top of the boiler. After passing the entire length of the reservoir, the water enters the ejector. It would seem that the water is heated sufficiently by its passage through the reservoir to deposit the greater part of the solid matter it contained on entering the boiler. The ejector keeps the greater part of this matter, and it may be removed from the boiler by use of the blow-off valve on the ejector. This blowing down is sometimes done in a continual fashion by opening a cock on the ejector and leaving it partly open during all the time the boiler is in use. The steam on leaving the ejector passes to the feed water collector on the bottom of the elements, and from there to the tubes. The water level in the boiler is about at the middle of the height of the tubes.

The ejector is used every 12 hours on each boiler. The valve is simply opened wide and then closed. This is repeated two or three times, and, as already said, may be used in a continuous way. This latter method is not used except in the case of leaky condenser tubes and the consequent presence of salt water in the boiler. Towards the end of a trip, the blow off cock is used every four hours.

With salt water in the boiler for any cause, the fires are forced and the circulation is thus kept rapid. Lime is added to the feed water in sufficient quantities to neutralize it completely, and frequent use is made of the blow-off cocks. The saturation of the water should not be allowed to exceed 2.

The amount of lime added to the feed is about eleven pounds per ton of feed water. The throttle valve should be closed as much as possible, and thus the "priming" is reduced. There is more danger of "priming" with salt water than with fresh water, and as even with fresh water there is never less than 10 per cent. of water in the steam at the cylinders, there is great danger in the use of salt water of getting so much water that the working of the engines would be interfered with. There is always danger of tubes giving way with the use of salt water, and the boiler is then of no use until the tube is replaced. This is of little danger in any other way, as the breaking of a tube is dangerous to those in the fire room only if the furnace door is opened by the first shock. After that there is no danger of the steam entering the fire room. The average life of the tubes is from two to three years. The causes of burning are the failing of the feed, or the internal corrosion in the tubes, which is the result of use in whatever conditions.

The feed regulator is liable to fail in use. The wire test placed on each regulator is used as often as possible, say every hour. Nevertheless, the regulators are apt to give trouble, by "going to sleep." This may be caused by the formation of deposits on the regulator rods, or on the valve itself. Even dust on the outside of the regulator, on the moving parts, is liable to cause it to fail to act. As one of the engineers on the *Australien* said: "A regulator may not fail for four hours, but then again three or four of them may fail in that time." All the water levels are protected, and fully as much attention is paid to them as with the ordinary boilers, but frequently the regulator will fail, and the drop in the water of the boiler will not be noticed till too late. The great trouble with the regulator is that when the water is lowest the effort on the regulator is the greatest, and several times they have opened after the water had entirely disappeared from the boiler, and even when the boiler was red hot. In that case it is clear something had to break. It was always a tube or tubes. In one case, tubes of every element in a boiler burned out at the same time, and due to the above cause. This failure of the feed, due to a failure of the automatic feed, is the cause of most of the accidents to the boiler. The engineers of the Messageries Maritimes have tried to do without the regulators, but have not succeeded in regulating the water well enough in this way to run them without a man on each boiler with that for his duty and nothing else. As soon as the regulator is found to have failed, which will generally be discovered when a tube bursts, the fires are drawn from that boiler. It requires about ten minutes to empty a boiler and to burn out a tube after the regulator fails.

Steam.—The baffle plates in the reservoir at the top of the boilers do not prevent the carrying away from the boiler of about fifty per cent. of water in the steam. The separator reduces this amount about five fold, and the reducing valve makes a further though unimportant reduction in the amount of water in the steam. There is not, in general, enough water in the steam to interfere with the working of the engines, though this sometimes occurs. The trap on the separator does not work well. It is designed to be automatic, but is always worked by hand.

The reducing valve works well and maintains a constant pressure at the engines while the pressure at the boilers is above 185 pounds. When the engines are working slowly, or when they are stopped, the pressure at the engines has a tendency to be the same as that at the boilers, but as the pressure at the boilers is then generally below the working pressure of the engines, there is no harm in this inconvenience, common to all reducing valves.

Feed Pumps.—It is said that these pumps are the soul of the boilers. When there is too much water in the boilers the pumps stop, and on the contrary if the water in the boilers gets low the pumps go very fast. This seems to me to be the result of the more or less complete action of the feed regulators. The pumps are, however, of the design that is necessary for these boilers, with large steam cylinders and consequent sure action of the pumps. The action of the boilers depends entirely on the action of the feed pumps, and these pumps must be sure in their action. The ordinary feed pumps that were used in part on these boats have not given satisfaction, and the Belleville pumps are the only French feed pumps that can be used.

Sweeping the Tubes by Steam.—At first, the boilers of this ship were cleaned as is usual with all boilers, by steam. No great difficulty was experienced with the arrangements for sweeping the tubes, and the satisfaction was perfect in all but one respect.

The quantity of steam required was so great that it was not possible to make enough fresh water to make up the waste feed. After the trial of salt water for this purpose, the bad results on the boiler tubes were so apparent that it was seen that only fresh water could be used. For that reason, the sweeping of the tubes with steam has been entirely discontinued.

Now, the practice is to have three or four of the twenty boilers out of use at all times, so that all may be cleaned in rotation, and each one after about three days' use. As soon as the boiler is cold it is cleaned, fires lighted, and another boiler put through the same treatment. The tubes of the lowest row are often covered with silicious barnacles, which are carefully removed every time the boiler is cleaned.

Banking Fires.—This is done in the ordinary way. The pressure in the boilers is reduced to about 75 pounds, the blow-off cocks frequently used, and the feed pumps kept running slowly. The blow cocks are used as when under way. Banking fires in these boilers is bad for the tubes. The water has no circulation to speak of, and that in the lower tubes soon becomes highly concentrated. The slow evaporation sends the steam to the reservoir at the top of the boiler and the steam being there condensed the lightest water remains at the top of the boiler, and the heavy water, containing all the sediment, at the bottom and in the lowest tubes.

Cleaning the Boilers Completely.—The outside of the boiler is cleaned by brushes in the regular way. The inside is cleaned after being washed with caustic soda. For this washing, about 35 pounds of caustic soda is put in each boiler. The boiler is then completely filled by adding fresh water. The fires are then lighted and a pressure of about 15 pounds is kept up for two or three hours. Then the feed water collector at the bottom of the elements is opened, and the height of the water reduced to the normal working level. The fires are then worked and the engine turned at the dock. This is kept up for three or four hours. The working of the engines cleans not only the boiler but also the piping and the cylinders, the amount of water carried over to the engines by the steam being sufficient for this. The boilers are then completely blown down and the water put overboard. It will be found that the water contains a great deal of oil, and even that there are solid particles in the water thus thrown away. This cleaning is done every three months.

After the boiler has been washed, the joints of all tubes are broken, and the mud that remains in them is removed while it is still soft. The quantity of this mud is not great. During this cleaning of the inside of the boiler, care is taken to look out for corrosion, or the beginning of the burning of a tube.

The washing of the boilers is done while they are still warm from working, but after the fires have been drawn, of course.

As summed up by one of the ship's engineers:

"The great advantage of these boilers is the ease with which they can be repaired. A tube can be replaced in two hours, and this is the most frequent accident to the boilers. The tubes are the weakest part.

"The Belleville feed pump is what makes the boiler. It is perfect.

"The ejector is good for what it is intended for. With fresh feed water, even without a filter (which would be a great improvement), and by adding lime to the feed all the time, there is no danger from any deposits in the tubes. There will always be some deposits in the tubes, but nothing to speak of.

"The reducing valve is very good, and always works well.

"It is rare that there is sufficient priming to interfere with the working of the engines, although it is always considerable.

"It is not possible to keep up the water level by hand, except by using a man for each boiler for this purpose. The great trouble comes from the use of even a small quantity of salt water in the boilers. The regulator is soon clogged up and does not work, and then firing must be stopped. Yet some feed regulator is indispensable.

"The firing is difficult. An ordinary fireman can never succeed here.

"The Belleville boilers are much less economical than the ordinary ones, and the cost of making repairs to them is greater than for Scotch boilers. Besides this, their first cost is greater.

"Great care has to be exercised with all these delicate machines, and you can never tell what will be the next thing to break down.

"If you want Belleville boilers you must have engineers everywhere.

"It seems to me that there is no doubt that the ordinary (Scotch) boilers are the boilers to have, and that there is no use of bothering one's self with all this machinery.

"If the regulator sticks, the boiler must be put out of use.

"The automatic separator trap is not satisfactory, and is always worked by hand."

An attachment has been fitted permitting the fires to be drowned with water while on the grates.

The Belleville boilers show a saving in weight over Scotch boilers about equal to the weight of the water in the latter, and a saving in space of about 7 per cent. This saving in space varies according to the ship from zero to 10 per cent.

The ratio between the heating and the grate surfaces is about 30.

The cost of running the engines of the *Australien* during the year 1893 was 2.30 pounds per I.H.P.

The estimates for this ship called for a speed of 19 knots on the trials (17.52 realized), and for 17 knots in ordinary running (14.60 realized). The cost of the power was set at 1.54 pounds per I.H.P. It is evident that these boilers have not been remarkable in their economy.

On the ships of this line which use Scotch boilers, and those of an old type with pressures of 90 and 100 pounds, with old compound engines, the cost of a horse-power during the year 1893 was 2.02 pounds per hour. If the use of triple expansion engines gives an economy of 20 per cent., the cost of the Belleville boilers in coal alone exceeds that of Scotch boilers by 42 per cent.

If the *Australien* had been fitted with Scotch boilers she could have made a trip to Australia with a less weight of coal and machinery than with the present boilers. The question of cost, it will be remembered, has not been touched upon.

BELLEVILLE BOILERS IN THE FRENCH NAVY.

Nearly one half of the vessels now being constructed for the French Navy are to be fitted with Belleville boilers. Those now in use have given fair satisfaction.

On the ships now fitted with these boilers, a filter is always used between the air pump and the feed pumps. Lime is always added to the feed water in much the same way as on the *Australien*. The automatic feed regulators have given poor results in the Navy, and the satisfaction is less than with the Messageries Maritimes. In some cases the feed regulators have been taken off the boilers, and the feed regulated entirely by hand. Great difficulty is experienced in properly regulating the check valves, but this is thought to be better than relying on the regulators.

The lack of economy of these boilers has been condemned in the Navy as in the merchant marine. On the trials of the *Brennus*, a battleship fitted with Belleville boilers, and the largest ship, in point of power at least, to be fitted with them, the results of the preliminary trials were most unsatisfactory. The coal per I.H.P. was 3.95 pounds on one trial, and later, when the firemen had become more accustomed to the boilers, this figure was reduced to about 2.45 pounds. This is at the most economical rate of speed for the ship. In calculating the consumption of the engines, there is an auxiliary boiler that supplies all the auxiliary machinery except the air and circulating pumps, and the power of the main engines is used for the calculations. The power of the feed pumps is neglected and acts as a loss for the boiler furnishers. Neither of these trials was long enough to necessitate the fires being cleaned.

On the official trials I suppose these figures for the cost per I.H.P. were much improved. It may be interesting to compare these trials with those of the boilers of the *Jemmapes* fitted with D'Allest boilers, and with those of the *Friant* fitted with Niclausse boilers. The *Jemmapes* burned at the reduced rate of speed for which the Belleville boilers in the *Brennus* were tried, 1.84 pounds, while the *Friant* burned 1.94 pounds at the same reduced power. These trials took place at the same time and at the same place (Brest). The engines did not come from the same place, and were not of the same type. Those of the *Brennus* were probably the best, though those of the *Friant* were about as good. The engines of the *Jemmapes* were as good as those of either of the other ships, except that they were horizontal instead of vertical, as the others were.

THE D'ALLEST BOILERS OF THE *CARNOT*.

Dimensions:	
Pressure of steam at boilers, pounds	213.6
Grate surface (of 8 of the 24 boilers on the ship), square feet	361.73
Heating surface of the tubes, square feet	10,316
surface of the water legs, square feet	404.8
Total heating surface of 8 boilers, square feet	10,720.8
Number of tubes	1,592
Interior diameter of tubes, inches	2.874
Exterior diameter of tubes, inches	3.15
Length of tubes between sheets, feet	7.88
Section of opening of front ash pit doors, square feet	9.47
above the middle brick wall, square feet	9.04
of opening between tubes at entry of gases, square feet	7.75
of opening between tubes at discharge of gases, square feet	7
of smoke pipe for 8 boilers, square feet	61.9
Volume of steam in boilers and steam collectors, cubic feet	1,059.5
Weight of water in boilers, tons	24.8
Weight of one boiler:	
Front water leg, outside sheet, pounds	735
tube sheet, pounds	880
Back water leg, outside sheet, pounds	1,129
tube sheet, pounds	1,124
Forward end of steam drum, pounds	440
After end of steam drum, pounds	440
Angle iron on forward water leg, pounds	264
after water leg, pounds	374
Shell of steam drum, pounds	3,080
Side of forward water leg, pounds	627
after water leg, pounds	561
Rivets (for the heads only), pounds	330
One manhole plate complete, pounds	304
129 tubes at 30.8 pounds each, pounds	6,129
398 tube plugs complete, at 2.2 pounds each, pounds	876
16 screw stays for the steam drum, pounds	1,197
Screw stays for the water legs, pounds	1,155
Angle irons for attaching the smoke pipe, pounds	334
Reinforcements for the safety valves, pounds	77
Total weight of the boiler without water or fittings, pounds	20,056

MOUNTING OF THE D'ALLEST BOILERS OF THE *CARNOT*.

The first D'Allest boilers to be manufactured at the government shops at Indret were those of the *Carnot*. The design came from the inventor, who sent with the drawings a set of instructions for the mounting of the boilers. Those instructions are as follows:

Tube Plates.—After the forging, chamfering and drawing out of the edges of these plates is finished, the holes for the tubes and those for the water-leg stays are drilled in the tube sheet. The holes for the tubes are 3.15 inches for the rear tube sheet, and 3.23 inches for the forward tube sheet. The holes for the screw stays must be carefully centered between the holes for the tubes. After this operation the tube sheet is assembled with the angle iron attached to it in the design.

Plug Sheet.—These plates are assembled with the ends of the steam drum as soon as they have been forged, chamfered and drawn. The holes for neither the tubes nor the stays are made at this time.

Assembling the Water Leg.—Each tube sheet is then assembled with the corresponding plug sheet. Then the side of the water leg so formed is fitted to the plates. When the joints are faired the rivet seams *a*, *b*, *c*, *d* and *e* are made.

Assembling the Water Legs Together.—Each tube sheet having been united with the corresponding plug sheet, and a water leg having been thus formed, the two water legs of a boiler are then placed at the designed distance, and the sheets of the steam drum mounted after being faired. When the joints between the drum and the water legs are fair the holes for the rivets of the seams *ab*, *cd*, *ef* are drilled, and the location of the various accessories on the steam drum fixed. The tube holes in the tube sheets are then projected on the plug sheets. The holes in the plug sheets must be exactly opposite those in the tube sheets.

It is a good idea to fix the water legs at a fixed distance from each other as soon as the boilers are assembled, and before the rivet holes are drilled or the tube holes on the plug sheet marked out. For this purpose a brace *G* is fitted between the water legs.

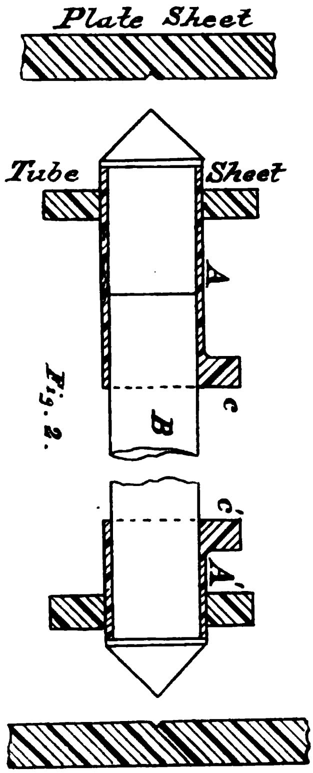


Fig. 2.

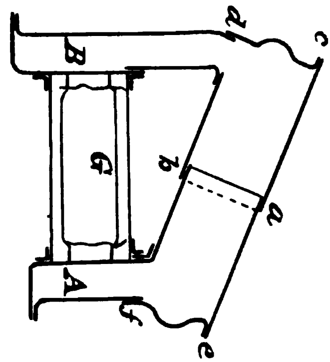


Fig. 1.

To project the holes on the plug sheet from the tube sheet some such contrivance as that shown in Fig. 2 must be used.

A, *A′*, are hollow mandrels passing in the holes in the tube sheets with an easy friction and sliding on a mandrel *B*. At the ends of the mandrels *A*, *A′*, are cones of hard steel, forming points. To project the holes from the tube sheets to the plug sheets it is necessary simply to hammer on the projections *C*, *C′*.

Drilling the Holes in the Plug Sheets.—The whole boiler is then dismounted, and the holes in the plug sheets are drilled. The plug holes are all 3.27 inches in diameter for the back, as well as for the front tube sheets. After the holes are drilled in the plug sheets, the surface around the outside of the holes is faired so as to give a good bearing surface for the rings used in forming the joints of the plugs. The faired diameter is about 4.15 inches.

The sheets are then sent to the annealing furnace and are carefully annealed.

Riveting.—After annealing, the plates are reassembled and riveted. A hydraulic riveter is used with a pressure of 80 to 100 tons on the stamp. All the seams are caulked. As many as possible are caulked on both sides.

Screwing and Placing of the Stays.—The screw stays are threaded and put in place by the ordinary method. They are riveted at both ends.

First Trial of the Boiler.—When the boiler is riveted, caulked, and the stays riveted, it is tested for the first time before the tubes are put in place. This is done because it is advisable to be sure that all the seams are tight before the tubes are in place, so that any change may be made easily. For the first trial, the plug sheets are closed by the regular plugs. The holes for the tubes in the tube sheets are closed by plugs of the same form as those used for the plug sheets, except that they are of a smaller diameter. These plugs are used in succession for all the boilers. The pressure for this trial is about 327 pounds.

Putting the Tubes in Place.—The tubes are then put in place, and expanded in the usual way. There are no stay tubes in the boiler, and all the tubes except those of the bottom row are ordinary tubes. The tubes of the bottom row are Serve tubes. It is best to expand the tubes with wire between the expander and the tubes.

Second Trial of the Boiler.—After the tubes are in place the boilers are tested as before by hydraulic pressure. This trial is to see that there are no leaks at the joints of the tubes and to correct any other leaks not corrected after the first trial.

Mounting of the Boiler on its Supports; Mounting the Uptakes.—The boilers, assembled two by two, are then mounted on their supports, and the uptakes and smoke pipes mounted. There must be no leaks in the joints of the uptakes or the draft of the boiler will be ruined. To prevent these leaks asbestos is placed between the plates.

Steam Trial.—When the boilers are completed they are tried for coal consumption at different rates of combustion. They are then sent to the ship to be mounted on board.

Modifications.—The above process was modified with the boilers of the *Duchayla* by securing the fair bearing of all plates of the boilers before drilling any holes for the tubes either in the tube sheets or the plug sheets.

COMPARATIVE TESTS OF NEW AND OLD STYLE D'ALLEST BOILERS.

The following is the description of several tests made by the French Government of a D'Allest boiler. The description is by Mr. D'Allest. The tests determined the use of these boilers in the Navy.

Description of the Boiler.—The D'Allest boiler is modeled as far as the circulation of the gases is concerned after the Scotch boiler. This was with the hope of increasing the small efficiency of the tubulous boiler so as to have it equal to that of the Scotch. The aim has been to give the gases a chance to burn after they have been effectively mixed. Such is the function of the combustion chamber.

The distance between two tubes multiplied by the length of a tube will give a section corresponding to the tube section in the ordinary boilers.

When the gases leave the nest of tubes they are at a comparatively low temperature, and so occupy a smaller volume. In this boiler, these gases would tend to circulate at the top of the vertical row of tubes furthest from the combustion chamber and to leave the tubes at the bottom of this row of tubes without heat. To avoide this a baffle plate is placed at the top of this row, forcing the gases to leave the tubes at the bottom of the side furthest from the combustion chamber.

The ratio of the heating to the grate surface is in the design of these boilers about 30; in those of the *Carnot* it was 29.64.

The space occupied by these boilers is as follows:

Height, 13 feet 1½ inches; width, 14 feet 5.2 inches; depth, 10 feet 2.1 inches. That is to say, the volume occupied is 0.716 cubic feet per square foot of heating surface.

The working pressure of these boilers is 213.6 pounds, and the weights are as follows:

Total heating surface of one boiler, square feet	1,340
Weight of boiler without water or fittings, pounds	20,056
Weight of supports, doors and grates, pounds	5,830
Weight of water in boiler, pounds	6,850

This is equivalent to 639 pounds per square foot of grate surface, or 21.6 pounds per square foot of heating surface of the boiler without water; and as the weight with water and fittings, 789 pounds per square foot of grate, or 26.7 pounds per square foot of heating surface.

Method of Making the Trials.—The quantity sought in each of these trials was the evaporative value of the coal in the boiler. The amount of coal burned was increased from 10 to 31 pounds per square foot of grate per hour.

The coal was weighed, the water pumped in the boiler was weighed, and the chimney gases were carefully analyzed. The temperature of the gases was taken at several places in the boiler, and the amount of priming shown by the calorimeter in each trial was found to be negligible.

The boilers used were old style Lagrafel changed for the trials into the new form. The pressure in the boilers was kept down to about 50 pounds, so as not to endanger the old boiler.

To obtain a certain fixed rate of firing of the grates, the quantity of coal to be used in each charge was weighed in advance. The furnaces of each boiler were fired in turn, and at regular intervals of ten minutes. The charges of the two boilers coupled on the same combustion chamber were five minutes apart.

The coal used in all the trials was Cardiff-Cory. The ashes were weighed after each trial, and were found to be about 8 to, 10 per cent.

The measuring of the feed water was done at the feed tanks which were carefully graduated.

Gases were taken from several points in the travel of the gases: under the top of the furnace, above the brick wall in the combustion chamber, and at different points in the nest of tubes. These gases were taken at the same instant, so as to be sure of the circulation of the gases of combustion. The instant chosen was that of firing the grates.

From the trials the volume of air necessary for the combustion of one pound of coal was found to be 15.2 cubic feet.

The temperature of the gases was taken at different points: in the combustion chamber at *d*, in the uptake at *m*, and at the points in the nests of tubes indicated by *a*, *b*, *e*, *e'*. The temperature was measured by means of small bars of copper. These were plunged in known weights of water and the rise of temperature of the water was noted.

The trials were made on two boilers that had between them 1,076 square feet of heating surface. The ratio of the heating to the grate surface was varied from 35 to 30, and afterwards to 25.

The dimensions of the boiler under trial were:

Grate surface, square feet (at ratio of 25)	43.06
Heating surface of the tubes, square feet	1,041
Total heating surface, square feet	1,076
Ratio of heating surface to grate surface	25, 30 and 35
Section of side ash-pit doors, square feet	9.04
above brick wall, square feet	9 47
of passage for gases entering tubes, square feet	18
of passage for gases leaving tubes, square feet	9
of smoke pipe, square feet	10.22

Natural draft was used in all trials except the fifth and the sixth.

RESULTS OF TRIALS.

	First.	*Second.*	*Third.*	*Fourth.*	*Fifth.*	*Sixth.*
Ratio of H.S. to G. S.	30	35	30	25	30	30
Temperatures *a*	863	674	726	831	903	924
b	389	554	567	632	506	627
c	382	581	......	545	651	615
c′	693	......	......	......	768	770
d	1660	990	1122	1585	1083	1145
m	370	......	466	512	427	510
Length of trial, hours	6	6·45	6	6	3	3
Total coal burned, lbs	2216	3146	3326	3960	2693	3326
Weight of residue, lbs	176	267	512	336	229	285
Pressure of steam, lbs	50	43	50	50	48	43
Temperature of feed	77	77	70.6	80.5	69	70
Coal per sq. ft. grate	10.31	15.1	15.46	15.3	25	31
Steam per lb., coal	10.67	9.58	9.23	8.97	8.02	8.75
combustible	11.65	10.47	10.92	9.8	8.763	9.652
Temperature of air	71	79	79	82	77	77
Draft in inches of water:						
At base of stack	......	......	......	0.16	......	......
Combustion chamber	......	......	......	0.10	......	......
Furnace	......	......	......	0.08	......	......
Ash-pit	......	......	......	0.02	......	......

In the third trial considerable air must have entered the boiler from the other boiler connecting with the combustion chamber, as the central doors to combustion chamber were closed.

RESULTS OF TRIALS (OLD BOILER).

For these trials the same boiler was used with the combustion chamber removed. The sides and the ends of the boiler were bricked up, and bafflers were interposed among the tubes to prevent the gases from rising directly to the stack.

The trials were under the auspices of French naval engineers, as were those preceding.

Natural draft was used in all the trials of the old boiler.

	First.	*Second.*	*Third.*
Ratio of H.S. to G.S	30.	30.	30.
Temperatures, *a*	460.	509.	510.
b	1,006.	965.	670.
c	1,274.	1,119.	1,005.
c′	590.	748.	656.
m	590.	568.	670.

	First.	Second.	Third.
Length of trial, hours	6.	3.	3.
Pressure steam, pounds	50.	52.5	53.5
Temperature of feed	73.	72.4	74.
Coal per square foot of grate	15.55	15.58	20.6
Steam per pound of coal	6.725	5.436	6.526
Temperature of air	77.	77.	79.

In all cases there was a thick black smoke at the time of firing and for some time after that. The flame in the furnace was reddish, showing incomplete combustion.

COMMENTS ON THE PRECEDING TRIALS.

It was noticed that the combustion of the gases was much better in the first trials. The amount of carbonic oxide was much less.

It was also noted that the gases lost much more of their heat in the first trials than in the second set of trials. The temperature at the base of the stack (m) was less in the first trials. The economical results were so much superior in the first set of trials that no comment seems necessary.

It would seem that the presence of a combustion chamber on a tubulous boiler is a good thing.

From the results of the first set of trials it appears that 1 pound steam can be produced

At 10.2 pounds per square foot grate with a weight of 7 pounds.
" 15.3 " " " " " " " 4.94 "
" 25 " " " " " " " 3.81 "
" 31 " " " " " " " 2.86 "

The evaporation per square foot of heating surface is:

At 10.2 pounds per square foot grate per hour, 39.6 pounds.
" 15.3 " " " " " " " 55 "
" 25 " " " " " " " 72.6 "
" 31 " " " " " " " 96.8 "

CARE AND PRESERVATION OF THE D'ALLEST BOILERS ON THE *LIBAN*.

The first sea-going vessel to be fitted with D'Allest boilers was the *Liban* of the Fraissenet line. This company is the one that owns the boilers, Mr. D'Allest being the engineer for the company.

The D'Allest boilers were placed on the *Liban* in 1890. At that time the engines were changed from compound to triple-expansion by adding a high pressure cylinder forward of the old engine. The *Liban* has performed the service to the Gold Coast and to Constantinople from Marseilles. Lately she has been put on the Corsican service. I made a trip in her to see the running of the boilers. The results following are what I saw then. The instructions of the manufacturer for the care of the boilers follow:

It was not possible to obtain any figures of the power of the ship that were at all accurate, and, in consequence, there was no possibility of obtaining any results of the boilers' performance. The only results to be obtained were those of the manner of managing the fires, and the general care of the boilers.

Raising Steam, Getting Under Way.—If the brick work is newly made it is dried before the fires are lighted for getting under way. This is done by keeping a light fire under the boiler for about four hours.

When the brick work is dry, the grates are covered with a layer of coal of as nearly a uniform thickness as possible. Fires are lighted as in the Scotch boilers, and are not forced. The heating of the boiler must be slow. The method of construction makes the danger from unequal expansion of the different tubes very great. In general, about four hours is taken to raise steam, but it is better to allow six hours for this purpose. The fires can be so pushed as to raise steam in one hour, but there will be many leaks at the plugs in the tube sheets, and at the tubes. These may take up after the boiler has been under way some time, but there is danger of their becoming so great as to necessitate the drawing of the fires under the boiler.

The feed pumps are started only when the steam is raised. The quantity of steam taken to the engines is regulated solely by the throttle valve, and the stop valves are opened wide on all the boilers. This is to ensure the same pressure in all the boilers.

Generally, when the fires are lighted there will be several leaks at the plugs in the tube sheets, due to the fact that the rings used to make the joint between the plugs and the sheet are not usually good conductors. As soon as the temperature of the boiler is practically the same in all parts these leaks will take up; or they may be stopped at once by setting up on the screws that secure them in place.

Working the Fires.—In working the fires, great use is made of the dampers at the base of the uptake to regulate the draft. As the steam rises the dampers are closed, and *vice versa.* When the fires are fresh the dampers are wide open, and as they are burned the dampers are closed.

Care is taken with the firing. The layer of coal on the grates must be equal in thickness in all parts to secure the maximum efficiency. This is not so necessary in this boiler as in the Belleville, on account of the bringing together of all the gases before they pass to the uptake. But it is always an advantage to keep the fires in their best condition. Great care is taken to keep the stokers from firing only on the front of the grates, and the thickness of the fires is kept as low as possible without leaving holes in them.

The furnaces are charged regularly at intervals of ten minutes, and the furnaces that are coupled together are charged five minutes apart. This rule is not kept by a watch, but it is observed as nearly as may be. The two furnaces that are coupled together (by having a common combustion chamber) are never fired at the same time. The doors to the combustion chamber are kept closed, as it is found that enough air reaches the fires by the ash-pit doors to give good combustion of the coal. Every quarter of an hour or so the combustion chamber is examined by one of the peep holes on the front of the boiler, and care is taken to have it full of flame. Too much air makes the combustion chamber fill and empty of flame. Too little air gives a reddish flame that is easy to recognize.

Feed.—In this boiler, as in all others of the water tube type, the water must be fresh. Mr. D'Allest makes no claim that his boiler can be worked with salt water, differing from Mr. Belleville, who says that the use of salt water is not dangerous, but requires some special care to be taken. Mr. D'Allest says that the use of salt water is absolutely dangerous, and that the presence of oil or greasy matters in the feed water is equally dangerous. This is due to the amount of tube corrosion that occurs with the use of salt water, and from the presence of oils in the boiler. The boiler should be filled in the first place with distilled water, but the use of fresh river water is allowable. For making up waste feed the use of distilled water is necessary. A complete distilling plant is fitted on the *Liban* for this purpose, steam for the distiller being taken from the first receiver, and the steam produced sent to the second receiver.

No oils except mineral oils are used for the piston rod, as well as for the cylinders and the valves. A filter is fitted on the pipe between the air pump and the feed pump, and lime is added to the feed water in the same way as on the *Australien*. Mr. D'Allest gives as the reason for the use of lime in the feed water the quantity of salt water that must inevitably enter the boiler from the condenser. He also says that the lime combines with the oils and grease in the feed water, and that this is precipitated for the most part at the bottom of the rear water leg. The amount of lime used on the *Liban* is about six pounds per day per 1,000 I.H.P.

The lime is introduced in a small tank placed abaft the filter, and connected at the top with the discharge of the feed pumps, and at the bottom with the main feed tank. A fine sieve is placed near the bottom of the tank to keep the lime from entering the feed water in a solid form.

The feed pumps used are of the Thirion type, which are used on all ships in the French Navy not fitted with Belleville boilers. This rule is applicable to the French merchant marine also. Of course, there are exceptions, but this is the standard pump in France.

Use of the Blows.—Every eight hours both the surface and the bottom blows are used. The saturation is limited to 3 or 4, and preferably to 2.

General Working of the Boilers.—In this respect there is no difference to be remarked between these boilers and Scotch boilers, except that the smaller quantity of water in them makes the liability to variations of the steam pressure greater. It is also slightly more difficult to keep the water level. The ordinary check valve is used to regulate the feed water, and the water level has to be watched carefully, although there is no trouble in keeping it constant. Great care must, however, be taken with the firing. This must be regular. It is by care with the fires that the steam pressure is kept constant. If the firing is not regular the pressure may rise beyond the gauge pressure, or it may fall very low.

Salt Water Leaks in the Condenser.—The only legitimate cause of salt water in the boilers is a serious leak in the condenser. This must always be kept clean. If there is a leak in the condenser that cannot be repaired before using the boilers, the following precautions must be observed:

The dose of lime must be tripled.

Only a part of the boilers will be used, and the fires will be forced under them to give rapid circulation in the tubes, and so to prevent the deposit of salt in them.

The blows must be used a great deal.

Cleaning Tubes.—The tubes being placed behind a water leg there is great difficulty in sweeping them from the front of the boiler. The hollow stays in the front water leg may be used for a steam jet; this has been tried, but has not given good results.

A plan for sweeping the tubes from the side has been tried on the *Liban* with success, and will be fitted to all future installations of D'Allest boilers for the French service. This consists essentially of a steam tube at the middle of the side of the boiler farthest from the combustion chamber; it has universal joints at both ends, and can be turned through a half circle so as to turn the small tubes fitted on the central tube between each row of tubes through the tubes. Thus the small tubes are so placed as to cover most of the tube surface. By turning on the steam to the central tube, each of the small tubes acts as a steam jet, and as it is turned around it serves to sweep the tubes. Holes are fitted in the small tubes pointing in all directions, up, down and ahead. When the central tube has been turned back and forth five or six times the boiler is practically clean. The soot goes up the chimney for the most part, but some of it settles at the bottom of the uptake and is shovelled from there. This operation takes about three minutes for each boiler, and takes about four inches of water from the boiler. The tubes are cleaned every two days.

The tubes may also be cleaned with brushes of a special form. This brush consists of wires seized between two steel sheets and arranged in a layer about ⅜-inch thick. It is introduced between two rows of tubes and turned through a right angle. Then it is pushed the length of the tubes. This can be done when the boiler is in use, but only with great difficulty. The sweeping of the tubes with the brush has not given as great satisfaction as the use of the latest scheme for sweeping tubes by steam.

When the ship comes into port the tubes are always swept by steam to use up spare steam.

Coming to Anchor.—The quantity of coal on the grates is made as small as possible when coming to anchor. All doors are closed, and the boilers are left to cool off as with ordinary boilers. The spare steam is used in sweeping the tubes and in running the winches. The blows are opened wide several times to reduce the concentration as much as possible. In this way it will rarely be found necessary to blow off steam to the condenser.

Cleaning Inside of the Boiler.—In spite of the use of the filter, there will always be found more or less grease in the boilers and the tubes may be entirely covered with a scale of grease and lime and salt. To guard against this the boiler is washed every three months with a solution of caustic soda. This washing is very easily done, and often avoids scraping the inside of the boiler. About 11 pounds of caustic soda are introduced in the boilers per ton of water contained. The soda is introduced in a liquid form and by the feed pumps. The concentration of the water in the pumps is not allowed to exceed 1 pound of caustic soda for 7 quarts of water, in order to avoid danger of attacking the brass of the pumps.

When the soda is in the boiler a light fire is started and kept up for two or three hours, a pressure of 30 to 40 pounds being maintained. Very little steam must be made and the fires are consequently very light. The surface and bottom blows are then used and the boilers are left to cool down. When cold, they are completely emptied by the cocks on the bottom of the water legs. It will be found that there is a large amount of oil sent off with the water.

While the boiler is being emptied the man-hole plate on the steam drum is taken off and the drum cleaned by simply sweeping it with a broom. It is important that the cleaning be done as soon as the water has left the drum so that any sediment in the drum can be removed while soft.

Some of the tubes are then opened, especially those over the combustion chamber. It is not often that there is any necessity to clean these tubes, but if at all dirty they are cleaned by passing a metallic brush through them. One or two tubes of each row are then opened for inspection, and finally all the tubes of the lowest row are opened and carefully cleaned. The bottom of the water legs is cleaned also.

If there is any salt in any of the tubes it must be removed. The tubes are scraped by means of a special scraper. The water legs are scraped, if any salt is found on them, from the holes opposite the tubes in the front sheet of the boiler.

Repair of the Brick Work.—The bricks used in the boiler are not cemented together, but simply placed side by side. Those of the arch above the combustion chamber, and those above the upper row of tubes will last almost indefinitely if only left alone. Some of those in the lowest row may be broken when cleaning the boiler, but they can easily be replaced. These bricks are ordinary fire bricks, cost little, and can easily be replaced when broken.

The sides of the furnaces and the brick walls are of ordinary fire brick laid against each other and covered with fire clay.

Preservation of the Tubes.—The only tubes that require any special attention are those of the lowest row, immediately above the fires. If they are kept absolutely clean they will not burn out and will not bend. But it is not possible to keep them quite clean. There is always more or less greasy deposits in them. They will then bend with the concavity turned towards the fires, and will leak at the joints in the tube sheets. These leaks are not of any importance, and can be easily stopped by expanding the tubes. Tubes are also sometimes burnt. This occurs only with the tubes of the bottom row, or to those tubes above the combustion chamber. The breaking of a tube may be foreseen by the presence of small reddish spots on the inside of the tube. If any of these spots are seen when cleaning the tubes, the tubes must be changed. These spots mark places where there will soon be a pocket, and where the tube will be burned. A broken tube has, however, been known to run for forty hours without the size of the break appreciably increasing.

The tubes that best resist the action of the fires are the Serve tubes. They are stronger to resist bending, and consequently less liable to give trouble from leaks; also, even if they are covered with a deposit, they may not burn, as the projections are large enough to conduct the heat from the tube to the water. For these reasons Serve tubes are used exclusively for the lowest row.

If the water level gets too low the tubes at the top of the combustion chamber will become empty and therefore more liable to burn. Such an accident happened to the boilers of the *Liban* when they were first tried. Two men were killed.' Since that time there have been three rows of tubes over the combustion chamber, and these have more recently been Serve tubes.

Where the power of the boiler is too great for that to be expected from the heating surface of the boilers, the more Serve tubes there are the better, as the efficiency of the heating surface is increased by their use. In projected designs of these boilers, Serve tubes will be used for all tubes in contact with the flame.

Changing a Tube.—If it is a tube of one of the outside rows of tubes that requires changing, it can be reached by the furnace or by the sides of the boiler, and may be cut near the tube sheet. The tube is then drawn out, and also the small ring that remains in the tube sheet, but this last after the rings are deformed by a hammer.

If, however, the tube to be removed is in the middle of the nest of tubes, it cannot be reached except by the holes in the ends of the boiler opposite the adjacent tubes. The ends of the tube are deformed as usual. The chisel used is of a special form calculated not to injure the boiler sheets. Generally it is sufficient to deform only one end of the tube and to force the tube from the back end by a tube driver.

A new tube is put in place and expanded in the ordinary way.

Plugging a Tube.—No tube should be plugged by a stay, as the stay not being in the water will expand when heated and the plugs will no longer be of any use.

It may also be stated that it never pays to plug a tube if there are any spare tubes on the ship. The time required to plug a tube is as great as that required to change the broken one and replace it by a new one. This is aside from the advantage of having a full set of tubes in the boiler.

A tube may be plugged by screwing on the face of the tube a plug of the same form as that for the outside sheet of the boiler. The screw that holds the plug in place is held by the plug in this outside sheet.

Leaks at the Plugs in Boiler Front.—There is frequently a case of a leak at one or more of the plugs in the outside plates of the water legs. These are caused by the introduction of a quantity of cold water in the boiler, or by the too rapid cooling or heating of the boiler. The rings of asbestos, used in a large measure to make these joints, are not good conductors of heat, and the temperature of the plugs is not the same as that of the boiler when that of the boiler is changing. The use of the improved rings of copper and lead has done away with most of the leaking at the plugs. If there is any leak at these joints, all that is necessary to do is to wait till the boiler has attained a fixed temperature, after which the leak will stop.

Boilers not in Use.—When a boiler is not to be used for some time it is filled completely, after being washed, as already described. The water in the boiler is fresh water, with about 22 pounds of caustic soda added per ton of water. This is to avoid all internal corrosion. All doors are tightly closed to avoid drafts in the boiler, and so to avoid any external corrosion.

For this reason it is best to cover the smokepipe.

General Instructions.—The boilers must receive only fresh water to fill to working level, and to make up waste feed. Consequently, loss of fresh water from the boiler must be guarded against, and the condenser must be in good condition. A distiller must be used, and lime be added to the feed to destroy the effects of the oils and salts in the water. This will also reduce "priming." A filter to remove the grease from the feed water is a necessity. Only the best mineral oil can be used in the cylinders.

In starting the fires, they should not be forced at all. They should not be pushed until the engines are well under way. While under way, the grates should be covered regularly and with as thin a layer as possible. Care must be taken not to charge the front of the grate to the exclusion of the rest.

When stopping firing, there should not be a large amount of coal on the grate, and the doors should be closed, and the boiler cooled down as slowly as possible.

The two furnaces coupled together on the same combustion chamber must never be fired at the same time.

The tubes of the lowest row must always be kept absolutely clean. Every three months or so, if the boiler is in constant use, the washing described must take place.

The brick work must be kept in good condition and all broken or lost parts replaced as soon as possible. The arch above the combustion chamber must be kept in good condition.

With proper care in managing the firing, the safety valves will never open. All that is required is proper care when getting under way and coming to anchor.

Specialties in the Design of the Boiler.—No solid drawn tubes have been used.

The boilers have zinc plates in all accessible parts. The quantity is fixed at about 2 pounds per 1,000 square feet of heating surface. The use of zinc plates is found to be a very good thing in these particular boilers. Mr. D'Allest said that it was absolutely essential, and that with it the boiler would last double the time it would without it. The plates are put in a box of the same form as that used in our Navy. Two plates are put at the bottom of each water leg, and two are placed in the steam drum. Those in the water legs are placed on the outside sheets, so as not to interfere with the circulation of the water in the tubes. The plates in the rear leg are not placed at the bottom, but opposite the second row of tubes from the bottom.

In placing these boilers in a ship, space is always left at the sides for getting at the tube nest. This space does not exceed that necessary for the uptakes.

OFFICIAL TRIALS OF THE D'ALLEST BOILERS OF THE *BOUVINES*.

Natural draft was used in the first two trials of these boilers. In the last two trials the draft was assisted by blowers. The third and fourth trials were in succession. The grates were not cleaned between these trials, which were the official trials for the acceptance of the boilers.

The ratio between the heating and grate surface was 30.

	First trial.	*Second trial.*	*Third trial.*	*Fourth trial.*
Length of trial, hours	6.	12.	3.	3.
Coal burned per square foot of grate, pounds	20.5	12.3	24.5	30.7
Temperature of feed	119.5	123.5	125.	127.
Pressure of steam, pounds	185.	185.	185.6	185.6
Evaporation per pound coal, pounds	9.8	10.068	9.501	9.235

TRIALS OF THE *JEMMAPES*.

The engines of the *Jemmapes* were designed for 8,400 I.H.P. with forced draft, but the official trials gave 9,250, and this with a consumption of 2.03 pounds per I.H.P. The coal burned per square foot of grate was 29.66 pounds.

On another of the trials the cost of an I.H.P. was (7,711 I.H.P.) 1.802 pounds. The coal per square foot of grate in this trial was 22.05 pounds per hour. The second trial was of twelve, and the first of six hours' duration. The results of the other trials were not public when I left France.

All D'Allest boilers are designed by the inventor, though most of them are manufactured by other firms than the one of which he is engineer.

THE NICLAUSSE BOILERS.

These boilers are on the principle of the Field tubes. Each of the evaporating tubes is fixed at one end in a water leg with two divisions, one for steam and one for water. To carry the water from the water side of the leg there is a tube fitted connecting the water leg to the end of the evaporating tube. The water then turns in the tube and passes through the outside or evaporating tube to the steam side of the water leg.

The features of the boiler that are peculiar are the way of making the joints between the tubes and the water leg; the form of the tubes and the water leg, and the kind of nappe on the top of the steam side of the water leg at the point where the steam enters the drum.

The tubes are all of welded steel, and are reinforced at the joints which are always conical, whether the joints are screw or not.

The joint between the evaporating tube and the water leg is a flat conical one at both the outside sheets of the water leg. The joint at the partition between the steam and the water sides of the leg is a loose one, not water tight. The cones forming the joints to the outside sheets are shrunk on the tubes and are then turned to the required diameters. The cones are not exactly the same, as in placing the tube in place the cone on the inside sheet of the water leg begins to bear last. The cone on the tube for the outside sheet is made comparatively flexible by being secured at one end only. The inside diameter of the outside cone is made the same as the outside diameter of the inside cone. The tube can be drawn out, and it is in equilibrium for the steam pressure. The tube does not tend to leave the water leg. Nevertheless, a safety bar is screwed on the outside of the water leg to ensure the tube staying in place in case of shocks, etc.

The end of the evaporating tube is in the form of a lantern with a section at the middle partition of the water leg that is approximately the same as that of the tube. The diameter of the hole in this partition is very slightly larger than that of the tube at the inner cone.

The inner tube which serves for the circulation of the water to the end of the evaporating tube is screwed into the outside of the latter. The joint is conical. The tube has a small lantern to form the junction between the two parts of the tube. The tubes are shown in the accompanying sketches.

The nappe at the top of the steam side of the water leg is made conical with the large diameter at the top of the nappe so as to give a small velocity to the steam when it is entering the drum at the top of the boiler.

The disposition of the nappe gives dry steam at rapid firing of the boiler.

The collectors are of malleable iron, and there is a separate collector for each pair of vertical rows of tubes. The tubes are arranged staggered. This is to give the gases of combustion a zig-zag course through the tubes. Space is left between the collectors to sweep the tubes by steam. The joints between the collectors and the drum are conical, and the drum is fastened to the collectors by bolts, to make the joints tight. The collectors are united at their lower part to enable the blowing down under pressure. There are pipes to make this connection.

The feed water is introduced in the upper drum in a stream going in the steam. No ejector is fitted to the boiler, and no part of the boiler is particularly apt to have more sediment than another unless it be the bottom of the collectors where the bottom blows are placed.

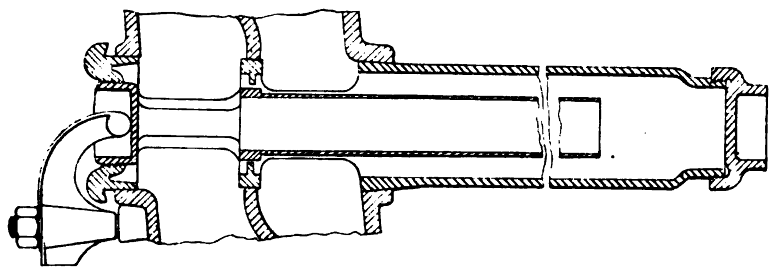
It seems to me that there is too much machine work on the tubes. This makes the boiler costly. The conical joints are satisfactory and appear to be good. I think, however, that the joint between the collector and the drum might as well be of the ordinary form.

The circulation of the feed water in the boiler depends entirely on the difference in weight of the different columns in the water leg. The higher the boiler the better the circulation. The circulation is, however, good.

The economy of the boiler is not great at high rates of combustion. I think if a combustion chamber were fitted the economy would be as great as that of the D'Allest boiler, if not superior.

The great advantage of this boiler is the freedom of expansion of the tubes and the consequent ease of forcing. When forced, the tubes bend, and I suppose that they will wear out sooner than if Serve tubes were used for the bottom row.

Section & Views of Evaporating
& Circulating Tubes
Niclausse Boiler.



The inner tube is not supported and will sag so as to bear on the evaporating tube, but it is in a constant state of vibration and this would not necessarily be an objection of weight.

The floor space occupied for a given heating surface is here reduced to a minimum. The tubes are slightly inclined but the ends of the boiler are vertical.

All work on this boiler can be done from the front of the boiler, and no space is necessary at the sides or back.

The boiler does not work regularly enough, due to the small amount of water in it. But it can be worked without any auxiliaries such as are needed on the Belleville boiler, and will give fair satisfaction even when used alone without Scotch boilers.

It is very easy to repair, and the repairs are quickly made.

The inventor claims the advantages of small weight and good utilization of coal in addition to those given, but the weight is slightly greater than that of the D'Allest boiler, and is much greater than that of almost any type of bent tube boilers in use in this country. The weight may be reduced, but it is already a great deal less than that of the Scotch boilers whose place it is trying to take. The advantage of using straight tubes lying in the ease of cleaning and repair, overcomes the advantage of the smaller weight of the bent tube boilers.

The inventor claims that the impossibility of emptying the tubes except when cleaning the boiler is a great advantage. He says that this retains whatever deposits may be made in the tubes in a soft muddy state that facilitates the cleaning wonderfully.

The tubes and all other parts of the boiler are made interchangeable. The boiler is in small elements and can be taken out of a ship with ease. Any part that requires replacing can be changed without great cost, owing to its small size.

Care of the Boilers.—The inspections of the tubes will be more or less frequent according to the quality of the water used, and the amount of work done by the boiler. When the boilers are first used the tubes should be examined frequently, especially those of the lowest row. This is to determine when and how often the boiler should be cleaned.

The part of the collectors that is most liable to become dirty with use is the upper part. Cases have occurred when the deposits in the top of the collectors have stopped the circulation, and tubes have been burned out.

The boiler should not be emptied except when about to clean it, as the deposits would otherwise become hard and much more difficult to remove. The deposits will be found to be in most cases in the circulating tubes to the exclusion of the evaporating tubes.

Both the surface and the bottom blows should be used at least once a day. The cocks are very liable to get choked, and must be frequently examined to see that this does not occur.

To clean a tube, it is necessary to remove the safety bar, and to unscrew the inner tube. These tubes contain the deposits, which are removed by washing, or, if it is necessary, by using a metallic sponge. A special key is furnished to prevent the turning of the outside tube when the inner one is unscrewed. This turning of the outside tube is not frequent. If the evaporating tube needs cleaning, it can be done either in the boiler or it can be drawn, the screw plug at the back taken off, and the tube cleaned outside the boiler. To draw the evaporating tube, it is started with a hand hammer. Before replacing a tube in the boiler, the joints are carefully cleaned and covered with grease.

In general, all the tubes of a boiler are cleaned at the same time, commencing with the bottom row in removing them, and with those of the top row in replacing them. While the tubes are out of the boiler the collectors are wiped and cleaned.

The tubes are cleaned on the outside by a steam sweep that is placed in the openings between the collectors. They are swept in horizontal rows, beginning at the top of the boiler.

Other parts of the boiler requiring to be examined from time to time are the feed pipe and the fittings of the drums.

Boxes to collect the deposits from the feed water are put in the drum, and must be cleaned frequently.

The feed water is regulated entirely by a check valve placed on the boiler. Any sudden increase in pressure is stopped by use of more feed water.

In case of leaks, it is not well to screw up on the nuts on the safety bars. This may break the joint and cause an explosion of the boiler. All leaks are the result of dirt in the joint, and no leak can be stopped without remaking the joint. If the joints are properly made in the first place, no leaks will appear during the working of the boiler.

During stops, the ash-pit doors are closed, but neither the furnace doors nor those to the tubes are opened. More especially if the feed water falls below the bottom of the glass should these doors be closed. In this case, the fires must be drawn at once unless the cause of the lack of water is at once discovered.

When the boilers are no longer required, the blows are used and the water level is raised to the top of the glass. The fires must be pushed to the back of the grate or even drawn. Sudden changes of temperature will have no bad effects.

When a boiler is not to be used for some time it is cleaned and then completely filled with water.

EXTRACT FROM A CIRCULAR FROM THE MINISTER OF MARINE CONCERNING THE USE OF LIME IN THE FEED WATER.

According to the opinion of the Inspector General of Engineers it is best to add lime to the feed water after it leaves the filter, as, for example, in the feed tank, but care must be taken to prevent the lime from settling at the bottom of the tanks. It is best, on the contrary, that the lime should go to the boiler and mix with the water there, and be dissolved. In certain cases it may be advantageous to introduce the lime directly into the boilers. In this way it would not pass through the feed pumps. As to the amount of lime to use, it is better not to use too much, and for this reason, it is essential to determine at least once a watch the acid or basic condition of the water in the boilers by using litmus paper, or in some other simple way.

Until further orders, the amount of lime to be delivered will be 1.7 pounds per ton of coal in the bunkers. But it is understood that the amount to be used will vary so that the water in the boilers will never have any trace of acidity, but give a good basic reaction.

COMPARISON OF THE ENGINES AND BOILERS OF THE *BUGEAUD*, *CHASSELOUP-LAUBAT*, AND *FRIANT* FITTED WITH BELLEVILLE, D'ALLEST AND NICLAUSSE BOILERS.

These ships are exactly the same except in the fire-rooms. They were intended to give a comparison of the three types of tubulous boilers used on them.

The engines of these ships all come from the shops of the Forges et Chantiers de la Mediterranée, at Havre, and are the same in all particulars.

The boilers come from the inventors of them.

The hulls of the *Bugeaud* and *Chasseloup-Laubat* come from the navy yards at Cherbourg; that of the *Friant* from the navy yard at Brest. They are identically the same.

The ships are second class cruisers of 3,725 tons displacement. Length, 308 feet; beam, 43 feet 6 inches; depth below main deck, 29 feet 6 inches; draught, 17 feet 6 inches at midship section, and 20 feet 8 inches aft; area of the immersed midship section, 697 square feet. The lines of these ships are derived from those of *Davout* that gave satisfaction. The ships are designed to give a speed of 19 knots with forced draft of 1 inch water pressure in the fire rooms. They have each a crew of 356 men, all told, and were all launched in 1893.

The designed power of the engines at forced draft was 9,000 I.H.P.

The contract calls for the following powers and dimensions of engines and boilers for the three ships:

The total power of the main engines at the forced draft trial is 8,650 I.H.P. If the number of revolutions is less than 135 it will be increased to that figure. If at 135 revolutions the power (with a screw given by the Government) is less than 9,000 I.H.P. the dimensions of the screw may be changed to increase the power.

The price of the engines of each ship is 1,314,700 francs. The price of the boilers is for the Belleville boilers of the *Bugeaud*, 603,570 francs; for the D'Allest boilers of the *Chasseloup-Laubat*, 503,300 francs; for the Niclausse boilers of the *Friant*, 615,170 francs.

The total weight of all machinery is to be (boilers and water, included), *Bugeaud*, 801 tons; *Chasseloup-Laubat*, 757 tons; *Friant*, 760 tons. For any excess in weight within 5 tons a penalty of 1,000 francs per ton is charged; for excess within 10 tons, 2,000 francs per ton is charged; for excess within 15 tons, 5,000 francs per ton is charged; if in excess above 15 tons the machinery may be rejected.

There are to be the following trials:

One forced draft trial of four hours, with a combustion of not more than 30.7 pounds per square foot of grate. The power on this trial must be as much as 9,000 I.H.P. for all machinery. If on this trial the consumption of coal per square foot of grate is as great as 27.7 pounds, no second forced draft trial is necessary; if it is not, there will be a forced draft trial with a consumption of coal at least equal to 30.7 pounds per square foot of grate per hour.

There will be a trial of twenty-four hours, of which four hours will be at about 6,000 I.H.P., two hours at 9,000 I.H.P., and eighteen hours at 6,000 I.H.P. This last period may be taken at any part of the trial. The grates will be clean at the commencement of the trial, and the coal burned per I.H.P. will be from 1.76 to 1.98 pounds per hour.

There will also be three trials of six hours each, with powers of 7,000, 3,500 and 1,500 I.H.P., and with coal consumptions of 1.87 to 2.09 pounds; 1.54 to 1.76 pounds, and 1.65 to 1.87 pounds respectively. If the consumption exceeds 2.21 pounds on the first trial, or 1.98 pounds on either of the others, the machinery may be rejected.

In each of the trials where the consumption is fixed, any excess involves a fine of 100 francs for each hundredth pound. There is an equal premium for all saving above the figures given. No premium is given for any excess of power, and no penalty is imposed for a failure to arrive at the required power. It is understood that the machinery will be rejected if it fails to reach the required power.

DETAILED WEIGHTS IN THE ENGINE ROOM.

	Tons.
Engines complete, (with reducing valves)	246.9
Line shafting	51.0

	Tons.
Propellers	12.0
Bilge pumps	1 6
Piping and water valves	49.0
Floor plates and ladders	8.6
Tools	5.2
Spare parts	8.0
Evaporators	3.0
Engine room ventilators	2.4
Water in condensers and pipes	10.0
Water in tanks	5.0
Lime tanks	1.3
Total weights in engine room	425.0

For the *Bugeaud* (Belleville) the weight of water in tanks is increased to 16.0 tons, making the total weight for this ship 436.0 tons.

DETAILED WEIGHTS OF BOILERS.

	D'Allest.	*Belleville.*	*Niclausse.*
Boilers proper	131.3	273.3	146.5
Uptakes	67.0		56.0
Accessories	11.8		6.6
Grates and fittings	19.1		18.3
Tools and spare parts	5.6	8.1	7.6
Feed pumps	5.2	11.4	5.2
Tanks	4.0	8.0	4.0
Smok epipes	17.0	23.5	19.8
Floor plates and ladders	9.0	9.0	9.0
Fire room ventilators	9.0	9.0	9.0
Air compressor		2.5	
Separator		5.2	
Water in boilers	53.0	16.0	53.0
Total of fire rooms	332.0	365.0	335.0
Total of all machinery	757.0	801.0	760.0

The difference in the weights of smoke pipes is due to the fact that the different contractors did not include the same height of pipe in their estimates, and the weights given do not include the same portion of the pipes.

The table is taken from the contract weights, and is not the same as the weights actually in the ships. The weight of the boilers of the *Friant* are given by the contractors as follows:

	Tons.
Boilers alone	202.61
Uptakes	10.76
Water in boilers	46.18
Tools and spare parts	7.26
Joint to smoke pipes	5.15
Total of parts mentioned	271.96
Adding weights of parts not included in above, as in contract weights:	
Feed pumps	5.2
Tanks	4.5
Smoke pipes	19.8
Floor plates and ladders	9.0
Ventilators	9.0
We would have a total weight in actual fire room	329.0

The increase in weight of the boiler proper, and the decrease in weight of uptake, together with the decrease in the weight of water in boiler are to be noted. The total weight remains about the same as before.

DIMENSIONS OF THE BOILERS.

	D'Allest.	Belleville.	Niclausse.
Number of fire-rooms	3	3	3
boilers	20	24	20
furnaces per boiler	1	1	1
Length of grate, feet and inches	6–8	4–7	6–8
Width of grate, feet and inches	5–4½	7	6
Total grate surface, square feet	732	755–2	782–8
Total heating surface, square feet	19,451	21,594	23,338
Ratio H.S. to G.S	26.6	28.6	29.8
Outside diameter of tubes, inches	3.25	3.23	3.23
Inside diameter of tubes, inches	2.91	2.86 and 2.60	2.97
Length of tubes, feet and inches	7–9	6–4	5–8½
Diameter of circulating tubes, inches	..	..	1$\frac{9}{16}$
Number of tubes in vertical row	10	9	9
Weight of water, tons	53	16.2	46.2
Volume of steam space, cubic feet	1,879	784	830
Boiler pressure, pounds	214	242	214
Pressure at engines, pounds	170	170	170

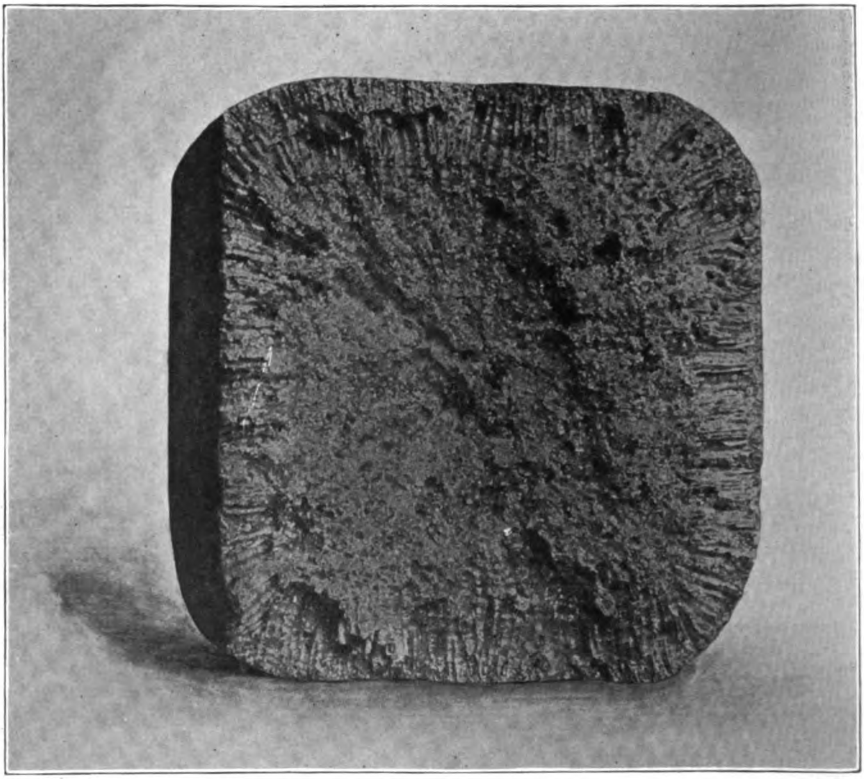
The excess in weight of the Belleville boilers is partly explained by the short grates on those boilers. The Niclausse boilers have a much larger heating surface than the D'Allest for the same power, and considerably more than the Belleville. This is while retaining a weight only equal to that required for the D'Allest boilers, and while having 40 tons less weight than the Belleville.

The ease with which the D'Allest boilers can be forced makes them far the most powerful boilers in an emergency of the three sets given.

There are two air pumps for each engine with diameters of 24.6 inches and stroke of 15.75 inches. The number of turns of the air pump was designed at 168 at full power. The air pump turns the circulating pump also. The diameter of the turbine is 47.2 inches.

The ratio of the final volume occupied by the steam to its volume on admission to H.P. cylinder is 7.4129.

Only fresh water is to be used for feed. A filter is placed between the engines and the boilers, and there is an apparatus for adding lime to the feed water. There are two feed pumps for each fire room, of which one is large enough to supply the boilers. There are two evaporators to supply waste feed. To make the working of the fires easier, there is a damper at the base of each smoke stack near each boiler.



FRACTURE OF OPEN-HEARTH STEEL INGOT.

AREA, 6½ BY 6½ INCHES.

Number of cells immediately under surface exposed to fracture, 253. Average depth of cell, 1⅛ inches. Average diameter of cell, ⅛ inch.

NOTES.

PHYSICAL REASONS FOR RAPID CORROSION OF STEEL BOILER TUBES.

The following statement by Mr. W. H. Gibbons, president of the Parkersburg Iron Company, on the above subject is from the "American Engineer and Railroad Journal":

In investigating the oft repeated assertion that "boiler tubes made from steel corrode, and become unserviceable much more rapidly than those made from charcoal iron," we have made the following experiments, as given below:

Taking a "heat" of ingots made of 7 inch × 7 inch × 4 inch, weighing about 650 pounds each, of the best open-hearth basic steel of following analysis: Carbon, .10; phosphorus, .014; manganese, .21; sulphur, .026; copper, .05, we first gave them a "wash heat," and cut them into two nearly equal pieces, then transferred them to heating furnaces again, and after another slight heating rolled them down direct to No. 9 gauge and sheared them into skelp for 4-inch tubes, being careful to keep separate the skelp made from tops and bottoms of ingots.

We found that the "bottoms" of the ingots invariably worked smooth and clean into plates, and sheared with only a normal wastage, but that the "tops" were almost uncontrollable in rolling, working soft, spongy and with much irregularity, and the surface of the plates when finished had a muddy, dirty appearance, indicating an excessive amount of cinder. Allowing one of the "tops" of ingots to cool after the first wash heat, on close examination its whole surface was found to be closely covered with minute holes, so close together that in a diameter of 1 inch as many as 25 of these minute holes could be counted, into which in many instances a needle could be entered to the depth of from 1 inch to 1½ inches.

Our next step was to nick and break with a heavy drop the upper or "top" of one of these ingots before heating, with the result that the fracture developed an almost entirely spongy or honeycombed structure extending from ⅛ inch under the skin or surface to about 1½ inch in depth uniformly around the four sides of the ingot, and in many instances these cells ramified and extended to the center. Actual count of these cells in face of fracture 6½ inches by 6½ inches was 253.

This spongy condition no doubt revealed the at first unaccounted for difference in working between "top" and "bottom," as the same ingot when broken cold, half way up, showed much less of the cellular structure, which no doubt almost entirely disappeared on a nearer approach to the bottom, owing to hydrostatic pressure of molten steel in the mould driving out the gases before solidification occurred.

Our next step was to have tubes made from "tops" and "bottoms," with a report as to the working of the two, which only went to confirm our earlier investigations that the "tops" welded freely, and even blistered sometimes, while the "bottoms" worked hard and stubborn and were difficult to weld. Taking sections of these tubes made from the respective portions of ingot, they were put in a lathe, burnished, and subjected to microscopical examination, which revealed these same "cells" or "honeycomb" structures much decreased in size, but still present in great numbers in the "top" section, while the "bottom" was comparatively smooth and solid.

Each one of these compressed cells has walls of solid metal encasing infinitesimal shot of slag, which, in the boiler tube in service, with the incessant expansion and contraction of greater or less heat, will finally open slightly, admitting a little dampness, which under the heated condition of action will undoubtedly set up very rapid corrosion and early disintegration of the whole tube.

Before we had the opportunity of making this thorough test we were at a loss to know why steel tubes made from finest obtainable open-hearth stock should show such short lives when compared with those made from *charcoal iron*, but this would seem to be ample confirmation, for the known fact that, as a rule, steel has been most disappointing in service when compared with the possibly less pure chemically, but more homogeneous and durable charcoal iron.

To make a free welding steel for boiler tubes, this sponginess *must* exist, and the more pronounced it is, the more thoroughly it will weld and the more rapidly it will corrode. Conversely, the more solid and free it is from "honeycomb" in the ingot, the more difficult, if not impossible, it is to weld, and the longer the *unwelded* life in the boiler.

It is a matter of record that the United States cruiser *Chicago* put new steel tubes into some of her boilers about two years ago, that were riddled with holes as large as shot inside of forty days' service, while others of her boilers had the original charcoal iron tubes that were put in when they were built, and which were still good after service of some five years.

COAL CONSUMPTION OF SOME BRITISH VESSELS.

During the discussion of a paper before the Institution of Naval Architects, Lord Charles Beresford stated that the coal consumption of the *Grafton* for a speed of 10 knots was 1½ tons an hour. From the following results obtained on a voyage to the Cape of Good Hope and back, and published in "Engineering," it appears that this figure is based on her consumption per I.H.P. for all purposes at 12.5 knots, and assuming 1,300 I.H.P. for 10 knots, which, of course, does not take into account the fact that the auxiliaries at the lower speed would tend to make the consumption per I.H.P. for all purposes greater at the lower speed. The following are the figures for the voyages:

	Outward.	*Homeward.*
Mean speed	12.46	12.54
I.H.P. for speed	2,500	2,500
Coal, in tons, per hour, making distance	2.46	2.44
including auxiliary engines	2.85	2.83
per day for all purposes	68.40	67.92
Pounds of coal per I.H.P., making distance	2.21	2.18
for all purposes	2.63	2.60

The *Grafton* is a first-class cruiser of 7,700 tons displacement. The *Crescent*, a sister ship to the *Grafton*, has completed two voyages to Australia and back, the figures for which are given as 54,000 miles, 14,000 tons of coal, and a mean speed of 12.4 knots; which is equivalent to about 77 tons of coal a day.

It has been stated in the House of Commons that the *Sharp-shooter*, since being fitted with Belleville boilers, has steamed for thirty consecutive hours, developing 2,326 I.H.P., on seventy-four tons of coal for the time.

Mr. J. I. Thornycroft has given, in the "London Times," the following record of the coal consumption trials of the *Speedy*:

Hours.	*Speed.*	*I.H.P.*	*Air pressure in tenths of an inch.*	*Coal per I.H.P.*
10	13	1,026	..	1.74
8	15	1,904	2	1.52
21	12.5	1,000	3 to 1	1.79
16	10	530	0	1.90
15	10	560	0	1.79
42	10.4	640	1	1.92
20	14.5	1,659	2.5	1.58
4.	16.5	2,806	6	1.67
38*	7.3			

*Coal 812 pounds per hour.

SHIPS.

AUSTRIA.

Monarch.—"Mittheilungen aus dem Gebiete des Seewesens" gives the following particulars of this coast defense vessel, which is 305 feet long, 55.8 beam and 21 draught:

	Tons.
Hull, including 462 tons of deck armor	2,145
Armor	1,132
Machinery	836
Guns	600
Equipment	521
Crew and provisions	79
Coal at normal draught	197
Coal with full bunkers	492
Total weight with normal coal	5.510

She has two barbette turrets, each with two 24-cm. guns, six 15 cm. rapid fire in casemate, and eighteen smaller rapid fire guns.

The armor belt amidships is 10.6 inches thick, tapering to 4.7 at the bow, and terminating abaft the after magazines in 8-inch armor with an 8-inch bulkhead forward and aft at the end of the heavy armor. Above the belt is a citadel protected by 3-inch armor. There are two conning towers protected by 8-inch armor.

Her twin screw engines have been designed for 5,920 I.H.P. with natural and 8,380 with forced draft; they have cylinders 33½, 51 and 78¾ inches diameter by 35½ inches stroke, and work with a boiler pressure of 156 pounds. The air and bilge pumps are worked from the engines. The condensing surface is 11,840 square feet for the main, and 860 for the auxiliary condensers. Steam is furnished by three double and two single ended boilers, all 13.75 feet diameter; the double ones 18.63, and the single 8.83 feet long; the grate surface is 568, and the heating surface 15,770 square feet. There is one smoke pipe, the top of which is 63 feet above the grates.

The speed expected of this vessel is 17.25 knots.

BRAZIL.

The following dimensions of the five torpedo boats built by Schichau, and delivered to the Brazilian government last year, are from the "Zeitschrift des Vereines Deutscher Ingenieure":

Length on water line, feet	152.5
Breadth, feet	16.73
Draught aft, feet	8-z
Displacement, tons	136.
Coal in bunkers, tons	40.

The engines are of 2,200 I.H.P., and the speed on trial was as high as 28.3 knots, though the mean speed is not stated. They were designed for 26 knots.

ENGLAND.

New Cruisers.—The four first class cruisers provided for in the Navy estimates are to be similar in general design to the *Powerful* and *Terrible*, though somewhat smaller. Like the latter vessel, they will be sheathed with wood and coppered. Their dimensions will be:

Length between perpendiculars, feet	435
Length on water line, feet	455
Breadth, feet	69
Mean draught with keel, feet	25.25
Displacement, tons, about	11,000
Coal on above displacement, tons	1,000
Bunker capacity, tons	2,000

They will be named *Diadem*, *Europa*, *Niobe*, and *Andromeda*.

The armament will include fifteen 6-inch rapid fire guns, fourteen 12-pounders and twelve 3-pounders, besides a number of machine guns, and three torpedo tubes, two of which will be submerged.

The machinery will consist of two sets of triple expansion engines on each shaft, the combined I.H.P. of which will be about

20,000, which is expected to give them a speed of $20\frac{1}{2}$ knots. The boilers will be of the Belleville type.

The four second class cruisers will be all steel vessels, and of the following dimensions:

Length on water line, feet	320
Breadth, feet	57
Draught, mean, feet	22
Displacement, tons	5,750

The battery will be the same as that of the vessels of the *Talbot* class. They will be named *Vindictive*, *Gladiator*, *Furious*, *Arrogant*.

The engines will be of 10,000 I.H.P., natural draft, giving a speed of 19 knots. The boilers will be of the Belleville type.

The two third class cruisers, *Pelorus* and *Proserpine*, will be "improved Barhams" of the following dimensions:

Length on water line, feet	300.
Breadth, feet	36.5
Draught, mean, feet	13.5
Displacement, tons	2,100.

The engines will be of 7,000 I.H.P., and the speed expected 20 knots. The boilers, as in the case of the first and second class cruisers, will be of the Belleville type.

The armament will comprise eight 4-inch and eight 3-pounders, besides torpedoes.

In addition to the above mentioned vessels, twenty torpedo boat destroyers, with a speed of from 30 knots, are to be built.

Bruiser.—This torpedo boat destroyer, a sister vessel to the *Ardent* and *Boxer*, described in the last number of the JOURNAL, was launched from the works of Messrs. John I. Thornycroft & Co., on the 27th February, and had a successful trial on the 29th of March, the following account of which is condensed from "Engineering":

The *Bruiser* steamed easily down to the Lower Hope, meeting the young flood, the wind being W.N.W., with heavy squalls and hail showers at intervals. The weather was so bad that is was decided to run the trial miles on the Lower Hope course, instead of going out to the Maplin, as is now usual. Seven runs were

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made on the mile—the first, done in 2 minutes 6 seconds, being thrown out, the counters not being put in gear until the middle of this mile. The mean speed of the six runs was 28.14 knots. The rest of the three hours full speed running was made between the Mucking Light and Warden Point, in an awkward sea, the wind meeting the tide. The speed for the three hours was 27.97 knots. It is a curious fact that in this trial the boat only missed making the even 28 knots by rather less than her own length on each hour.

The average results for the measured mile runs were:

Steam pressure in boilers	204
Air pressure in fire rooms	2
Vacuum	26.2
Revolutions	376 6
I.H.P.	4,156
Speed in knots	28.14

For the entire three hours, the steam pressure averaged 202 pounds and the revolutions 374.3.

The coal consumed was 17¼ tons on the three hours' run; but it will be understood that it was not weighed as used—such a procedure would be manifestly impossible upon a full-speed trial of a vessel of this class—but it was carefully weighed before being put on board, and what remained over was estimated. It will be remembered that this was an official trial, so the records were taken by disinterested persons. The rate of combustion gave a fuel consumption of about 68 pounds of coal per square foot of grate per hour. In previous trials as much as 79 pounds have been burnt per hour per square foot of grate. The indicated horse-power on the six mile runs averaged 4,156, the trial being run with engines linked up.

At the conclusion of the speed trials, circles were turned on both hands. The circle with helm to port was accomplished in 1 minute 46 seconds, with the helm to starboard in 1 minute 52 seconds. This was in a strong wind, the force being 5 to 6. The weather was too rough to make circles astern, so that part of the trial is reserved for another time.

The machinery is the same as that of the other vessels of this class constructed by the Messrs. Thornycroft, except that the boilers are like those of the *Ardent*, in which a slight increase in heating surface has been made over those in the *Daring*, and that the screw propellers are of manganese bronze, with blades cast with the hubs.

It has long been the practice of the torpedo boat builders to forge the propeller blades separately and key them into a boss. This plan answered well so long as steel blades only were used, but when manganese bronze was required, it was found there was danger of the blades getting loose in the boss. In order to avoid this, a new method of keying in was devised, but it is now thought desirable to have the propellers cast in one. The screws of the *Bruizer* are three-bladed, all surfaces being polished.

The furnace doors are fitted with springs so as to be self closing, and the ashpit doors being self closing, there is less danger to the stokers in case of a burst tube, as the steam would go up the chimney.

In the *Speedy* a new device was tried for controlling the distribution of the feed in the water-tube boilers with which that vessel was fitted. It is this question of feed distribution which was so long the rock ahead for the water-tubists when an attempt was made to run these boilers in groups. It was argued, not without reason, that in steam generators of this sensitive nature, and with so small a water-holding capacity, unless the feed were very evenly distributed, disaster would follow. In order to avoid this, various devices have been tried, with more or less success. That introduced by Messrs. Thornycroft consists of a hollow steel float, capable of withstanding the boiler pressure, which is placed inside the separator or steam-collecting cylinder which forms so important a feature in the Thornycroft boiler. By a system of levers, somewhat too complicated to describe without the aid of diagrams, the float regulates the opening of a check valve which is placed within the boiler, the amount the valve is opened determining the volume of feed. In this way the water level in the boiler determines the amount of feed admitted; thus, if the water level falls, the check valve is thrown wider open, if it rise the check valve is closed. Unlike most gears of the kind, the motion of the float has not to be conveyed to the exterior of the boiler through a stuffing-box. An arrangement of the latter nature must lose much of its sensitiveness, and herein the Thornycroft gear has a manifest advantage. There is, however, in this device a means of regulating the normal water level by hand, and this is effected through a rod which passes outside the separator through a stuffing box, and is worked by a handwheel. In this way the gear may be set so that the water level can be carried at any required height. The gear has been found in practice to act admirably, and it is contemplated using it in some vessels built by other firms. On the occasion of the *Bruizer's* trial the feed water between the three boilers was properly distributed by it, the report being that no hand adjustment was required throughout.

The following is a resumé of the principal dimensions and trial data of the five vessels of this type built by Thornycroft and Company:

	Daring.	*Decoy.*	*Ardent.*	*Boxer.*	*Bruiser.*
Length on water line, feet	185.	185.	201.5	201.5	201.5
Breadth, feet	19.	19.	19.	19.	19.
Depth, feet	13.	13.	13.	13.	13.
Draught, mean, feet..........	6.28	6.25	6.67	6.67	6.67
Displacement, tons	240.	240.	280.	280.	280.
Revolutions per minute, three hours	379.	364.	396.	410.5	374.3
Revolutions per minute, measured mile	389.	365.5	398.	412.5	376.
I.H.P., three hours..........	4,409.	4,049.	4,306.	4,543.	......
measured mile.	4,644.	4,009.	4,343.	4,487.	4,156.
Speed, knots, three hours......	27.706	27.763	27.973	29.175	27.970
measured mile..	28.213	27.641	27.840	29.080	28.144

The engines in all are of the twin-screw triple-expansion type, with cylinders 19, 27 and 27 (2) inches in diameter by 16 inches stroke. The boilers have 189 square feet of grate and 8,892 of heating surface in the *Daring* and *Decoy*, and slightly more heating surface in the others. The screws of the *Daring* are 6 feet 2 inches in diameter and 8 feet 9 inches pitch, and have a blade area of 13.5 square feet.

A coal consumption trial of the *Ardent* was made on the 26th of March, lasting twelve hours. She had thirty tons of coal on board, and was drawing 7 feet 4 inches (aft) at the start. Six runs were first made on the measured mile to determine the number of revolutions necessary to give a speed of 13 knots; this was found to be 170 per minute, or 785 revolutions per knot. Two of the three boilers were used with natural draft.

The fires were kept light, and a good deal of attention was given to their condition. The steam regulating valves were set to maintain a pressure of 180 pounds in the boilers, and the engines were linked up as high as possible. Observations and diagrams were taken every half hour.

The coal was carefully weighed on this trial, an account being kept of that used. During the 12 hours 9,196 pounds were burnt. The indicator cards, about 240 in number, were worked out afterwards, giving an average of 499.1 indicated horse-power. This comes out 1.53 pounds per indicated horse-power per hour. The fans were not running, but the steam steering engine and evaporator were in use all the time, about three-fourths of a ton of water being distilled. There was more water in the boilers at the finish than at the start.

The *Ardent* had a commissioning trial on the 7th of May, during which she made two runs on the mile, the result being 24 knots and 3,670 I.H.P.

Rocket, Shark and Surly.—Three torpedo boat destroyers, built by Messrs. J. & G. Thomson, Clydebank, have recently completed their trials. The following are their dimensions:

Length on water line, feet	200
Breadth, feet	19.5
Draught, mean, feet	5.25
Displacement, tons, about	235

They have straight stems without bow torpedo tubes, the tubes being mounted on deck instead, giving greater accommodation for the crew. The deadwood is cut away so as to give a free flow of water to the propellers, and to facilitate manœuvring.

The engines are of the triple-expansion type with three cylinders each, the diameters of which are 18½, 26⅝ and 40½ inches, and the stroke 18 inches. The steam valves are of the piston type worked by the Stephenson link motion. The screws are of manganese bronze. The boilers are of the Normand type, four in number, and contain 163 square feet of grate and 8,600 of heating surface. The tubes nearest the fire are of steel, and the others of copper. (This change was made after the accident on board the *Shark*, mentioned in the last number of the JOURNAL, and similar changes from copper to steel tubes are now being made in all the "destroyer" boilers which have copper tubes.) There are three smoke-pipes.

The following are the results of the measured mile runs:

	Rocket.	*Shark.*	*Surly.*
Date of trial	Feb. 27.	March 1.	March 28.
Steam pressure	188	184	...
Air pressure	3.5	3	...
Revolutions per minute	398	398.5	398
Speed	27.7	27.5	27.6

The three-hour runs gave—

Speed	27.4	27.6	28.05
Revolutions per minute	396	401	405
I.H.P.	4,200	4,250	...

Banshee, Contest and Dragon.—Vessels of the same general type, built by Laird Brothers, Birkenhead. They are similar in construction and general appearance to the *Ferret* and *Lynx*, described in the last volume of the JOURNAL, and are of the following dimensions:

Length on water line, feet	210
Breadth, feet	19.5
Draught, mean, feet	5.7
Displacement, tons	265

The engines are of the triple-expansion type, with cylinders 19, 29 and 43 inches in diameter and 16 inches stroke, and are both worked from a platform at the forward end of the engine room. There are four boilers of the Normand type similar to those in the *Ferret*.

Their armament comprises one 12-pounder and five 6-pounder rapid fire guns, and two 18-inch torpedo tubes mounted on deck;

the same armament is carried by all the larger boats of this type.

The results of the official trials were:

	Banshee.	*Contest.*	*Dragon.*
Date of trial	Feb. 21.	Feb. 22.	May 7.
Speed, measured mile	27.96	...	27.4
Revolutions, per minute, three hours	345	350	353.
Speed for three hours	27.6	27.4	27.14

Sturgeon.—One of the same class building by the Naval Construction and Armaments Company, Barrow, has had considerable difficulty on her trials. While making her preliminary trials early in the year several tubes in her boilers burst or were burned, resulting in the fatal scalding of some of the crew, which led to the substitution of steel tubes for the copper ones. It is further stated that, in order to get the men to run the official trials of these boats, the company insures their lives for a certain sum for the benefit of their families, and supports the men if injured during the trials.

The *Sturgeon* on an unofficial trial made 27.86 knots with 401 revolutions of her engines, and is said to have subsequently made as much as 29 knots for two hours. On her official trial, which took place on the 11th of April, one of the H.P. piston rods bent, necessitating the discontinuance of the trial. This was the second time that the same rod had bent and interfered with her trials. On her next official trial, April 18, she had to stop for two hours on account of hot bearings; and then, after being under way a short while, the same piston rod, which had given trouble on the former trials, was bent, and the trial had to be again postponed.

The contract price of this boat is £33,977.

Janus and Lightning.—Two of the destroyers, building by Palmer's Shipbuilding and Iron Company, were recently launched from their works at Yarrow. Their dimensions are:

Length on water line, feet	200
Breadth, feet	19.75
Draught, mean, feet	6.5
Displacement, tons	277

Their engines are of the triple-expansion type, both in the same compartment, and are supplied with steam from four Reed boilers placed in two compartments. These boilers are similar in general design to the well known Thornycroft boilers with an upper central steam and water drum and two lower wing water drums, one on each side of the grate. The tubes are arranged very much the same as those of the Thornycroft boiler, except that some ingenuity has been displayed in the form of bends in the tubes, and that the tubes deliver into the upper drum below the water line. There are outside downcast pipes at each end, and removable plates on the lower drums for reaching the tube ends.

The price of these boats is £37,107 each.

Handy.—One of the torpedo boat destroyers building by the Fairfield Company, was launched on the 9th of March. She is 194 feet long, 19 feet 4½ inches wide, has a mean draught of 5 feet 7 inches, and a displacement of about 225 tons. She will have triple-expansion engines and Thornycroft boilers.

Another one of the same type, the *Hart*, building by the same firm, will have Babcock and Wilcox boilers.

Havock and Hornet.—In a letter in the London "Engineer" of April 12, 1895, on the subject of Steamship Resistance, Colonel R. de Villamil gives the following figures for the progressive trial speed and power of the *Havock* and *Hornet*, stating that the figures are from a speed curve furnished by Messrs. Yarrow and Co.:

Speed.	*I.H.P.*	*Speed.*	*I.H.P.*
11	165	20	1,930
12	325	21	2,155
13	500	22	2,390
14	675	23	2,632
15	865	24	2,875
16	1,065	25	3,125
17	1,270	26	3,395
18	1,485	27	3,660
19	1,700	28	3,935

The boilers have been taken out of the *Hornet*, and the copper tubes replaced with steel ones. The cost of these boats was £34,400 each.

Renown.—This first-class sheathed battleship was launched at Devonport on the 8th of May. Like the *Centurion* and *Barfleur* she has been designed to pass through the Suez Canal, and to keep the sea for long periods without docking. Her principal dimensions are:

Length between perpendiculars, feet	380
Breadth, extreme	72.33
Load draught, feet	26.75
Displacement, tons	12,350

She is of the central citadel type, the sides of the citadel being constructed of two strakes of Harveyized steel, the lower 8 and the upper 6 inches thick. The protective deck within the limits of the citadel is 2 inches thick on the flat and 3 on the slope, and forward and abaft the citadel 2 inches thick.

The battery comprises four 10-inch guns in redoubts at the forward and after ends of the citadel, ten 6-inch in casemates on the upper and main deck, ten 12-pounders, twelve 3-pounders, and seven Maxim guns, and five torpedo tubes, four of which are submerged. The armor on the redoubts is 10 inches thick.

The machinery, built by Maudsley, Sons & Field, is similar to that of the other first-class battleships, with cylinders 40, 59 and 88 inches in diameter by 51 inches stroke. Steam is furnished by eight single-ended boilers working at a pressure of 155 pounds. The I.H.P. at natural draft is 10,000, and with forced draft 12,000, the corresponding speed being respectively 17 and 18 knots.

Talbot.—A second class sheathed cruizer, of about the same size as our *Olympia*, was launched at Devonport on the 25th of April. Her dimensions are:

Length between perpendiculars, feet	350
Breadth, extreme, feet	53.5
Draught, forward, feet	19.5
aft, feet	21.5
Displacement, tons	5,600
Coal stowage, tons	1,076

Her engines, which are similar to those of the other vessels of this type, described elsewhere in this number, are of 9,600 I.H.P., with which she is expected to make 19.5 knots. The cylinders are 33, 49 and 74 inches diameter by 39 inches stroke, and the revolutions at full power are 140.

The battery comprises five 6-inch, six 4.7-inch, eight 12-pounders and one 3-pounder, one 12-pounder field gun, four 0.45-inch Maxims, and ten 18-inch torpedoes.

Phœnix.—One of the two twin-screw sheathed sloops, described on page 615 of the last volume, was launched on the 25th of April, at Devonport.

Her length is 185 feet; beam, 32.5; draught, forward, 11, and aft 11.5 feet; displacement, 1,050 tons. She has bunker capacity for 160 tons of coal, and has been designed for 14 knots at full power and for 12 knots with natural draft. Her complement is 106 officers and men.

Her engines are of the vertical triple-expansion type, of 1,400 I.H.P., and have cylinders 13½, 20½ and 31 inches diameter, designed to run at 200 revolutions per minute at full power.

Her armament is six 4-inch and four 3-pounders, and three 0.45 inch Maxims.

Alert.—This sheathed sloop, which was described on page 203 of the last volume, recently completed her natural draft trial with satisfactory results. The result of the eight hours' run was: Revolutions, 178; I H.P., 1,156; speed, 13 knots. The forced draft trial gave 13.42 knots with 1,484 I.H.P., the revolutions being 202.8, and the steam pressure 150.8.

FRANCE.

Hoche.—Owing to the general top-heavy condition of this battleship, extensive alterations have been carried out on board her with a view to increasing her stability. The after military mast has been removed altogether, as also the light shelter deck forward and the admiral's balcony aft. The citadel above the 27-cm. guns has been greatly modified with a view to reducing its weight, six of the 14-cm. guns taken off altogether, and four 65-mm. added. The total saving of weight effected in the remodeling is said to be as much as 288 tons. Since the completion of the above mentioned alterations, she has had a trial, during which the speed made was 15 knots.

Dupuy de Lôme.—This triple-screw cruiser, whose trials have extended over a period of two years and been repeatedly interrupted by defects of various kinds in the machinery, the last of which involved the removal of the boilers, the cutting out of the furnaces (51 inches in diameter), and the substitution of smaller ones, has finally completed her official trials, the duration of the final one at full power having been reduced to one hour on account of fear lest the boilers might not stand the forcing.

The full speed trial was made on the 2d of April, when she made 19.8 knots on about 13,000 I.H.P. The revolutions of the engines were: Center, 135; starboard, 138; port, 140. The maximum speed reached during the trial was 20.4 knots.

The *Dupuy de Lôme* is of the following dimensions: Length, 374 feet; beam, 51.5; mean draught, 23.2; displacement, 6,198 tons.

Latouche-Tréville.—First class cruiser, mentioned on page 172 of the last number, has completed her trials. On the 4th of February she made an endurance trial at 10 knots and 2,400 I.H.P. On her official full speed trial she made 18.16 knots and 8,450 I.H.P., which was below the design, 19 knots and 9,000 I.H.P., but was regarded as satisfactory. On the 4th of March she made another trial at about two-thirds power lasting 24 hours, when, with 110 revolutions of the engines, she made 16.84 knots and 5,250 I.H.P.

Friant.—This cruiser, a description of which was given on page 171 of the last number of the JOURNAL, has completed her official trials, having made 18.8 knots for two hours with 9,503 I.H.P. On the measured base she made as much as 19.3.

On account of her lack of stability, her two military masts have been cut down to mere poles, four torpedo tubes and the proportionate number of torpedoes removed, and other modifications made in order to improve her condition.

Chasseloup-Laubat.—The trial of this cruiser, a sister vessel to the *Friant*, was carried out on the 28th of February, the speed on the measured base being 18.77 knots with 125.7 revolutions of the engines. The designed speed was 19 knots with 9,000 I.H.P.

Cassini.—This torpedo cruiser, building by Normand and Company, at Havre, had preliminary trials on the 7th and 18th of March, during the latter of which her engines were run up to 150 revolutions, giving the vessel a speed of 20 knots, when some of the bearings heated and the boilers gave trouble, to remedy which will involve a delay of a month or more.

Lansquenet.—This torpedo boat, which was described in the last volume of the JOURNAL, has, after many modifications, again been making trials. On a preliminary one she made 24.5 knots without difficulty, but while running the official trial she broke a cylinder and piston. She had made 25.45 knots against the tide during one run on the measured base. Her natural draft trial gave 18.79 knots.

Flibustier.—A Normand sea-going torpedo boat has had a preliminary trial, making 25½ knots. She is of 120 tons displacement, and has twin-screw triple-expansion engines and two Normand boilers.

No. 192, engined by Creusot, made 23.54 knots on trial.

No. 73 broke a cylinder and piston while making a trial.

GERMANY.

Wörth.—The following particulars of the machinery of this battleship, described on page 808 of the last volume of the JOURNAL, are from a paper by Professor Carl Busley in "Zeitschrift des Vereines Deutscher Ingenieure."

The engines are of the three-cylinder triple-expansion type, each in a separate water-tight compartment, and work with a boiler pressure of 170 pounds. The main steam valves are double ported piston valves of the Trick type, and are worked by Marshall gear. There are twelve single-ended cylindrical boilers, each with three corrugated furnaces 36 inches internal and 40 inches external diameter. They are 13 feet in diameter and 9.45 feet long, and have an aggregate grate and heating surface of 755.6 and 25,381 square feet respectively. The grates are 6.56 feet long.

The screws are three bladed, 16.73 feet diameter, and have a iean pitch measured at $\frac{7}{10}$ the radius of 17.71 feet.

Her trials, which were made at her designed draught, consisted f two of 24 hours' duration, on the first of which the I.H.P. ras 2,143 and the revolutions 66.75; and on the latter 4,144 .H.P. and 84.4 revolutions, with an air pressure of less than -inch in the fire rooms. These were followed by the forced draft rial, which was of six hours' duration, during which the revolu-ions averaged 109.5, and the I.H.P. 10,088. Subsequently, she nade a number of runs on a measured base two miles in length, t a speed of 111 revolutions, which gave a mean speed of 16.6 nots in water of 11 fathoms depth, and as high as 17.2 in 32 athoms. A week later, she made another 24 hours' trial, and leveloped 7,945 I.H.P. with $\frac{4}{10}$-inch air pressure.

The machinery of the *Wörth* was built by the Germania-Werft, Kiel.

Hohenzollern.—This vessel, which has been designed as an im-perial yacht in time of peace, and for a dispatch vessel in time of var, has been described and illustrated in the same publication by Prof. Busley, from which the following data are taken:

Length over all, feet	400.3
between perpendiculars, feet	382.5
Breadth extreme, feet	45.9
Draught forward, feet	17.3
aft, feet	19.3
Displacement, tons	4,160.

The engines are of the twin-screw triple-expansion type, with cylinders 35.8, 57.9 and 92.5 inches diameter by 37.4 inches stroke, and work with a boiler pressure of 170 pounds. The cylinders are not jacketed. The valves are of the piston type, all worked by the Klug gear. Each engine has two air pumps 19.7 inches diameter and 15 inches stroke, one worked from the I.P. and the other from the L.P. crosshead. The screws are four-bladed, 14.76 feet diameter and 22.64 feet mean pitch, and have a projected area of 41.12 square feet. The crank shafts and pins are 14½ inches diameter and the propeller shafts 15, and the cas-ing of the latter one inch thick. There are two boiler rooms,

each containing two double and two single-ended boilers, all
feet in diameter, and the double-ended ones 20.17 feet lon
There are four ribbed furnaces at each end, 39 inches diamete
with a combustion chamber 22 inches deep, common to eac
pair of adjacent furnaces. The tubes are 7.5 feet long betwe
plates, all 3 inches in diameter, the plain tubes .137 inch and t
stay tubes .236 inch thick. The front tube sheet is ⅞ and t
back one full ¾ inch thick. The total grate and heating surfac
are, respectively, 1,033 and 28,837 square feet.

On her official trial, on a displacement of 4,093 tons, she r
for six hours, the engines making 107 revolutions and developi
9,503 I.H.P. Twelve days afterwards, she made her runs on t
measured base to determine the speed at the mean number
revolutions made on the six hours' trial; with 110 revolutio
the mean speed was 21.53 knots, and the maximum during a
of the runs 21.82. This is equivalent to a mean speed of 20.
knots for the six hours; or, considering the method of trial, ful
21. After the six hours' trial, the vessel is brought to her lo
displacement, and runs made on the base at practically the me
revolutions of the trial, and the speed for the trial determin
from the revolutions.

The machinery of the *Hohenzollern* was built by the Vulc
Works, Stettin.

Professor Busley calls special attention to the remarkab
spacious fire rooms in this vessel, and in connection with the su
ject states that after his first visit to the fire room, the Emper
asked him how he found things down there; he expressed h
astonishment at finding so much room, whereupon the Emper
replied: "The fire rooms received my personal attention. Whe
I am up here on deck enjoying myself I do not want to feel th
the firemen down below are nearly dying with the heat. As it
now, they will have a thoroughly comfortable place to work
even in warm weather." The results will undoubtedly justi
the sacrifice that must have been made to accomplish this resu
and the end sought in her construction, the maintenance of h
speed for an indefinite period, accomplished.

RUSSIA.

Rurik.—The following details of this armored cruiser are mostly from "Mittheilungen aus dem Gebiete des Seewesens:"

Length between perpendiculars, feet	412
on water line, feet	425.8
over all, feet	434.7
Breadth, extreme, feet	67
Draught, mean, feet	25.6
Displacement, tons	10,760
Coal at normal draught, tons	1,634
total in bunkers, tons	1,968

She has an armor belt extending about $\frac{8}{10}$ her length; it is 6.9 feet deep, 9.8 inches thick at and above the water line, and 5 inches below. Her protective deck has a maximum thickness of 2.5 inches, tapering to 2 inches forward and aft. Her battery comprises four 8-inch, sixteen 6-inch, fourteen 5-inch, and eighteen small rapid-fire guns, besides five torpedo tubes.

She has two masts with double military tops, and three smoke pipes.

The original design of machinery contemplated two sets of triple-expansion engines of 6,000 I.H.P. each; but this was subsequently changed to four engines, two for each screw, with a collective I.H.P. of 13,070 I.H.P. with natural draft. The boiler installation has also been changed, so that instead of all double-ended, she now has one-half double-ended and one-half Belleville boilers. The former, of which there are eight, are six-furnace boilers, and are placed in four water-tight compartments.

The trials were made on the 15th, 20th and 23d of October, 1894, at a mean draught of 24.12 feet and a displacement of 9,407 tons, and resulted as follows:

Runs	*First.*	*Second.*	*Third.*	*Fourth.*
Revolutions per minute	80.5	82	82	82
Speed, knots	18.04	18.97	18.74	19.17

The maximum I.H.P. on these trials, which were at natural draft, was 13,370.

A sister ship, the *Rossija*, now building, is to have triple-screw engines, the side ones of 7,250 I.H.P. each, and the center one of 2,500.

Standard.—The Russian imperial yacht, building by Burmeister and Wain, Copenhagen, was launched from their works on the 10th of March. The following are her dimensions:

Length on water line, feet	370.64
Breadth, feet	50 34
Draught, mean, feet	18.53
Displacement, tons	5,116

The engines will be twin-screw, triple-expansion of 10,600 I.H.P., which is expected to give her a speed of 20 knots. Belleville boilers will be fitted. The screws are of Delta metal, 16 feet in diameter and 27 feet pitch, with a blade area of 77 square feet for each screw.

The yacht will, on the upper deck, have two saloons, a drawing-room, and a dining saloon capable of seating sixty persons. On the main deck will be a saloon for the Imperial family furthest aft, besides a smaller dining saloon and rooms for the Emperor and Empress, the Dowager Empress, and the grand dukes. There will also be rooms for the Imperial suite, the Naval Minister, and for the General Admiral. Forward will be the quarters of the officers. On the intermediate deck will be dining saloons and saloons for the suite, and some rooms for servants and crew. On the lower deck will be rooms for the non-commissioned officers, etc.

SPAIN.

Carlos V.—This armored cruiser was launched at Cadiz on the 12th of March. She is somewhat similar in general design to the English cruiser *Blake*, and is of the following dimensions:

Length on water line, feet	380
over all, feet	404.75
Breadth, feet	67
Depth, feet	39.75
Draught, mean, feet	24 54
Displacement, tons	8,710

She was designed for a speed of 19 knots with natural and 20 with forced draft, the I.H.P. being respectively 15,000 and 18,500 I.H.P. The bunker capacity is 1,770 tons.

There is a thin armor belt, in two thicknesses of one inch each, for a length of 167 feet, terminating forward and aft in bulkheads 6 feet high, and a protective deck 2 inches thick. The battery comprises two 11-inch guns in barbette turrets, one forward the other aft, protected by 9.8-inch plates, and the covering plate 4 inches thick; eight 14-cm., four 10-cm., and two 7-cm. rapid-fire guns, and eight machine guns.

The engines are vertical, twin-screw, triple-expansion with cylinders 52, 77.2, and two of 82.1 inches diameter by 45.3 inches stroke, working with a boiler pressure of 150 pounds per square inch. There are twelve single-ended boilers 16.3 feet in diameter and 9.85 feet long. The screws are four bladed.

Quiros.—A small single-screw gunboat, built for service in the Phillipine Islands, was launched from the Kowloon Docks, Hong Kong, on the 24th of January. Her dimensions are:

Length over all, feet	145.25
Breadth, feet	22.83
Depth, feet	11.
Displacement, tons	347.

The engines, of 500 I.H.P., are triple-expansion, with cylinders 13, 21 and 35 inches diameter and 24 inches stroke, and work with a boiler pressure of 170 pounds, steam being supplied by two single-ended boilers. The speed expected is 12 knots.

The battery consists of two 57-mm. Hotchkiss and two 5-barrel Nordenfelt guns.

MERCHANT STEAMERS.

The "Marine Journal" and "Marine Review" say that th Red D Line has entered into a contract with the William Cram and Sons' Ship and Engine Building Co. for the construction c a freight and passenger steamer for the trade between New Yor and Maracaibo. The dimensions are :

Length over all, feet	256
on water line, feet	248
Breadth, molded, feet	38
Depth, molded, feet	17
Draught, mean, feet	10
Gross tonnage	1,500

Her speed is intended to be 11 knots in service and 12 knot on the four hours' trial under the Postal Subsidy Act, which wil place her in the fourth class of the Reserve.

The hull is to be of steel. There will be a steel deck for hal the length of the vessel amidships, a steel deck house containing limited passenger accommodations, a forecastle for the crew forward, and turtleback aft. The vessel is divided by five watertigh bulkheads. There is a water ballast compartment aft of the engines and one at each end of the vessel, which will take abou 200 tons of water ballast. The number of first class passenger provided for is twenty-four.

She has three pole masts with leg of mutton sails.

Her engines are of the triple-expansion type, of 1,000 I.H.P. the cylinders being 18, 28 and 45 inches diameter by 30 inche stroke, steam for which will be supplied from two boilers working at 160 pounds pressure. There is also a donkey boiler or deck. The pumps will be independent.

Pomona.—The following details of two trials of the machinery of this steamer, one made before and the other after fitting the Howden system of forced draft to the boilers, is given ir

"Industry," on the authority of Mr. G. W. Dickie, of the Union Iron Works:

In the first trial the cylinder diameters were 23, 34 and 56 inches, and in the second $23\frac{5}{16}$, $34\frac{3}{16}$ and 56. The stroke is 46 inches. It thus appears that the cylinders were re-bored before the second trial. The heating surface was 2,963 square feet, the grate surface before the change 102, and after 73 square feet.

S. S. *Pomona*.—Result of machinery trials before and after fitting with Howden's forced draft system.	VOYAGES.	
	San Francisco to Eureka, Aug. 29, 1894. without forced draft.	San Francisco to Port Harford Nov. 29, 1894. with forced draft.
Duration of trial	6 hours.	16 hours.
Steam pressure, engine room	145.4	147.8
first receiver	41	42
second receiver	5.59	6 15
Vacuum	25.4	24.8
Revolutions per minute	91.22	99
Mean pressure in cylinder, H.P.	51.1	62
I.P.	21.23	25.8
L.P.	8.71	10.8
M.P. reduced to L.P. cylinder	25.06	31.5
Average indicated horse power, main engines	1,020	1,388
auxiliaries	58	84
total	1,078	1,472
Air pressure in inches of water	.29	.77
Coal burned, total	14,415	49,410
per hour	2,402.5	3,088
per I.H.P. per hour	2.22	2.09
per sq. ft. of grate surface per hour	23.5	42.3
Heating surface per I.H.P., square feet	2.74	2.00
I.H.P. per square foot of grate	10 56	20.16
Grate surface in use, square feet	102	73
Coal (Franklin), quality	Good.	Bad.
Draught of vessel, forward, feet and inches	7–11	10–8
aft, "	12–6	13–6
mean, "	10–2½	12–1
Displacement, tons	1,150	1,455

Prinz Heinrich and Prinz Regent Luitpold.—A short notice of these twin-screw steamers, built by Schichau for the Australian trade of the North German Lloyd, was given in the last volume of the JOURNAL, but as additional data of them are now at hand, all the available data are given here. The dimensions are:

Length on water line, feet	45
Breadth, feet	5
Depth amidships, feet	3
Gross register tonnage	6,1c
Load draught, feet	2
Displacement, load, tons	11,7

She has a double bottom and is divided into ten water-tigl compartments. There are three decks from end to end of th ship, and an orlop deck, so that extensive room is provided fo cargo, there being five compartments—two large ones forwa and three aft—for cargo in the hold and orlop deck, while th next deck is reserved for cargo or for emigrants. There is, to a large forecastle, with long promenade deck amidships, the fu width of the ship, and a poop, the three being connected gangways over the wells, providing access to the hatchwa forward and aft.

The accommodations for passengers are very good, everythi being in first-class style. She can carry 75 first-class, 76 secon class and 960 steerage passengers.

The two engines are in the same compartment, and are simi in general design and arrangement to those supplied the A trian battleship *Tegethoff*. The working platform is at the f ward end. They are of the triple-expansion type, with cylind 28.35, 46 and 70.86 inches in diameter by 47.25 inches stro and work with a boiler pressure of 175 pounds. Piston val are used on the high pressure, and slide valves for the other c inders, all operated by Stephenson link motion. The condens are cylindrical, of galvanized iron, and have a combined cooli surface of 7,330 square feet. The air pumps are worked fr the low-pressure crossheads. The shafting throughout is steel, the total length for each engine being 170 feet, and that the propeller shaft 50.84. The crank shafts are in interchan able sections. The propellers are 15 feet in diameter, the hu of cast steel and the blades of bronze; the pitch is 19.68 feet

There are two single and two double-ended boilers, each 1 feet in diameter, the former 9.18 and the latter 17.7 feet long; grate surface is 378, and the heating surface 16,512 square f

The furnaces are Purves' ribbed, 43.3 inches diameter. There is also a donkey boiler on the upper deck.

The following are the data of the official trial:

Speed, knots	15.5
Displacement about, tons	9,000.
Steam pressure	175.
Vacuum	27.2
Revolutions per minute	87.5
I.H.P., starboard	2,760.5
port	2,805.
collective	5,565.5

On the first voyage of the *Prinz Regent Luitpold* to Australia her average speed was 13.55 knots, the revolutions of the engines 80, and the ship's draught 22 feet. The I.H.P. was about 4,670.

Columbia and Alma.—Short descriptions of these vessels were given in the last volume of the JOURNAL, and also on page 191 of the last number. Since that, however, more complete description has appeared in "Engineering," from which this is taken.

They were built by Messrs. J. and G. Thomson from specifications prepared by Professor J. Harvard Biles, and are of the following dimensions:

Length on water line, feet	270
Breadth, feet	34
Depth, feet	23
Gross tonnage	1,145
Net tonnage	410

The frames are of the reverse angle type, and spaced about 21 inches apart. The interior is subdivided by 11 water-tight bulkheads into 12 compartments. The bulkheads are constructed of plates of flanges vertically instead of angles, the plates themselves overlapping—a system of construction which resists greater lateral pressure than the usual method of angle stiffeners. Three of the compartments are occupied by machinery, one in the center of the ship by first-class state rooms, one at the after end by second-class accommodation; while two at each end are entirely devoted to cargo, the others forward and aft being for storage, cargo, &c. The vessels would float with any two adjoining compartments flooded.

The center compartment in the ship, 33 feet long, was entirely given over to cabins arranged on three decks. Thus in the bridge house on the promenade deck there are five separate rooms on either side of a corridor, with a number of other rooms forward, principally for officers. On the next deck there are rooms at the side of the ship, with a number of rooms again in the center, with smoking room aft and breakfast and supper room forward, while on the main deck there are 16 rooms in the center.

Thus there are berths for 104 first-class passengers in some 43 separate rooms. The state rooms situated on the promenade deck are usually for two passengers only, and are specially light and airy, having large square ports, while those on the upper and main decks are exceptionally lofty, and throughout the greatest care has been taken to thoroughly ventilate the cabins. From the different compartments there are led air trunks, by means of which vitiated air is exhausted into annular spaces round the funnels, while fresh air is suppled by large cowls, and is led through trunks of large sectional area to the different state rooms, the supply to each of which is regulated by a sliding louvre. The first class dining saloon is situated on the upper deck, immediately forward of the machinery, and is beautifully fitted up, being panelled in polished sycamore, having carved panels alternating with mirrors. On the promenade deck is a spacious smoking room panelled in dark oak, furnished with marble top tables and with couches upholstered in red morocco.

There are two four-cylinder triple-expansion engines, in the same water-tight compartments, the working platform at the forward end, with cylinders 19, 29 and 33½ inches in diameter by 30 inches stroke. The valves are of the piston type with balance cylinders, and are worked by Stephenson link motion. The cylinders are supported at the back on cast columns, but the front columns are of forged steel, for securing both accessibility and lightness. The crankshafts are in two pieces, and, together with the thrust tunnel and propeller shafts, are of steel. The thrust blocks are cast iron, and the four collars are of cast steel. The latter are lined with white metal, and are of the horseshoe type, each separately adjustable. The screw propellers have three blades of manganese bronze fitted to bosses of cast steel.

The surface condensers are placed in the wings of the ship. They are built up of brass sheets, and the water spaces and casing doors, together with main eduction and other branches, are all gun-metal castings. The condensing water to each condenser is circulated by a centrifugal pump driven by an independent open-fronted engine. The air pumps are bolted to the backs of the soleplates in the position shown on the engravings, and are driven by levers off the forward low pressure cylinder.

In addition to the engines mentioned, there are in the engine room: One set electric light machinery; two of Weir's feed pumps and heater; two duplex bilge and fire pumps; one duplex sanitary pump, and one duplex fresh water pump.

Steam at 160 pounds pressure is supplied by two large single-ended boilers with four furnaces in each, worked under forced draft on the closed stokehold system, the air being supplied by two double-breasted fans, one in each stokehold. These boilers are similar in their arrangement to those fitted by Messrs. Thomson to many fast cruisers.

The guaranteed speed was 18.5 knots, which was easily maintained on a six hours' trial with 184 revolutions of the engines. On the measured mile the following results were obtained from the *Alma*:

	Starboard.		*Port.*
Speed, knots	...	19.3	...
Revolutions	191	...	192
I.H.P	1,910	...	1,830
total	...	3,740.	...
Steam pressure	...	160.	...
Vacuum	...	26.5	...

The high speed, with such comparatively large power, is explained by the fineness of form of the vessel.

Aco.—The results of the engine trials of this tank steamer, built by Messrs. D. J. Dunlop and Co., Glasgow, are from the "The Engineer," (London):

The *Aco* is of the following dimensions: Length between perpendiculars, 333 feet; beam, 43 feet; depth, molded, 30 feet; carrying capacity, 4,275 tons cotton seed oil and 600 tons coal.

She has a single-screw triple-expansion engine with cylinders 25, 40½ and 65 inches diameter by 48 inches stroke, designed to work with a boiler pressure of 160 pounds. There are two boilers 13.5 feet diameter and 16.25 feet long, each with six furnaces; the grate surface is 148, and the heating surface 6,128 square feet. The air pump is 22 inches diameter and 24 inches stroke, and the circulating pump 13 inches diameter and 24 inches stroke, the latter double acting, and both worked by the main engine. The condensing surface is 2,557 square feet.

On the trials, at 10 knots, careful measurements were made of the coal and water, and indicator diagrams taken every half hour; the feed water heater was not used, and all feed water passed through a meter before going to the boiler. The condition of the fires was "judged" at the beginning and end of the trials.

The weight of her machinery is given as follows:

	Tons.
Engines complete, including steam and exhaust piping and auxiliary engines	173
Boilers, mountings, funnel, auxiliary boiler, and fittings in fire room	190

THREE HOURS' FULL POWER TRIAL, TWELVE KNOTS.

Steam pressure in boilers	154.3
first receiver	52.6
second receiver	8.07
Vacuum	28.46
Cut off from beginning, H.P	.625
I.P	.6325
L.P	.6195
Nominal rate of expansion	10.81
Same, allowing for clearance	8.45
Revolutions per minute	83.5
I.H.P., H.P	729.54
I.P	741.96
L.P	934.5
total	2,406

FOUR HOURS' TRIAL AT TEN KNOTS.

Steam pressure in boilers	154.3
at engine	152.1
in first receiver	54.6
second receiver	0.33

Vacuum	29.08
Revolutions per minute	67.60
Rate of expansion, nominal	17.8
Same, allowing for clearance	11.84
I.H.P., H.P.	366.11
I.P	456.75
L.P	460.64
total	1,283.5
Temperature of injection	47
discharge	71
feed	52.47
gases 15.5 feet above grate	551.2
Water gauge pressure at same point, inches	$\frac{7}{16}$
Barometer	30
Coal per hour, pounds	2,000.25
per I.H.P., pounds	1.558
per square foot of grate, pounds	13.5
Water per hour, pounds	18,907.5
per I.H.P., pounds	14.72
per pound of coal, pounds	9.45
equivalent per pound of coal from and at 212, pounds	11.48

Sylvania.—The following particulars of this vessel are in addition to those given on page 191 of the last number of the JOURNAL.

There are nine watertight bulkheads extending to the upper deck. In all there are 24 compartments for water ballast, and part of the double bottom under engines may be utilized for carrying reserve fresh water for cattle or boiler use. The entire vessel, including all the holds, 'tween decks, engine and boiler spaces, and cabins, is lighted by electricity on the double-wire system, generated by two compound wound self-regulating dynamos situated in the engine room. At each of the seven hatches there is a cluster of 16 lamps of 16-candle power. The cattle fittings are on the most approved plan, and comprise Mr. Wm. Wyllie's patent slingable fittings, which enable the whole space to be closed and utilized for cargo. Special attention has been given to the safety of the cattle, and the water pipes are so arranged that water may be carried to any of the stalls. Utley's patent cowl and combination vents are liberally distributed throughout the ship. The two sets of triple-expansion engines have cylinders 22½, 36½ and 60 incl diameter by 48 inches stroke. There are two main l working on Howden's system of forced draft; they are in diameter and 20 feet 3 inches long, each with six 43 furnaces, and containing 229 square feet of grate and 9,(heating surface. The working pressure is 180 pounds. is also a large auxiliary boiler for winches, electric ligl The maximum speed on trial was 15¾ knots, and the I.H.P.

Aberdeen.—The following particulars of the machinery vessel, which is fitted with the Fleming and Ferguson wate boiler, as mentioned on page 642 of the last volume JOURNAL, are from the " Marine Review :"

Number of engines	One; quadruple ex
Diameter of cylinders, inches	18, 28, 35 ar
Stroke of piston, inches	
Clearance, top, inch	
bottom, inch	
Maximum revolutions per minute	
Indicated horse power with natural draft	
Steam pressure in boiler, pounds	
Boilers	Patent " Clyde " wa
Number of boilers	
Diameter of drums	Top, 6 feet; bottom
Diameter of tubes, outside, inches	
Heating surface in one boiler, square feet	
Grate surface in one boiler, square feet	
Weight of one boiler complete without water, tons	
with water, tons	
Feed pumps	Ordinary type, wrought off air pum
Number of pumps	
Diameter of pumps, inches	
Stroke of pumps, inches	
Propeller	Built type; four blades; manganese
diameter, feet	
pitch, feet	
surface, square feet	
Speed of vessel, knots	

YACHTS.

Giralda.—This yacht, which was described in the last number of the JOURNAL, won the Bennett cup at the races at Nice on the 11th of April, having covered the distance of 26.5 miles in 1 hour 8 minutes and 22 seconds, which, if the distance and time are correct, is equivalent to a speed of 23.25 knots, though it is given as 22.2 and 22.6 knots.

New Alcyone.—A steam yacht designed by Mr. Geo. H. Warrington, Jr., of Chicago, for Mr. H. F. Balch, of Minneapolis, is now under construction on the Lakes. Her dimensions are:

Length over all, feet	135
Breadth, extreme, feet	17
Depth, molded, feet	11
Draught aft, feet	8
Displacement, tons	144

She will be schooner rigged, spreading about 3,000 square feet of canvas, and will stow 32 tons of coal.

The steel plates to be used in the hull will be $\frac{5}{16}$ inch at the garboard and sheer strakes, the rest being $\frac{1}{4}$ inch. Her deck houses will be of steel, covered with mahogany and the interior will be finished in the same woods.

Her engine will be triple-expansion, with cylinders 12, 19 and 32 inches diameter by 18 inches stroke, and her boilers, two in number, of the Warrington water tube type. The boiler room occupies 23 feet lengthwise the vessel and the engine room 18. Her screw will be 6 feet 6 inches in diameter.

The speed guaranteed is 18 miles on trial, and she is expected to make 14 in ordinary cruizing.

The *New Alcyone* will carry an ice machine, and an electric storage battery plant for lighting and cooking purposes, and will be equipped with a powerful searchlight. She will carry an electric launch 24 feet long, a life boat 22 feet in length, and a dinghy 16 feet long. She is expected to cost $100,000.

The Detroit Boat Works have under construction a single-screw steel yacht for Merrill B. Mills, Esq., of the Detroit Yacht Club, which will be of the following dimensions: Length on water line, 110 feet; length over all, 132 feet; breadth on deck, 17.5 feet; depth, 8.75 feet. She will be rigged as a two-masted schooner, and will have three water-tight bulkheads, one a collision bulkhead, and the others at the ends of the machinery space. Her bunkers stow about 20 tons of coal.

Her engine will have cylinders 10, 16 and 26 inches diameter and 16 inches stroke, and has been designed for 350 I.H.P. Steam will be furnished by two Taylor water tube boilers each 8 feet in width and 9 feet long, both having 1,600 square feet of heating surface. The screw will be 4.5 feet in diameter.

She will be fitted up in most approved style. Forward will be a large deck house finished in red mahogany. It will be 24 feet long and 8 feet wide. This will be used as a dining and lounging room. The ceilings will be electro-plastic metal, and around the sides will be continuous divans, upholstered in the finest morocco leather, in colors to harmonize with the rugs and decorations on the ceiling. The floor will be covered with linoleum and rugs.

On top of the deck house, which will be surrounded by a brass railing, will be the steering wheel, binnacle and a powerful electric search light. Another feature will be an electric flag of 85 colored bulbs, forming the commodore's private colors. From each side of the top of the deck house a bridge runs to the edge of the ship. A mahogany staircase leads down to the smoking room, containing sofas on each side, which can be converted into berths. A door from the smoking room leads to the lavatory and galley. Forward of the galley will be located the crew's quarters, containing eight bunks of galvanized piping. Aft the mainmast is located a companionway. A mahogany staircase leads to the passage below the deck from which admission is gained, on the starboard side, to the owner's stateroom. It will be a marvel of beauty. The interior woodwork of this room, and the bath room adjoining, will be of Spanish white mahogany, natural finish and in Louis XIV style. The ceilings will be decorated in ivory with raised ornaments of silver. The berth will be finely decorated, the hangings being of the same general style as the deck house, of brocaded silk.

The main saloon is the full width of the ship and 17 feet long. The woodwork is quartered Cuba birch, and the ceiling will be made of raised ornaments, festoons and wreaths, colored and richly gilded, Louis XIII style. There will be continuous divans around the room which can be changed at will into four commodious berths, all upholstered in velour imperator, specially designed and imported for this room. The only occasion on which this material was ever before used in America was in the Pullman cars exhibited at the World's Fair. Leading into the main saloon will be two spare staterooms. The walls will be covered with French cretonne, tufted. The hangings will be light silk, trimmed with lace. There will be davits for two lifeboats, finished in natural wood with mahogany trimmings and gratings, and nickel plated fittings. There will also be a twenty-one foot naphtha launch.

The interior of the boat will be lighted by fifty 16-candle power incandescent lamps furnished by the dynamo in the engine room, in conjunction with a storage battery plant. A feature is the burglar alarm on the after companion way, communicating with an annunciator in the crew's room. [From the "Detroit Free Press."]

D'Allest Boiler.

Fig. 1.

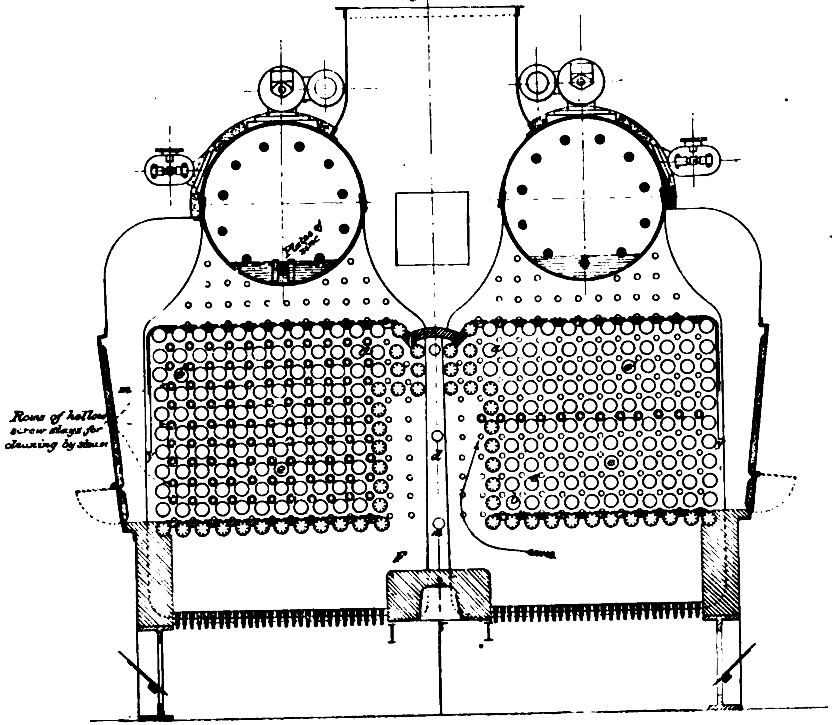
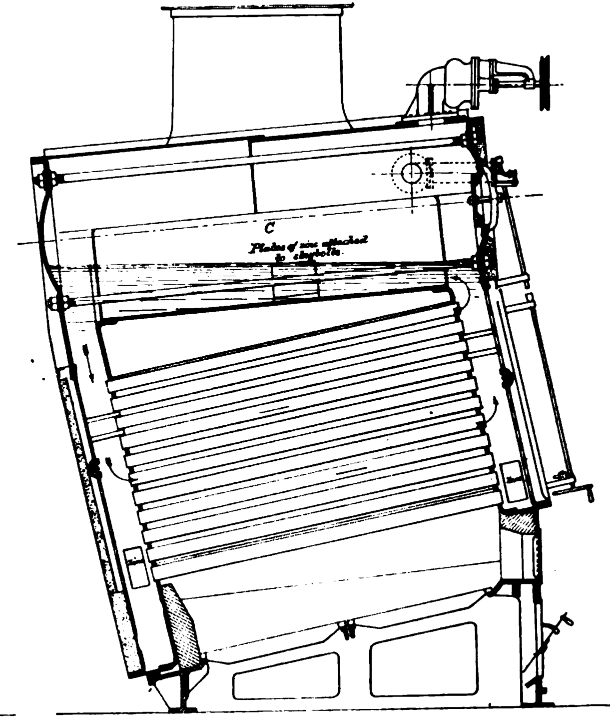


Fig. 2.



To face page 368, Vol. VII, No. 2, of the Journal.

JOURNAL

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ON THE NECESSITY AND VALUE OF SCIENTIFIC RESEARCH IN NAVAL ENGINEERING MATTERS AS RELATED TO THE U. S. NAVY, AND THE NECESSITY OF AN ENGINEER TRAINING FOR THE YOUNGER MEMBERS OF THE ENGINEER CORPS OF THE U. S. NAVY.

BY PASSED ASSISTANT ENGINEER F. C. BIEG, U. S. NAVY.

The writer, as many other engineer officers have done, has often deplored the want of some place where engineering experiments could be carried on in a thorough and scientific manner, where the numerous problems confronting our profession could be properly investigated and the interests of the Navy thereby advanced. A few of the more important questions that have from time to time arisen have, to the credit of a small, energetic number of naval engineers, been solved in a measure sufficient for the needs of the hour, even under the disadvantages of the other frequent demands of the Service and of no funds or suitable place for experimenting. A few results valuable to the Government have been obtained by engineer officers stationed at navy yards, by taking advantage of rare opportunities, and generally in addition to their numerous regular duties. Again, work started on some research, the results of which would have saved much money, has been interrupted or stopped by the transfer of the officer to other duty, a condition which has become of frequent occurence, owing to the small number of engineer officers. But these attempts were only make-shifts, and had they been carried on as the writer proposes, failures would have been prevented and money saved. It is not intended to refer in this paper to the valuable and necessary work done by the Experimental Board, to whom are sent all patented articles and devices for test, before their adoption for naval uses, but only to original investigation and research. The time of the Experimental Board is too fully occupied with its regular duties to leave any opportunity for such work as the writer has in mind.

Many of us have thought of problems, (or they have been presented to us during our sea and shore duty) which should be tested by experiment, but knowing the seeming impossibility of ever having time or opportunity to make these tests, have allowed the subject to pass from our thoughts. It is very much to be regretted that no opportunities have recently been given for doing such work as made Isherwood's Experimental Researches famous, and practically laid the foundation of marine engineering practice for the world. The writer believes that the present occasion, when the Navy and the Engineer Corps have been so brilliantly successful in the design of naval machinery, is not inopportune for bringing this subject before the members of this Society, in the hope that a discussion, showing the value and necessity of a properly-equipped Engineering Experimental Station or School, may lead to its adoption. Every engineering school is supplied with a laboratory, not only for the instruction of the students, but for the experimental uses of the professors. The valuable results of the researches of Prof. Thurston at Cornell University, of Prof. Peabody at the Massachusetts Institute of Technology, of Prof. Denton at the Stevens Institute, and of many others too numerous to mention at this time, are too well known to need more than passing notice. These researches are carried on by private means, and the results are generously published far and wide, and the Government has not been slow to take advantage of them. As we all believe in the old teaching that "It is more blessed to give than to receive", it seems to the writer that it would be proper for the Government to undertake many of these researches and, while profiting by its own results, let private institutions and persons partake of the advantage. There are many naval questions which the Government can solve, and from the solution of which it will reap a direct benefit, which are entirely beyond the means of private parties.

England has one such station as the writer advocates, devoted however only to one branch of the subject. How much actual money has been saved owing to the chemical researches on boiler incrustations by Prof. Lewes of England, can hardly be estimated.

The writer's outline plan for an Engineer Experimental Station or School, or whatever other name be chosen, is the following:

The School should be at some place where there is still and deep water, (as many of the experiments will be made with boats) and at a reasonably convenient distance from the manufacturing and engineering centers. There should be an engineer officer of rank in charge, under the immediate direction of the Chief of the Bureau of Steam Engineering. To put this school in a navy yard, where the officers attached to the yard are subject to all kinds of duty, would load it with useless routine and be disastrous to good results. As the experimenters are to be engineer officers, it would be just as well to encourage *ésprit de corps* and stimulate the efforts of individual engineers by putting them directly under officers of their own profession, thoroughly conversant with the engineering needs of the Service. With the officer in charge, who might be styled the Director, should be associated two or three officers, whose duties will be defined further on. The number of officers will, of course, depend on the other demands of the Service. The testing outfits and apparatus for the standardization of indicators, gauges, and other instruments, now at the New York navy yard, should be kept at this School.

Whenever an engineer officer has a plan for the investigation of any subject in practical engineering, chemistry, metallurgy, on propellers, lubrication, boiler deterioration, or any of the many other points directly connected with or useful to naval engineering, he would submit it to the Chief of the Bureau of Steam Engineering, through the regular channels, giving his ideas and the scope of the investigation as fully as may be necessary to a clear understanding. Should the Bureau approve his plan, or think the matter worthy of experiment, the officer would then be detailed to the School, as soon as the exigencies of the Service permit. In case of approval, no radical change in the applicant's proposed method of investigation should be made, as he should be given credit for his ideas and allowed to carry them out in his own way. Should any change in the method or the subject be deemed advisable, the applicant should be notified before the plan is approved. There is no use in ordering any one interested in a particular subject to investigate it in any radically different way from his own, for it deprives the experimenter of that personal interest without which there will be no success. Should the Bureau or the Director at any time wish to make original tests or experiments, engineer officers could be ordered as at present, if any are necessary in addition to the officers stationed at the School.

In connection with the experimental part of the School, the writer would suggest a course of instruction for the Assistant Engineers just after their promotion from Naval Cadets. Instead of the present way of allowing these young officers to pick up what information they can at the New York navy yard, where the senior engineer officers are more than sufficiently occupied with the regular work of the yard, they should be sent to the proposed school for instruction. The Director and the two or three officers composing the faculty, should act as the instructors. A properly prepared course of lectures on the management, care and repair of machinery, the estimating of work, &c., aided by the practical work of trial trips and assisting in the experiments, and extended visits to large ship and engine building firms, would fit these young officers for their duties on board ship and give them the knowledge which they might not pick up by themselves in years. These lectures should be so arranged that, while imparting facts to the students, their minds would be directed and trained to put to practical use in the Navy the information received. It seems to the writer that it would be much more advantageous to the Government and more beneficial to these young officers to order them to a course of instruction, such as here proposed, than to send them abroad to study at foreign schools. With the foundation of a good, practical engineering education, such as would be given by our officers—of whom it may be said in general, that they are the best existing combination of theory and practice—these young engineers would later on be much more efficient as attachés to our legations, in which position they would do important duty as knowing observers of foreign practice. The duty as assistants to the experimenters would be of the greatest benefit to these young officers and enhance their value to the Service; it would not only make them scientific and careful experimenters, but it would lead their thoughts in the direction of observing and studying engineering phenomena during their tours of sea service.

Surely, with the present system of appointing Assistant Engineers, some such plan of a post-graduate course of instruction, as outlined above, becomes an absolute necessity, and would be only justice to the new appointees. The education given at the Naval Academy must be supplemented, if the Navy is to have engineers who can be of assistance on their first cruise as commissioned officers.

In addition to the other functions of the School, the writer would add the collecting of an engineering museum. A systematized collection of engineering models, metals, instruments and supplies would be of the highest value, not only to the students at the School, but to the Navy Department and the older officers.

The founding of such an institution as proposed will prove a profitable and inexpensive investment for the Navy, excite individual efforts to brilliant results, and carry on, systematically and intelligently, the excellent work of Isherwood, Loring, Thurston, Emery and other American Naval Engineers.

Discussion.

Chief Engineer B. F. Isherwood, U. S. Navy.—No more judicious proposal in the interest of the Navy particularly, and in the interest of engineering science and practice generally—which latter, taken in a broad sense, is really the great interest of the world at large—could be made than that of Passed Assistant Engineer F. C. Bieg, U. S. Navy, for the establishment by the Navy Department of what may be called an Advanced School of Experimental and Scientific Engineering in its special application to the purposes of the Navy.

There would be no difficulty in getting Mr. Bieg's proposal put into practical execution were the necessity of submitting all problems in physical science to the arbitrement of direct experiment well understood, for no abstract solution can be accepted as final until it has received a concrete confirmation. In fact, the only reason for accepting such solutions in even the simplest cases, is that they predict the facts obtained by physical measurements when sagaciously made. For positive, infallible information, the appeal must be made to Nature, and must be addressed to her in her own language, that is, experimentally. When the question is so put, the answer will have no uncertain sound; it will be instantaneous and decisive; it will be in harmony with the entire system of physical laws of the universe; it will be the fruitful mother of other series of valuable facts, and it can be confidently applied.

In the Navy, whose ships, comprising hull, machinery and ordnance, may be taken as purely engineering, and whose expenditures for these constructions may be called immense, the importance cannot be exaggerated of having every question capable of experimental answer so answered before expending the money, and perhaps expending it for inferior articles on which, at some future time, the prestige, the interest, the honor and, possibly, the safety of the country will have to be staked.

One of the curious features of human nature is the difficulty of making it understand the value of securing a safe expenditure of a large sum by the sacrifice of a small sum; it objects to the expenditure of the small sum because an immediate tangible result is not produced, and will squander the large sum in all the self-sufficiency of ignorance without knowing whether the expenditure is judicious or not; it cannot understand that the small sum is a trifling insurance for the large sum. This feature is illustrated in the fact, common to all navies, that a new vessel having been constructed, is *never* properly experimented with to ascertain its qualities, that is, its merits or defects, in order that in future constructions the one may be adopted and the other avoided. There is not a navy in existence whose practice does not show every day expenditures of enormous sums on nearly worthless designs, and which might have been prevented by wisely substituting the lessons of experimental science for the crude notions of complacent folly. The man who does not know, and does not know that he does not know, will never be guided by the man who does know, and knows that he does know.

Whatever valuable experimental work has been done in the navies of the world, and in this respect our own is far in advance of all others, has been effected by the unaided efforts of individual engineers struggling against stupid inertia or actively jealous opposition, without appreciation, encouragement or reward, and solely for the furtherance of professional information and of the discovery of those physical truths so interesting to all highly constituted minds. Even these efforts, valuable as are their results, and made under the most adverse circumstances, would have had a greatly increased value had those who made them been properly supported and furnished with the necessary means and instruments. The proposal of Mr. Bieg is for supplying these deficiencies by the institution of a proper and thorough system of experimental research in naval engineering of the most difficult and delicate problems; and, also, of scientific research, for the latter is the outcome of the former, and must be based upon it. In other directions the advantages to the Navy would be equally important in the education of a highly developed class of engineers combining practical knowledge with scientific methods; a class of officers of strong and independent character in the proper sense of that word, as well as of great professional qualifications, whose sound judgments, honest purposes, extensive information and incessant supervision could be relied on by the Navy Department to design, construct and manage the machinery of its vessels. As such an education would qualify its possessors far beyond the comparatively narrow boundary just mentioned, the services of so accomplished a class of technical officers could always be employed by the Department on all construction or purely technical subjects with immense advantage to the public service. As a mere matter of common sense, the importance to a great department of the Government of a highly trained body of specialists must be evident, and such a body cannot be produced in any other way than by the act and under the control of the Navy Department. The sporadic work of a few gifted individuals can no more compensate the efforts of a large, compact, trained body acting under a well devised system of instruction and experience, than the brilliant performances of a few heroes can equal the results of a thoroughly drilled, armed and disciplined mass of regular soldiers. Such a body will always supply geniuses enough to lead them.

If it be asked what there is for such a class of specialist officers to do, the answer is, everything that relates to the construction and engineering management of a naval vessel from, not the keel, for there is none any longer, to, not the truck, for there are no longer either spars, rigging or sails. The sailing vessel and the sailor have vanished from the navies of the earth, and almost from its commercial marine. The substitution of exact experimental knowledge for "rule of thumb," of the laws of nature for ignorant caprice, of mathematical demonstration for guesswork, are what is needed, and these can only be had by some such means as Mr. Bieg proposes. The experimental school of engineering recommended must, above all things, be under no other direction than that of its own instructors. The ridiculous fatuity of putting persons who do not know in command of persons who do know must not be repeated if wheat instead of tares is to be gathered. The saving in the cost of a first class naval vessel under the system in question, would pay the expenses of the proposed school for many a year, besides guaranteeing that the qualities of the vessel when constructed would be all that could possibly be obtained from the dimensions and material employed.

To insist on such considerations at the close of the nineteenth century, with the public intelligence so conspicuously displayed in so many germane directions, seems like furnishing a very unnecessary demonstration of the multiplication table. They are made, however, in the hope of aiding in the sound patriotic work of obtaining for the Navy not only cheaper but better vessels, to indorse the very excellent suggestions which Mr. Bieg has made on an important subject, too long neglected, and to call attention to the fact that a practical realization of these suggestions would be greatly beneficial. They cannot be ignored without incurring the consequent and, under easily conceivable conditions, very considerable injury.

Passed Assistant Engineer C. H. Manning, U. S. Navy.—I think Mr. Bieg's scheme an excellent one, and that it should receive the support of every engineer officer in the Service. Experimental research is one of the best educators that a young engineer can have, and by utilizing the station as a school for a post graduate course and at the same time as an engineering experimental station, two great needs of the service would be filled.

Few besides those directly connected, either as pupils or as instructors, with the Cadet Engineer course at the Naval Academy, appreciate the influence which even the short life of that course has had on scientific steam engineering in this country. The same spirit that made that course what it was is alive in the Engineer Corps to-day, and, if given an opportunity such as this station would open, would bear fruit that not only the naval service, but the whole country would be proud of.

Such a station should be under the direct and exclusive control of the Engineer-in-Chief, subject only to the Secretary of the Navy; but its benefits should be open to all branches of the Service—it should not follow in the wake of some of the other service schools, open only to the elect.

Chas. H. Haswell, C. and M. E.—In the paper under consideration the writer suggests that the Government furnish an edifice designed and equipped for making experiments in engineering structures and operations, and the investigation of problems in physical engineering.

Now whilst I fully concur in the propriety of any method or course by which scientific knowledge could be imparted to the members of the Engineer Corps, or attained, whether by study, observation or experiment, I do not fully concur in the expressed value or importance of experimental engineering, as distinguished from practical, other than to obtain values, direct or comparative; inasmuch as I hold that a knowledge of physical laws renders experiments very generally unnecessary; as a mechanical design or construction that will not withstand the ordeal of physical reasoning, will not sustain itself in operation. It so occurs that in a professional experience of sixty-five years, I cannot refer to a case where I considered an experiment in a mechanical design necessary, and excluding chemistry, very rarely in a physical one.

To obtain relative or comparative value of a structure or instrument, however, in view of the great interests involved in the cost and efficient construction of marine engines and boilers, I am of the opinion that the suggestions submitted are well worthy of elaboration and approval.

In connection with this experimental edifice or school, it is also suggested that there should be instituted a course of instruction for engineers (Assistants) just after their graduation from the Naval Academy. Would it not be better for them to receive this instruction before graduating, and to include in it some "shop teaching" and "engine running," even if the academic term was lengthened?

Regarding the course to be imparted at such a school, I am of the conviction that it is neither by reading or lectures that Cadets or post graduates from the Academy are to be materially advanced in the practice of their profession; for there is more than academic knowledge and observation of experimental mechanics that is necessary for proficient steam engineering.

ne does not acquire by a lecture proficiency in determining the ondition under which a "hard patch" in a boiler is necessary, nd a "soft" one is practicable; how to set an eccentric; stave 1 air pump; manage an engine in operation, when the vessel in a narrow or tortuous channel or on a lee shore, and all outoard injections are clogged up with sand or mud; the use of a snake bellied" gasket; that a pine wood wedge is the very best rticle to stop a leak in a boiler (it being in operation); or how part or core a pattern for a metal casting, and that to shorten wrought iron rod (as a connecting rod) for a short length, it necessary to add more to the weld than is cut out between ie ends of it, etc., etc.

That a school embracing the general features of that proposed ould be highly beneficial to the Corps, and incidentally to the ervice, there cannot be any question; but the scope of it requires onsideration, as it should be borne in mind that *nihil simul est wentam aut perfectam.*

Professor W. F. Durand.—The purpose of this paper is one hich must strongly commend itself to all who believe that sucessful engineering involves something more than a blind copy f the past.

There is no use in attempting to disguise the fact that engineers re called upon to design within a region of uncertainty wider r narrower according to the circumstances. Physical knowledge ; not, and from its nature cannot be, absolute. We can only now physical phenomena between certain limits, and it is only s experience accumulates that the limits may be narrowed. We nay be certain in looking at any piece of machinery, for example, hat, as a mere question of fact, the material is either redundant r deficient; it is not properly shaped and proportioned; and ery probably its whole office might better be taken by some ntirely different combination of elements. While from the tandpoint of absolute knowledge such statement is safe, the oint is to determine where the material is redundant or deficient, vhat dimensions or proportions might be changed, or what hange might be advantageously made in the fundamental haracter of the mechanism, or of its mode of operation.

Advances in this direction are dependent almost entirely on the accumulation of data from experimental investigation.

We must remember that the ideal scheme for experimental work must always involve the provision for the determinate variation of one, and of one only, of the numerous variables which may affect the phenomena in question. Only under such conditions may we intelligently correlate the change in the phenomena with the change in the conditions. In addition, experimental work naturally requires expensive and delicate instruments, trained observers, abundance of time, and experienced direction.

It is evident, therefore, that in the natural course of events, the proper experimental investigation of a subject will rarely be accomplished by the observation of the phenomena arising in the routine of actual service. Very much might be and is done in this way, but it is plain that usually the condition of restricted variation of variables and the best facilities for observations are not present, and furthermore that the ground naturally covered in this way will be only a small part of that required to make the investigation exhaustive and conclusive.

The only way in which the limitations of uncertainty within which the engineer must work may be narrowed is, therefore, by systematically directed experimental investigation, in which the investigation is the fundamental business, and not an incident of regular service.

Again there are wide fields of experimental work, as suggested by the author, opportunities for the investigation of which would never arise in actual service. Only by organized and regularly directed effort can such subjects be reached.

It is perhaps unnecessary at this point to speak of the details of experimental plant, organization and administration, or of the various fields in which experimental work might advantageously be carried on. If the opportunity should present itself for the establishment of such an experimental station, the same genius and fertility of resourse which have already dealt so successfully with engineering problems connected with our Navy will doubtless deal likewise with all such matters.

It may, however, be suggested that in some way there should provision for some kind of continuity of administration and rk. Nothing could suffer more from frequent changes in the icers of administration and operation. While much may oend on natural endowment, it is certain that no one can come a successful experimenter or investigator by inspiration or ditation. No man, however brilliant, can as an investigator do tice to his own mental equipment without a very considerable ount of actual experimental practice. Officers ordered as sistants would necessarily have to spend much time in work of s character before they would reach satisfactory development investigators, and the unfortunate results which would follow o frequent changes in personnel are only too plainly evident.

The proposition to use such a station for educational purposes ems also worthy of the highest approval. There would seem be no possible doubt of the value of some such course of perimental engineering for young naval engineers. Such urses and such work are now considered a necessary part of e regular course of instruction in mechanical engineering by e leading schools of the country, while as yet they are but adequately provided for at the Naval Academy.

As a further suggestion, it might be found possible to place e scientific part of all Government trial trips under the direction such a station, and the whole scientific staff might be drawn om its officers and students. Valuable as these trial trips now e, it is well known that, due to various causes beyond the ntrol of the officers more immediately concerned, they are dly deficient in scope, being usually restricted to the determination of the fulfillment or otherwise of contract conditions. 'ith a regular experimental station it might be found possible have all ships ordered through a vastly more extended series trials under a uniform direction, and with a corps of observers oroughly familiar through repeated practice with every detail the operations involved.

The scientific value of the work which might be accomplished such an experimental station relative to trial data of our new ips, and in the wide field of marine engineering generally, needs no especial statement to the readers of the JOURNAL. Beyond its scientific value, the financial value would, without doubt, pay the expense involved many times over, even if consideration were restricted to the Navy itself. If, in addition, we consider the value from the industrial and commercial standpoint to the country at large of such a mine of engineering information, it would seem that in no way could the necessary money be better invested.

Though such a movement may meet with many difficulties, it is one which should receive the sympathy and support of all in any way connected with industrial and scientific engineering in the United States.

Chief Engineer Chas. H. Loring, U. S. Navy.—The main proposition of Mr. Bieg's paper cannot fail to commend itself, not only to those closely or remotely interested in matters involved in our own profession, but also to all engaged in the pursuit of any of the numerous vocations of the mechanical engineer.

Primarily instituted for inquiry into the problems that confront the marine engineer, the sequences of the results acquired through the work of such an experimental station, would extend themselves into the realm of all who are working within the range of physical laws, and so become of wide general value.

Large and comprehensive as has been the growth within recent years of our knowledge of the laws that underlie the art and science of our profession, (and for which, as Mr. Bieg says, we are largely indebted to voluntary individual research) there are still many occult phenomena awaiting solution, the interpretation of which will enable us to obviate or evade many destructive and wasteful agencies that now work evil and entail expense.

The needfulness to the economies of our professional work of continued systematic inquiry and research for the solving of these problems, goes without saying. In naval engineering of whatever kind, the unraveling of these perplexities will be of great value in future constructions, and in their subsequent management, and it seems that the National Government might ppropriately, through one of its departments, establish a station r this purpose, without fear of the charge of being too paternal, nce it would of a certainty find adequate return in economy ithin its own expenditures.

W. L. Cathcart, Esq.—While naval machinery, at this time, as reached a stage of perfection which in some lines seems to pproach a limit, there is undoubtedly—if steam continues to be e prime motor—a development still in store for it as great as e demand upon it shall be; for the history of all progress is e passing of what seemed limits in their day. Further, the henomenal growth of electrical power in land service makes it ifficult to estimate the part—principal or secondary—which it s to perform in naval work hereafter. These considerations ead to one certainty at least, the demand upon our engineer fficers for original investigations of a high order.

Such work requires facilities for experiment and research. he intuitive genius, who has no processes between conception nd execution, is not much of a factor in engineering problems. n idea of value presents itself usually in a complicated form, equiring often much thought and skill to reduce it to its simplest erms. It would seem, therefore, that the experimental station roposed is, for results of the greatest value, a necessity and ot a desirable adjunct. Such a station might, with advantage, e extended to serve as a post graduate school, in which officers ould be trained as specialists, for whom, in the ever widening ield of the Engineer Corps, there is ample room.

To know that the cost of maintaining a station for these uses vould be many times repaid, one has but to scan the unbroken ecord of success presented by the small body of brilliant men vho have designed the machinery of our modern vessels. In uch hands, the proposed station would be of the highest value o the service and to engineering science.

Chief Engineer C. W. Rae, U. S. Navy.—The subject of experimental research is one of paramount importance to the mechanical engineer, and has occupied the minds of all progressive members of the profession since the art first developed itself into a science.

The growth of the modern navy has brought the necessity of this research more prominently to the front, as in this growth problems have arisen, and are continually arising, which can be solved only in this way, and which must be solved if we are to continue in the front rank of naval engineering, a position of prime importance to ourselves, to the Navy, and to the country.

In all undertakings of this nature, if good results are to be obtained, absolute freedom of action is essential. Those engaged in the research must be unhampered, and must give their whole time and attention to the end in view.

In the paper before us, the author has suggested a station, to be fitted expressly for the purpose, and to be under the sole control and management of those most interested. In this he will meet with the hearty support of all who have striven to accomplish certain ends while continually interfered with by the pressure of other and necessary duties. All utilitarian ideas, in so far as regards the construction and repair of existing structures, should be absolutely dissociated from the scheme. It should be purely and simply a station of experimental research, of scientific enquiry, and of study. It should be in charge of the most eminent engineer the corps can produce, and the assistants should be selected for ability alone. It should be equipped in a manner worthy of the end in view, and every engineering problem upon which authorities are divided, and which is capable of solution by experiment, should be settled at once and for all time.

We point with pride to the investigation and instruction carried on at the Torpedo Station; to the improvement in guns and armor made possible by the experiments at Indian Head; to the problems discussed at the War College, the handling of ships and fleets, and the art of war; so we, too, should perfect our part, in order that at the crucial moment the good work of others shall not be rendered futile by our shortcomings.

The present system of appointment and education of our naval engineers is not without its disadvantages. It is advantageous in that they are educated to naval customs, routine and discipline, nd should consequently make good officers. Their purely rofessional studies, however, are confined to two years, the first f which, owing to other branches studied at the samè time and the fact that all are not preparing themselves to become ngineers, may be properly called introductory, although as much given them as the time allotted will permit.

Until some better system is devised, a post graduate course ill be essential, and nowhere could one be given so well as at a ation such as is suggested by the author of this paper. Even hould some better method of appointment and instruction be evised, such a course would still be of incalculable benefit to he Navy.

The majority of young men develop professionally after aving the Naval Academy, after the occasion for that close pplication to study such as is essential to the full growth of heir ambition has passed, and unless some such opportunity be iven them, the best efforts of their minds will be lost to the ervice.

Our most successful engineers to-day are those of the highest aining and culture, the exceptions being those who are successl in spite of their lack of it, and who possess that inborn faculty hich would make them leaders under all circumstances. They ealize their deficiency and rise above it. All men cannot do so.

It behooves us then to take the material we have, and to evelop it to its greatest extent, and in order to do so, a scheme ich as that laid out by the author of this paper becomes an bsolute necessity.

Passed Assistant Engineer F. W. Bartlett, U. S. Navy.— am heartily in favor of the excellent plan proposed by Passed ssistant Engineer Bieg. During the last two years, my time as been almost entirely occupied with instructing at the Naval cademy the cadets who have selected, or who have been seected for, the engineer division, and the endeavor has been made give them in one year as much engineering as possible. The esult is an excellent course, as arranged a few years ago and dded to or revised each year, for the time allotted; but it is merely a skeleton of instruction, the filling out to be gotten by the cadet as it falls in his way on duty.

Of experimental work, there is time for almost none, even of the most elementary kind, only a few drill periods being devoted to setting of valves, testing gauges, etc., as there is little enough time for the cadets to get a smattering of the machine work they should know.

All but this skeleton must be acquired haphazard as they are ordered about on duty. Little can be done during the short cruise taken while at the Academy, as only three days are allowed for visiting one ship-building establishment. Here again a very spare skeleton can be given them of the plant, tools used, methods employed, etc.

So the whole course is a skeleton course, as it must be with the present plan of giving only one year in which to make an engineer.

The post graduate school, as proposed, would be exactly what is required, and would also fulfill the many and crying needs for experimental work that are so well put in the paper by Mr. Bieg.

Assistant Engineer Herman O. Stickney, U. S. Navy.— In his valuable paper outlining a plan for a school of experimental engineering Mr. Bieg says, "with the present system of appointing Assistant Engineers, some such plan of a post graduate course of instruction * * * becomes an absolute necessity, and would be only justice to the new appointees."

He has stated the case clearly, and certainly none too forcibly. I was commissioned an Assistant Engineer with the same training that is now given to naval cadets of the line division, and for a part of my first cruise I was entirely out of my element. It could not have been otherwise, since I had been launched suddenly into a position where I was to perform professional duties of which I had only a faint conception.

To discover the causes of difficulties that are continually confronting naval engineers, both at sea and on shore, and to successfully apply the proper remedies, is a task the magnitude of which is evidenced by the fact often asserted that we age more rapidly than other officers.

Of course, persistent investigation and long experience are ecessary, but of equally great importance is it that young igineers be given a deeper foundation on which to build their ture ; without a good foundation any structure, whether mental · physical, is apt to be shaky. Much valuable time is lost hile young engineers are picking up volumes of information at should be placed within their reach before they fairly enter oon general service, where routine duties prevent extended udy and investigations.

Good as the course of instruction for the engineer division of ival cadets now is, it can be regarded as but the stepping stone their life's work. ·

The experimental feature of Mr. Bieg's plan should be warmly lvocated by everyone, for, to quote that eminent engineer, Mr. eaton, " until very recently most investigations of practical roblems connected with the marine engine have been conducted such a way as to confuse rather than enlighten, and the ferences drawn have been rather in accordance with the desires f those interested than with the facts elucidated by experiment."

Passed Assistant Engineer T. W. Kinkaid, U. S. Navy.— Ir. Bieg's scheme for an experiment station is advocated none oo soon, and, although I may not be able to add anything of alue to his succinct, but complete, statement of the necessity or such an institution, yet I am glad of an opportunity to applaud he movement. Experience has shown that the best experiiental work done at the technical institutions to which the uthor refers is accomplished by post graduate students, and I elieve that our young assistant engineers are capable of bringing o the work such enthusiasm, discipline and intelligence as will urely give results of the greatest value.

The search for a non-volatile lubricant, the transfer and stowige of dust fuel at sea, the successful employment of rotary steam engines, the washing of smoke from torpedo boat boilers (to ender the boats less visible) are some of the questions whose minor problems are fit work for an experiment station. Some day t may be deemed advisable to issue to ships and to navy yards a compact and simple apparatus for coal analysis. There is nothing of the kind now in the market, but doubtless the apparatus could be evolved at an experiment station. The throttling calorimeter is widely used, but, although the best we have, it is not wholly satisfactory, chiefly because we cannot get a fair sample of steam. Here we have a problem towards whose solution the Government ought to perform its share of work.

Some of the best men that have belonged to the Engineer Corps of the navy are now pursuing honorable and profitable careers in civil life. It would be a distinct advantage to the navy, if the establishment of a lecture course at the experiment station would result in the bringing of these men of mark into renewed contact with their former brothers of the Engineer Corps.

As to the probable value of the work of the station in training the younger members of the corps, I believe that very few will dispute it.

Assistant Engineer L. M. Nulton, U. S. Navy.—I think the idea of establishing an engineer experimental school, or laboratory, as given in Mr. Bieg's paper, an extremely good one. It is evident that the necessity for such laboratories exist, or outside institutions or firms, whose sole object is that of making money, would not incur the expense of maintaining them unless there was some benefit in so doing.

Every one knows that problems that have been presented during sea or shore duty have, in the majority of cases, been allowed to pass and remain personally uninvestigated because of a lack of opportunity for such investigation.

A short tour of duty at the New York yard showed how discouraging it must have been to carry on experiments, where the officer I have in mind was obliged to oscillate from one part of the yard to another for different parts of his experiment, watch his opportunity to use this or that piece of apparatus belonging to another department, and, probably, at the moment his results were all collected for arrangement and investigation, be put on some Board requiring him to drop the whole experiment for a while.

I think a course of instruction at this school for assistant engineers, just after their promotion from naval cadets, would be of immense value to them. Some such course is absolutely necessary if, as has been done so far, cadets are appointed assistant engineers who have had the course of study prescribed for the line officers, and who have made their two years' cruise as line cadets, as did those of my own class ('89) who entered the Engineer Corps.

We were the first, I believe, to be sent to the New York yard for a kind of post graduate course. The year spent there was very valuable to me. The officers on duty there did everything in their power to assist us, but they were necessarily occupied with their regular duties, and much more good would have resulted if there had been some one detailed as an instructor, whose duty it would have been to direct our attention to those things we did not know because we had never been brought in contact with them.

Since my graduation from Annapolis, the classes there have been divided and the course for engineers has been revised and expanded in every way; but, with the limited time for the course there, it seems to me that a supplementary course, as suggested by Mr. Bieg, bearing directly upon the practical work they would have from the time they went on board ship as assistant engineers, would result in a benefit to them and to the Service.

This part of the discussion is principally with reference to those who enter the Engineer Corps without having had the regular engineer course at the Academy.

It is my own experience, but it cannot be radically different from the experience of all those who enter the Corps under similar circumstances.

Passed Assistant Engineer Edgar T. Warburton, U. S. Navy.—If through the investigations of anyone who is familiar with the disastrous action on copper piping the cause and prevention were discovered, there would be saved to the Government an amount sufficient for the maintenence of the suggested experimental station for several years, and a serious deficiency in our fine ships would be overcome.

Almost every step in the construction of vessels for the Navy is the result of experiment. The splendid material available for the machinery contributes largely to the success of the boldness and originality of design; but this perfection of material was not attained until, to meet the exacting requirements of the Navy Department, the steel makers improved their products by costly experiments, at the expense of the users, of course, though the ultimate reduction in cost more than compensated for this.

Other materials have been brought into prominent use—the several bronzes, aluminum, nickel steel—all the result of experiment.

While the Government has indirectly borne the expense of much of this experimentation, the Navy Department has not been slow to initiate investigation where there is occasion for it. There is about to be constructed an armored 13-inch gun turret similar to those designed for the battleships, and a test will be made of the effect of the shock of projectiles on the turret machinery.

The wise administration of the Navy Department thus assures successful advance by preliminary investigation, and I presume when the Engineer-in-Chief has a matter of importance requiring experiment the means would be provided; but this would necessitate the organizing of a special Board, which would not have the appliances and facilities which add to the ease and accuracy of investigation.

The need is therefore apparent of a well equipped station, as proposed in the paper under discussion, which would not only stimulate and encourage individual experiment and research, but would form a valuable adjunct to the Bureau of Steam Engineering, relieving the designers of many vexatious matters by placing at their service a small corps of trained experimenters.

There is a demand for higher education; young and old participate in the University Extension course, and the summer school at Chatauqua is thronged with voluntary students, who are seeking knowledge for the pleasure and culture it gives.

During the college month of June thousands of graduates were told, with many variations, that their education had but begun;

o none does this apply more closely than to the young men who were yesterday naval cadets and to-day are assistant engineers.

A two or three years' course abroad is considered desirable or the young constructor, and occasionally an engineer officer as a similar advantage; but we should be in a position to give ne instruction at home, and when all need it, it should not be enied.

A summer course of lectures for older officers, similar in plan o the course at the War College, suggests itself as enlarging the cope of the proposed station, to the further advancement of the Engineer Corps and the Navy.

The Government has precedents for such an establishment: he Torpedo Station and War College for the Navy, the Artillery nd Cavalry Schools for the Army, would be kindred organizaions to the Naval Engineer Experimental Station.

Passed Assistant Engineer A. B. Willits, U. S. Navy.—Mr. Bieg's suggestion is a most apt one indeed, and in hearing it, one is strongly reminded of the many times one has soliloquized on the same subject when problems which could only be solved by extensive and expensive experiments have been confronted in practical experience. No doubt we have all felt at such times the keenest regret from the realization of the impossibility of acquiring the exact information we want on many subjects which could be properly elucidated by some such school as is proposed.

The details of the arrangement of such an experimental station is a subject upon which the members of the Engineer Corps will naturally differ, and a free expression of these opinions will greatly facilitate the drafting of the most feasible plan upon which to base any formal proposition for the establishment of the institution.

For my part, I have always felt that the scope and appropriation for the work of the Experimental Board is too limited, and while I must confess to much ignorance in regard to its duties, I cannot see, from my point of view, why the desired goal cannot be reached through a broadening and extension of the duties and control of this Board, so as to expand an already existing feature into a far more comprehensive one, and (without introducing a novelty) gracefully make the transition from a Board with but few duties, as in the sense of variety, *but with an excellent title*, to one with a boundary as unlimited as that title would signify. Of course, the construction of this new Experimental Board would have to be rearranged as regards numbers, etc., and to their present work would be added all the new work desired. I would suggest also a careful revision of the scheme for ordering the inventive individuals to conduct their own experiments, as I do not think that is a good idea at all. It would lead to prejudice and non-uniform success, I am sure, and it is not at all necessary. Frequently a very good idea will be presented to the Board by a man who is not at all qualified to carry on the analytic work necessary to prove its practical utility, and there seems to be no good reason why the work should not be perfectly performed by a corps of skilled men with a clearly expressed synopsis from the inventor.

As to the composition of the Board I would suggest: One Chief Engineer, as director; two Chief Engineers, as assistants; four Passed Assistant Engineers; four Cadet Engineers.

The magnitude of the work and its great importance to the service would preclude a lesser number of officers being assigned to this duty, and the Experimental Board as then constituted should be under the direct control of the Bureau of Steam Engineering, and independent of any navy yard or station.

There should be also a skilled chemist of ability as an analyst, and a first class electrician; a fine tool maker and clock work hand, together with fine machine hands for special work. A finely appointed laboratory and a complete machine shop would be necessary, and the museum suggested by Mr. Bieg would be a valuable adjunct.

It might be very wise to include the trials of the new ships (not the work of inspection) in the duties of the new board, as the data would be in the line of work valuable to them.

The cadets could be changed every six months, with possible advantage to them.

The location of the school or board is not so important, as experiments with ships and boats could be arranged for at the nearest navy yard.

Experiments with screw propellers alone, with some of the large new ships, would be invaluable. Trying several forms or sizes on some one of these ships and finding out more than we can do without trials would be of great and practical benefit. Establishing economy curves early in the "life" of a ship, making tests of material and establishing the standard of "best" for ships' use, developing to practical utility the ideas which may be advanced by the "head workers" of the Corps, and which may present valuable features; all these things would show a net saving to the Government beyond that which is conceivable by those who do not count the money wasted through ignorance of the actual cost due to lack of detailed information in this line.

The magnitude of the work included in this scheme is such as to command a liberal appropriation, and there can be no reasonable doubt as to the value of the "returns."

Mr. Bieg deserves a vote of thanks for so ably broaching this matter, and I hope the results will prove a great satisfaction to him.

Passed Assistant Engineer E. R. Freeman, U. S. Navy.—The subject under discussion is certainly one of very great importance to Naval Engineers, and it is devoutly to be hoped that this discussion will lead to some tangible and practical results.

I must, however, take strong issue with the author on his statement that "the education given at the Naval Academy must be supplemented, if the Navy is to have engineers who can be of assistance on their first cruise as commissioned officers." The author's idea must be that it is not to be expected that such instruction as his proposed post graduate course is intended to furnish could be given at the Naval Academy, and in that I fully agree with him; but I certainly cannot agree with him if he also means, as he states, that engineer graduates of the Academy generally are of no assistance on their first cruise, even before they are commissioned officers. At the same time I do not think the academic course for engineers is what it should be and what it could be, and to prove that, I think I have only to show what it has been, citing in evidence the markedly superior standing which has been taken, both at the Academy and subsequently in actual service, by that class which, in my opinion, had decidedly the best education as marine engineers, and the best edification as officers of a military organization that the Academy has ever given. I refer to the class of '78.

I also fully agree with the author that a post graduate school for young naval engineers should be established, and that it should be entirely independent and untrammeled in its operations. And it seems to me that this might be best accomplished by more firmly establishing the existing Experimental Board of Naval Engineers, and merging it, adequately strengthened in membership, of course, into the faculty of a post graduate college. Its work, as well as the work of its students, would then be both instructive to the latter and also of immediate use to the Service. And, as Mr. Bieg urges, it is, furthermore, most important that the practical information which young Assistant Engineers are now given "the chance of picking up at the New York navy yard," should be obtained under the direction of the officers of this college, and should be extended not only to other ship yards, but also to works where material used in the construction of vessels for the Navy is produced. Just as it has been found of great and all around advantage to institute manual training *in lieu* of the former haphazard, sluggish and altogether unsatisfactory apprentice system in the liberal arts instruction, so it must be even more fruitful of good results to instruct the young marine engineer in the actual practice of his profession in all its branches, rather than trust to the uncertainties incident to the Service, which in many cases eventually bring an officer to conduct operations of which he has only a theoretical knowledge. It is quite impossible that any young officer, during the year of his subordinate service, can get a proficient practical knowledge of all the branches of his profession, although zealous ones may and usually do get a creditably efficient one.

P. R. Voorhees, Esq.—I have read Mr. Bieg's paper carefully, and with great interest. I think it appeals strongly to the best engineering talent of the country, and I further think that the matter therein contained should receive the hearty indorsement of such talent. Not alone will the engineer officers of the Navy receive the benefit of the plan outlined for the establishment of an experimental school, and of a course thereat of post graduate practical instruction for the Assistant Engineers, but the country itself, and the engineering profession at large throughout the world, will be benefited in no small degree by the researches and experimental data which will result from the labors of the school. I hope that the proposal may result in the practical fulfillment of its author's ideas and plans.

Chief Engineer H. Schuyler Ross, U. S. Navy.—I am glad to see that the Council of our Society has taken in hand the subject of an organization to prosecute "research" in engineering matters. This subject should have been acted on long ago. Our Bureau of Steam Engineering has for many years instituted many scientific tests for the benefit of the service, as the opportunities occurred, but there has been no regular organization, other than the Experimental Board, for such purpose. There can be no question as to the need of some organization for this work, as problems are constantly arising in modern marine engineering which need practical solution; but I fear that the difficulty to overcome will be the necessary plant and outfit of the varied instruments so necessary to prosecute accurately the researches as they arise. We have plenty of talent in our Corps to carry out accurately any needed scientific investigations, as well as the ability to devise, adapt and analyze them. The sore need will be the material, as well as the "sinews of war" necessary to maintain a permanent organization. Any scheme of action that will accomplish these should meet the hearty approval of all. Mr. Bieg's plan, if it can be accomplished, will give all that is needed, and should enlist the energetic assistance of all.

Chief Engineer R. W. Milligan, U. S. Navy.—Mr. Bieg has taken hold of two subjects, of which it may be truly said, the importance of either cannot be over-estimated. An experimental station such as he outlines would more than pay for itself, in information gained, in a very short time. As an illustration of this fact, if such a station had been established years ago, we would not have carried on the pernicious practice of making all the scale possible in boilers, when we thought we were doing the very opposite. The point involved was under discussion among engineers for years before it was finally settled; an experiment of one week's duration at an experimental station would have demonstrated what we all now know to be true, and the money saved the Government would have run up into the millions. Other questions still unsettled could be determined, and numerous ones will, no doubt, spring up in the future.

The post graduate course for engineers is of equal importance, and the necessity for it has been recently emphasized by the appointment as Assistant Engineers of three young men who have received very little instruction in their profession; in fact none at all with a view to becoming engineers.

An ideal place for such instruction would be at some large establishment like Cramp's, under suitable instructors; but this is, of course, impractical, as no firm would care to have the trouble connected with it. Of late, the New York navy yard has been a good place for such instruction, and will be for the next year provided competent instructors be detailed for this special purpose, and to see that time and opportunities are made good use of. But the New York yard, or any other yard, may at any time drop from a "construction" to a "repair" shop, and thus be less desirable than if new work were always in progress. Still, taken in connection with the adjacent private plants, to which short visits could be made, I think it the best place we have, provided the course has proper supervision, and the only thing to interfere with this is the scarcity of engineer officers.

While it may be economical to combine the experimental station and the post graduate school at one station, it is a question whether the results would be as favorable for the post graduate course as they would be if the two were separate. They certainly would not be for some years, or until the experimental station had the proper plant.

Chief Engineer G. B. Ransom, U. S. Navy.—Of late the press has been devoted to the subjects appropriate to the close of the educational year, and many good suggestions relative to intellectual progress have been made in connection therewith. In its broadest aspects, I consider the subject under discussion to be in line with current opinion upon the theory of evolution, and one worthy the most thorough consideration.

The development of power from fuel concerns not only the steam used, in its pecuniary aspect in this steam using age, but it is an intellectual problem—a better solution than any yet offered will mark an era in the advance of civilization as typical as that of the steam engine. In its design and construction the steam engine calls upon the acquirements of the mathematician and physicist, the delineating ability of the draftsman, directly upon the skill of six varieties of handicraftsmen, while indirectly there are but few branches of labor left unrepresented in the finished article; the world is interested in its efficiency.

An engineer, worthy of the title, must be thoroughly informed, not only in regard to theory but in regard to practical work as well. To acquire a respectable position in the profession requires much application; to be a leader in it calls for qualities usually ascribed to genius. An engineering education is necessarily an expensive one, for during the progress of work questions demanding investigation are continually arising, while new applications of theory to practice call for experimental constructions which involve an outlay that the experimenter could not be expected to make. Considering the interests involved, a request for aid in money, books and apparatus, instruction, and opportunities for research, cannot be considered unreasonable. Its extension would be consistent with the action of the Government in regard to objects which, in a financial sense at least, are not of greater importance than the marine steam engine.

The Army has its Engineering and Artillery schools as well as its school for both Cavalry and Infantry. The medical profession is recognized in the costly Army Medical Museum, Naval Museum of Hygiene, and the Naval Medical School at the Brooklyn Laboratory. The naval Line officer is instructed in ordnance at the Washington navy yard, in torpedo practice at Newport, and in the general principles of his profession at the War College. The suggestion that the Naval Engineers should also in some form combine both study and experiment, needs no argument to support it. Engineering failures in the past have completely demonstrated the costliness of ignorance. I am inclined to go much further in the direction indicated by Mr. Bieg than to simply ask for the detail of two or three members of the corps as instructors, the gathering of a class, and the attempt to establish a marine mechanical engineering laboratory. I would add a Naval Constructor to the faculty, and a professor in chemistry. The course should be systematized, and its satisfactory completion should be requisite for promotion. The class should be composed of ten from each of the two lower commissioned grades, and the duration of the course of instruction should be not less than six months. Those showing special aptitude should be given longer time for the preparation of theses involving original investigations and the statement in proper form of the latest successful applications of theory to practice.

In addition, I would have every member of the corps submit an annual report of his connection with engineering operations. These reports should be properly digested, and those items found worthy should be published. Any member of the corps desiring it should have either an opportunity to experiment directly with an approved process or contrivance, or, if this should not be feasible, his directions should be followed and a report made of the results obtained.

I should be inclined to prefer the navy yard at Boston for the location of this school of application, mechanical marine engineering laboratory and experimental station.

Finally, I would be liberal in extending its privileges to all naval officers desiring them, and should expect that once started its development would be rapid, sufficiently so at least to render it possible for American naval engineer officers to obtain therein a good practical and theoretical preparation for the arduous duties incident to their profession.

Passed Assistant Engineer W. M. McFarland, U. S. Navy.—I am very glad that this subject has been proposed for discussion, for I believe it of the greatest importance, and I am satisfied that if the proper authorities had the merits of the case adequately presented to them, they could not fail to move in the matter. A very slight acquaintance with engineering history will show how absolutely essential to progress is proper experimentation, and instances could be multiplied to prove an absolute saving to the Government if proposed schemes were tried by competent experimenters on a small scale instead of being at once put in use on a large one.

One of the most notable instances of this was the controversy about the use of steam expansively. Our own Isherwood, with rare sagacity, aided by his famous experiments on the *Michigan*, had realized that, with the low pressures in use at the time of our late war ('61–'65), there was an actual economic loss in carrying expansion beyond a very moderate degree, while the weight of machinery was greatly increased. Yet it remained for the actual trial of the machinery of the *Pensacola* to show the utter failure of the ideas of the advocates of extreme expansion.

For many years, all navies committed the absurdity of "blowing down" to reduce the formation of sulphate of lime scale, until Cousté's experiments showed that this was the very plan to cause the greatest amount. We also had the absurdity of boiler corrosion being charged to everything under the sun except the reason which was right under our eyes, the plan of emptying the boilers and opening them *to dry*, really to rust. The researches of the British Admiralty Boiler Committee set us right on that point, and have saved all countries thousands of dollars.

Finally I may mention the experiments on triple screws made by M. Marchal of the French Navy, which led our Engineer-in-Chief to adopt them for the *Columbia* and *Minneapolis*. Had it not been for these, and the application of triple screws on the Italian gunboats in consequence of them, which assured satisfaction in their use, I think it is very safe to say that our two flyers would have had twin screws and would not have been as fast as they are.

There are many problems awaiting solution which can only come from exhaustive experiments, and these can only be had when some such plan as Mr. Bieg proposes is adopted. And it must not be imagined that these problems are speculative or merely educational. Many of them are of an intensely practical nature, and a thoroughly satisfactory solution would increase the efficiency of our ships and cause a saving to the Government.

The second part of Mr. Bieg's plan, the school for young engineers, is a matter on which I have thought a great deal, and I consider such a school a vital necessity for the efficiency of the Engineer Corps. There is no branch of modern technical science in which there is greater progress or more change than naval engineering, yet our officers are left to "pick up" information as best they can. The very journal in which this discussion is printed was the outcome of the desire of our officers to do what they could, at their own expense, towards keeping the members of the Corps informed of all the latest improvements in our profession. We have already in the Service the Torpedo School, the course of Ordnance Instruction at Washington, and the Naval War College, while the Army has its Post Graduate School for Engineers and the Artillery School. It certainly seems that, if these institutions serve a useful purpose, of which there can be no doubt, a school of application for Naval Engineers would also be useful.

We need such a school now especially, because some of our young officers, through no fault of their own, are coming to us with very inadequate preparation, and something must be done to give them proper training, and I am sure we all realize from personal experience how greatly we would have been benefited by a course at such a school after our cruises as cadets.

Machinery is playing a more important part in our Navy every day, and it is of vital importance to the efficiency of the Navy that the officers charged with its care should be thoroughly trained and competent. Only engineers who are conversant with the facts realize what apparently small things may cause great losses of efficiency. We must try to convince the authorities of the importance of the proper training of our engineers, and then the school will follow as a matter of course.

Passed Assistant Engineer John R. Edwards.—There has been handed down to the deck officer, for his guidance, a wealth of war experience and strategic literature which must be of great use in working out the solution of problems that confront him. Despite the fact that some branches of his profession are exact sciences, it is considered a necessity that he should receive post graduate instruction at the Washington gun foundry, the Torpedo Station, and the Naval War College.

Naval engineering science is a developing one, and there are many problems to be solved by the Corps of Naval Engineers in their work of designing, maintaining and repairing the machinery of war vessels. The opportunity to acquire such knowledge must be given them, and the establishment of the projected institution would be productive of great results, not only to the Naval Service, but to the country at large.

With the growing importance of engineering science and with public sentiment commending the work of the naval engineer in his effort to make our vessels of war more efficient, this officer finds no reason for excusing his action in taking aggressive measures for the improvement of the Naval Service. There should be established without delay an engineering laboratory and post graduate school, where the full measure of the Engineer's worth could be developed.

Professor Ira N. Hollis.—The plan of establishing a station for experimental and educational purposes should commend itself to the Bureau of Steam Engineering and the Navy Department for two reasons: first, to determine accurately disputed points in engineering; second, to afford additional training to graduates of the Naval Academy. In regard to the first point, there is no place in the United States where the larger questions in mechanical engineering can be examined. The expense is usually too great for private establishments. For instance, there are many doubtful points about boiler construction, such as the proper stiffening for manholes in the shells, the best shape of the heads and the strength of fastenings between heads and shells, the influence of length upon the bursting pressure, and the effect of the heads upon the strength of short cylindrical shells. These seem to be matters that mathematics and mechanics cannot determine; at the same time they are of great importance to the whole country. While all boiler makers are interested in them, no single firm could undertake experiments on a sufficiently large scale to obtain really useful results. The Government could not put money to a better purpose than to provide for the safety of the thousands of men now engaged in running and caring for the plants scattered all over the country. Every city is filled with mines, often placed beneath the sidewalks, dangerous alike to attendants and passers by. The boiler question is not alone in the demand for experimental work, but the engines and various devices that go into our ships require careful examination. Money spent in experiment is often saved over and over in the subsequent adoption of the most efficient machines.

The group of men detailed to such an experimental school would be useful in other directions too. Smaller Boards could be sent from time to time to ships in commission for the purpose of determining economic results of machines already in use. The log books are practically useless, because no ship has trained officers enough to make the necessary observations and keep track of them. No man can run the engines of a modern war vessel and take accurate data at the same time. No merchant ship company would be foolish enough to undertake it; yet the Bureau of Steam Engineering is forced into this position by the lack of opportunity to train its own men and to detail them to the best advantage. The increase of efficiency and the knowledge gained by three or four additional engineers placed on board a new ship for one year, would more than pay for the extra expense.

This brings me to the second point, that of education. There is no place where such a detail of engineers could gain the proper training for the above work better than in an experimental station. Our young men come out of the Naval Academy prepared to become engineers. Their education has simply made them ready to study the profession. A post graduate course, after two or three years at sea, would therefore be extremely valuable. It would not only give them the very best training in engineering, but it would bring them, more or less, in contact with men outside of the Service and gain for the Navy an experience with commercial questions which our men would find most useful. There is nothing so deadening to the energies as a number of years spent in a subordinate position upon one of our ships. That Navy is fortunate which keeps alive the interest and zeal of its officers in time of peace. I can conceive of nothing that would afford a greater stimulus than such work as a well equipped experimental station would supply.

It strikes me that one of the causes of our success in designing the machinery of the new ships has been the singular ability of the Engineer-in-Chief to awaken the interest of the younger men in the Corps, and thus to bring out their best work.

The success of the modern ship cannot be attained by one man, however able; it must depend upon the hearty co-operation of the officers serving on board, and anything which tends to enlist their co-operation and make it intelligent will be of the greatest value to our country.

Passed Assistant Engineer F. C. Bieg, U. S. Navy.—I am deeply sensible of the kind consideration given this paper by the members of the Society, and may be pardoned for feeling flattered at the general tone of approval of the discussion.

There are only a few points which require some comment and explanation.

With all due deference to the high authority of Mr. Haswell's statements, I beg to differ in regard to his view of the value of properly prepared lectures as a help to proficiency in the practical work of our profession. While the teachings of personal experience impress themselves more firmly on the mind, I cannot see why the imparting of any one's experience should not help and instruct another who is without that experience. I think one of Mr. Haswell's own examples, "That to shorten a wrought iron rod for a short length it is necessary to add more to the weld than is cut out between the ends of it", will show how valuable a point can be given in even a short lecture. To gain the above knowledge would cause, under the system of "acquiring personal experience", the ruin of at least one rod, or require a "streak of luck". Much must come by experience, and by experience alone, but whatever those who have had experience can do to prevent the inexperienced from falling into error, should be done, and I am convinced can be done with profit to the Navy and the inexperienced individuals.

In regard to Mr. Freeman's objection, I think it will be found, taking the extract quoted by him in connection with the first part of the paragraph to which it belongs, and the statements of Mr. Stickney and Mr. Nulton, that he has labored under a misapprehension. As one of the class of '78, to whom Mr. Freeman refers, I confess that my services during the first part of my first cruise would have been more valuable to the Navy and to the Chief Engineer of the ship to which I was attached if I had had some such instruction as proposed. I do not for one moment wish to impugn either the intelligence or energy of those young officers who, from Naval Cadets of the Line division, enter the Engineer Corps and upon its arduous and unappreciated duties, but I do say that all means should be employed to give them, in practical, useful form, the results of the experience of their predecessors. They should not be sent out on their new duties unequipped, with the expectation that all they need know they will pick up. I repeat, such a course is neither just to the young officers nor beneficial to the Navy.

In regard to the suggestion that the scope of the present Experimental Board could be enlarged to take in the duties of the proposed station, I think that such a course would be injudicious. The researches, experiments and course of instruction at the station should not be interfered with by any call to other duty except that of war, and, therefore, its location in a navy yard was not advocated. The tests carried on by the Experimental Board are, frequently, subject to conditions of time and place, depending on the patentee of the article to be tested—conditions which would be disastrous to the usefulness of the station.

It has also been suggested that the post graduate course of instruction might be given at the Naval Academy. It seems to me that the mixing of commissioned officers under instruction, to whom the Academy Cadet rules could hardly be made to apply, and young Cadets would be demoralizing to the discipline of the Academy. Again, to separate the Experimental Station and the Engineer School, would prevent the training with the experimenters which has been advocated.

Unless the proposed Station is established on independent lines, it would be better not to have it at all.

In conclusion, I desire to express my thanks to the members who have taken part in the discussion, and to hope that their valuable suggestions may soon turn the outlined proposal into a welcome fact.

Since the above paper was written, the new Assistant Engineers of this year have been ordered to various ships for duty. The great need of Engineer officers probably has made this necessary; but it is to be hoped, for the sake of the proper training of these officers, that the details will be temporary only.

EXPERIMENTS IN CONNECTION WITH EVAPORATION.

By D. B. Morison, Esq.

[Read before the Liverpool Engineering Society.]

The universal practice on steamships a few years ago was to supply the loss of water due to leakage in a condensing engine from the sea direct to the boilers, but since the introduction of triple expansion, with its higher pressures and temperatures, the necessity for minimizing the scale in boilers has resulted in the use of an independent apparatus, in which sea water is evaporated by means of steam, and the generated steam, being condensed, is delivered to the boilers free from all impurities. Apart from the necessity of such an arrangement from an engineering point of view, there is the commercial consideration of reducing the boiler scaling expenses, minimizing the liability to accidents, and prolonging the life of the boiler, as, whilst it is possible for careful engineers of long experience to work boilers without an evaporator, there are few superintendents who do not realize the fact, that in order to obtain the greatest engineering and commercial efficiency, and as a safeguard against accidents, an evaporator is a necessary auxiliary on board a modern steamship. The quantity of water lost depends on the design and workmanship of the various details subjected to steam pressure, to the number of appliances and arrangements for preventing waste, and to the care of the engineers in charge.

The chief sources of loss in the main engines are from the piston rod, valve spindle and feed pump glands, but these may be minimized by the use of automatic water drainers and special water saving appliances, examples of which are shown on Figs. 1 and 2. Careful attention of those in charge to all the details of the various steam connections is the chief factor, however, as

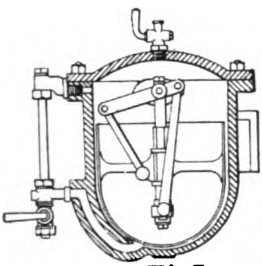


Fig. 1.

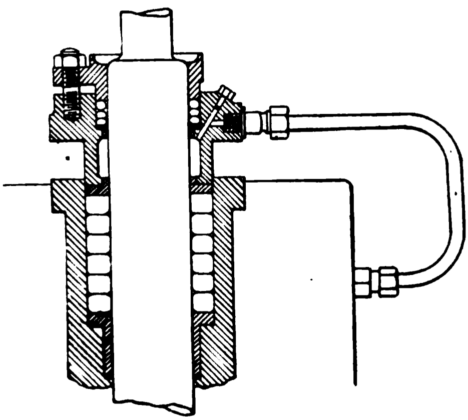


Fig. 2.

there is no better index of the efficiency of an engine room staff than the quantity of auxiliary feed water required.

The ease with which loss of water in marine machinery can be made up, by simply allowing it to flow from the sea to the hot well, has often tended to mislead those in charge as to the quantity which should be required and the quantity actually used. The natural result is that there is a large number of boats in which the loss is most extravagant, the engineers being either unaware of the fact or accepting the condition as normal.

One of the many examples which have come under the writer's notice was a steamer with an evaporator, which, even when coated with scale, would have been capable of producing four times the amount of fresh water which should have been necessary. The engineer reported that the evaporator was certainly of assistance, but he had to keep it going continually, clean it every day, and use, in addition, a large amount from the sea. This is an apt illustration of the unconscious influence the old auxiliary supply from the sea had over the engineer, as his entire efforts were concentrated in endeavoring to compel the evaporator to produce sufficient water to make up the loss, he being totally blind to the fact that the amount of loss was both extravagant and unnecessary. An example of what may be considered an exceptionally high efficiency has been obtained on a steamer belonging to the Peninsular & Oriental Company, on which facilities were kindly given the writer by Mr. Manuel, for obtaining reliable data extending over several voyages. The engines are 28, 44, 72 by 48 inches stroke, with two boilers of 160 pounds pressure, steam steering gear, electric light and the usual auxiliary machinery being fitted.

At sea the average indicated horse power is 2000, and the amount of auxiliary supply five tons per day. In the previous example the indicated horse power was about 1000; each boat was fitted with identical evaporators; the Peninsular & Oriental boat used 2½ tons per 1000 indicated horse power per day, and the other certainly not less than 15 tons, but probably nearer 20 tons. In order to allow a margin for auxiliary engines, it may be assumed that the consumption of water in the Peninsular

& Oriental example is 15 pounds per indicated horse power per hour, and by reference to the annexed table it is seen that 2½ tons is equivalent to 1½ per cent. of the total feed water.

AUXILIARY FEED WATER.

Calculating the feed water at 15 pounds per I.H.P. per hour.		Calculating the feed water at 18 pounds per I.H.P. per hour.		Calculating the feed water at 20 pounds per I.H.P. per hour.	
Percentage of auxiliary feed to total feed water.	Auxiliary feed in tons per day per 1,000 I.H.P.	Percentage of auxiliary feed to total feed water.	Auxiliary feed in tons per day per 1,000 I.H.P.	Percentage of auxiliary feed to total feed water	Auxiliary feed in tons per day per 1,000 I.H.P.
1 per cent.	1.6	1 per cent.	1.93	1 per cent.	2.14
2 "	3 2	2 "	3 86	2 "	4 28
3 "	4.8	3 "	5 79	3 "	6.42
4 "	6.4	4 "	7.72	4 "	8.56
5 "	8 0	5 "	9 65	5 "	10 70
6 "	9.6	6 "	11 58	6 "	12.84
7 "	11.2	7 "	13.51	7 "	14 98
8 "	12.8	8 "	15.44	8 "	17.12
9 "	14 4	9 "	17 37	9 "	19.26
10 "	16.0	10 "	19.3	10 "	21.4
11 "	17 6	11 "	21 23	11 "	23.54
12 "	19 2	12 "	23.16	12 "	25.68
13 "	20 8	13 "	25 09	13 "	27.82
14 "	22 4	14 "	27.02	14 "	29 96
15 "	24 0	15 "	28 95	15 "	32.1

The consumption in the other boat would probably be about 18 pounds, and assuming 20 tons of auxiliary feed, the percentage of the total would be 10.3 per cent. These cases may be considered extremes, but the greatest care is necessary in order to obtain maximum efficiency, as a number of very slight leakages when combined produce a large quantity at the end of 24 hours. The trials of the S.S. "Iona," by the Research Committee of the Mechanical Engineers, may be taken as an example, as the loss was 6 per cent. of the total feed, although beyond a slight leakage at the feed pump glands during a portion of the trial, there was nothing apparent to the many observers on board which would account for such a large loss.

The Committee on Naval Boilers recommend in their Report that not less than six tons per 1000 horse power be allowed, which would be about equivalent to three per cent. of the total feed. This allowance seems very small when the large number of auxiliaries is considered, but probably the estimate is made on the maximum indicated horse power, which is, of course, very seldom obtained. It will be evident, therefore, that not only does the amount of auxiliary feed vary for different types of engines, but the variation may be very great in ships of the same class, depending entirely on the condition of the main and auxiliary machinery. In passenger boats, where the labor is sufficient to keep everything in good order, a safe allowance is eight tons per 1,000 indicated horse power at sea, which, assuming a consumption of 15 pounds of water per indicated horse power, is five per cent. of the total feed; but in cargo boats, where the available labor is much less and so much attention cannot be given to details, ten tons per 1,000 indicated horse power is advisable. In both these cases there is ample margin for contingencies, and if evaporators are fitted of these capacities but still are not sufficient, then the waste of water is highly extravagant and altogether unnecessary.

The arrangement of multiple evaporators working in series so that the generated steam from the first is utilized to generate steam in the second, and so on, although being the universal system for sugar refining and distilling, is not in use to any extent on shipboard, as it involves unnecessary complication and initial cost, besides entailing more attention when working; so that what is generally understood by a marine evaporator is a single vessel in which salt water is boiled away, the heating medium being steam. From the elementary nature of the apparatus the different designs are exceedingly numerous, as, given a vessel in which water is evaporated by means of steam within a tube, there is ample scope for variation of detail. But simple variation is of no value unless accompanied by definite improvement, which only results from development based on the practical requirements of those engaged in the working of the apparatus at sea; and it is becoming more and more recognized by designers that not only must all auxiliaries on shipboard be simple, but that the labor necessary to maintain efficiency whilst at work must be reduced to a minimum. There is only a certain amount of labor available, and the requirements from that labor are ever increasing; in fact, if engineers at sea are hampered with any detail which requires an undue amount of attention, then, as a consequence, something else suffers. It is, therefore, practically imperative for success that such an elementary apparatus as a marine evaporator must not only be efficient from a scientific point of view, but also from a marine engineer's point of view, which is equivalent to saying that it must be simple in construction, strong, requiring but little attention when working, and the least possible labor in cleaning. It would be altogether beyond the possibilities of a paper to deal with all the designs which have been proposed, so the writer will refer only to some of those which have been adopted. Long before marine evaporators were introduced, Messrs. Normandy, Kirkaldy, and others, had been engaged in the manufacture of distillers, but it was the well known engineer, Mr. Weir, of Glasgow, who showed the marine engineering world the advantages which would result by the use of what are now generally known as marine evaporators. Mr. Weir's first apparatus was designed in 1884, but his evaporator in its present form was introduced in 1887, and since that date Mr. Weir's lead has been followed very largely. Evaporators may be divided into the following classes, viz., those in which—

(1.) The heating tubes are connected to steam and exhaust chambers within the evaporating vessel, the means of access to the tubes for cleaning or removal being through hand-holes in the sides of the vessel, as, for example, the early designs of Messrs. Kirkaldy, of London, and Mr. Quiggin, of Liverpool.

(2.) The heating tubes are attached to the door in such a manner that on removal of the door the coils can be brought without the vessel for examination and cleaning, as, for example, the designs by Messrs. Weir, Rayner, Kirkaldy (1894), and Mudd.

(3.) The heating coils are attached to the base or lower vessel containing the steam connections, the coils being covered by a dome which, on being lifted, exposes the coils, as in Morison's dome type.

(4.) The heating coils are attached to steam and exhaust chambers within the vessel, such chambers being arranged to

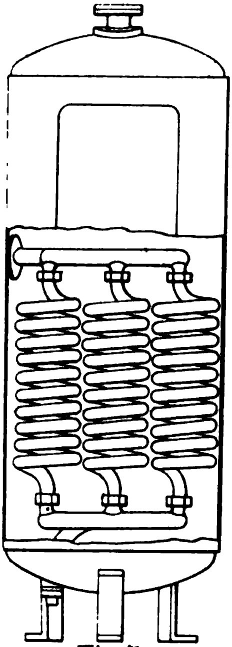


Fig. 3.

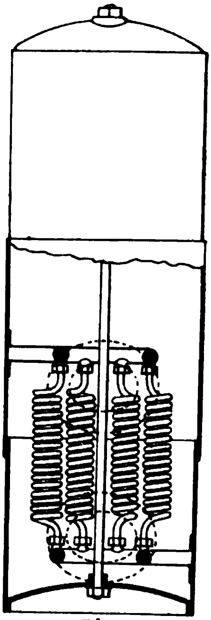


Fig. 4.

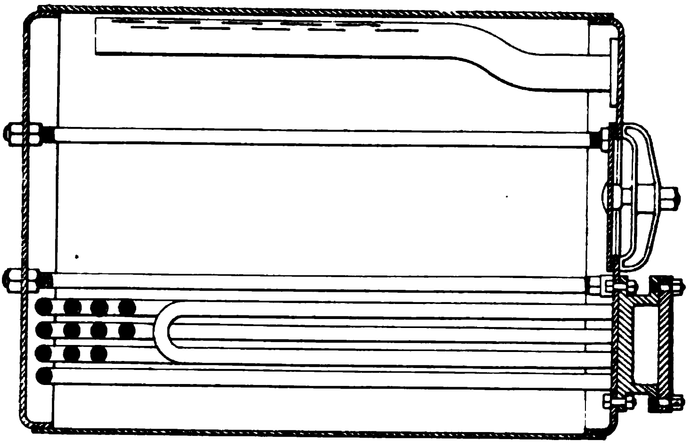


Fig. 5.

terminate in a trunnion, so that each coil can be revolved to a position opposite a door in the side of the vessel through which it can be removed, as in the design by the late Mr. Blair, of Stockton.

(5.) The heating coils are independent of the door, and are arranged on arms terminating in trunnions, so that the entire heating surface can be swung without the vessel into a position for removal or cleaning, as in Morison's radial evaporator.

The early design of Mr. Kirkaldy, the well known maker of feed heaters, distillers, &c., consisted of a vertical cylindrical vessel, Fig. 3, within which were a number of spiral coils connected at their upper and lower ends to brass steam inlet and outlet chambers, access being obtained by two doors, one opposite each chamber. Mr. Quiggin's early design, Fig. 4, is somewhat similar in general arrangement, with special features of detail which have rendered it a very successful apparatus. Mr. Quiggin also manufactures multiple evaporators of very high efficiency, but although multiple effects are used in some large steamships, the system is by no means common.

The well known evaporator of Mr. Weir, Fig. 5, consists of a horizontal cylindrical steel shell with two flanged ends, riveted throughout and fitted with the usual mountings. The heating tubes are of U section and are attached to a tube plate, forming part of a hollow door containing the inlet and outlet chambers. Each tube is flanged at its discharge end, and the diameter of outlet reduced to a minimum in order to maintain the pressure within the tubes and so increase the efficiency of the apparatus. Some very valuable experiments were made with this evaporator by Mr. Lang, who read an interesting paper on the subject before the Institution of Engineers and Shipbuilders of Scotland, in 1889.

Mr. Rayner's design, Fig. 6, consists of a vertical cylindrical vessel; the coils are attached to the door as in Weir's, but are in the form of volutes. Two valves controlling the supply to and from the steam and exhaust chambers in the door are fixed to the body of the evaporating vessel, and connections are made by co-incident ports in the flanges of the door and the vessel, so that when the door is jointed in position these form a continuous passage. The arrangement is very convenient and does not necessitate the removal of any mountings when withdrawing the tubes. The door and attached tubes are withdrawn from the vessel by a simple overhead runner, the whole forming a very compact apparatus. Mr. Kirkaldy's latest design is very similar in general detail, the coils being in the form of volutes connected to chambers in the door, the volutes being in pairs arranged in vertical planes, and not horizontal as in Rayner's. Another modification is that manufactured by Messrs. Maudslay, as in Fig. 7.

Mr. Mudd has also adopted the same general arrangement, Fig. 8, except that the door is hinged, and U-shaped tubes, in the form of arcs, are struck from the hinge of the door as a center.

Morison's steel dome type evaporator, Fig. 9, is in the form of a vertical cylinder, the lower part or base having attached to it the spiral coils arranged in pairs. The upper portion is in the form of a dome, which on being raised is supported by standards, thus exposing the coils and enabling them to be readily cleaned.

The evaporator designed by the late Mr. Blair, Fig. 10, is in the form of a vertical cylinder with a door in the side. The coils are spiral and mounted on a trunnion base, so that each coil can be revolved opposite the door for examination or cleaning. Morison's radial evaporator, Fig. 11, comprises a lower horizontally arranged water vessel, provided with a vertical cylindrical extension forming a steam dome. The lower part of the vessel is fitted with a door which is swung by a pivoted arm to which it is attached into such a position as will enable the coils to be withdrawn. The heating coils are arranged in pairs, and are detachably connected to two horizontal tubes, forming respectively the inlet for steam and the outlet for the resulting water of condensation. Each of these tubes is closed at its free end, and terminates at its other end in a cap mounted on a hollow plug, so that the tubes and the attached coils can be readily turned on the hollow plugs as a center, and so withdrawn from the vessel for cleaning purposes, and afterwards swung back again, these operations being affected without breaking any steam connections.

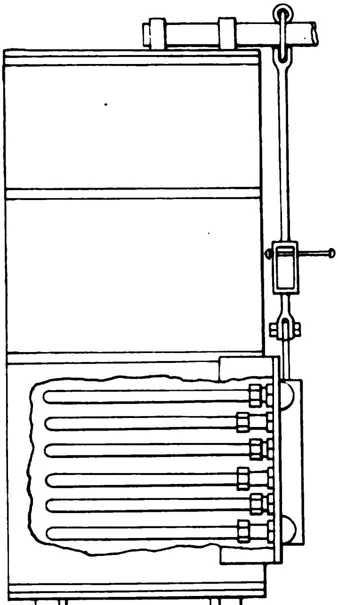


Fig. 6.

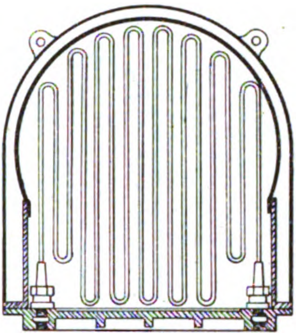


Fig. 7.

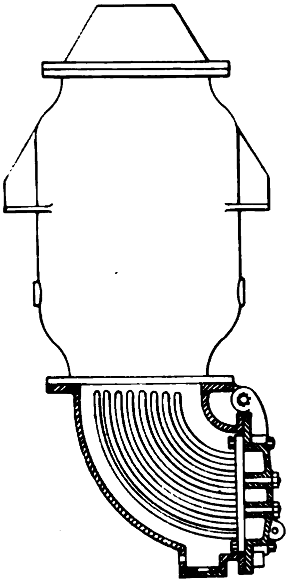


Fig. 8.

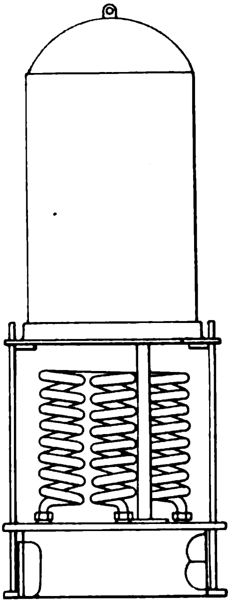


Fig. 9.

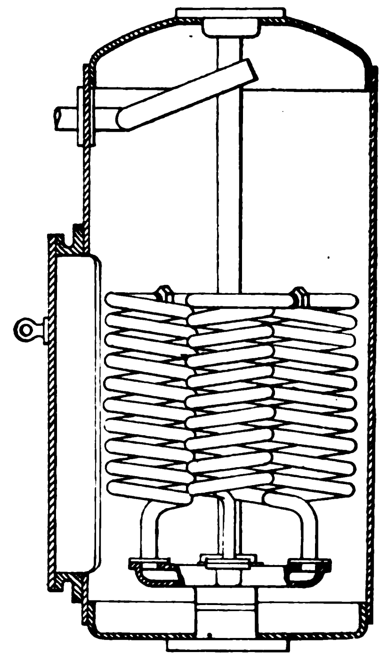
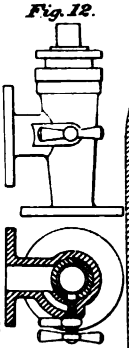


Fig. 10.

Fig. 12.



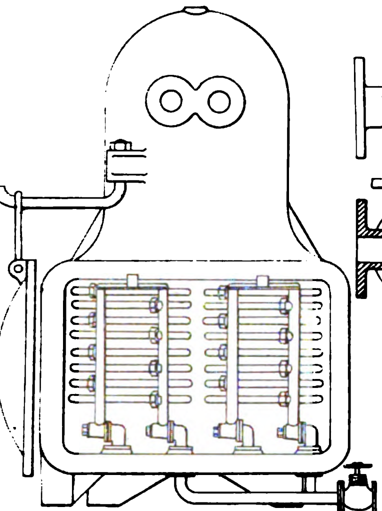


Fig. 11.

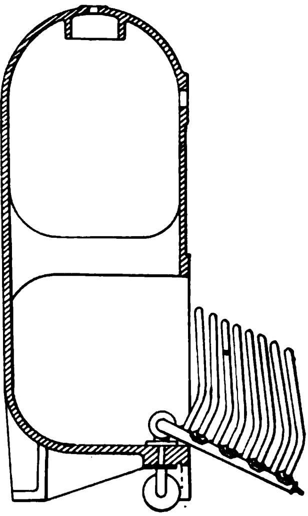


Fig. 11a.

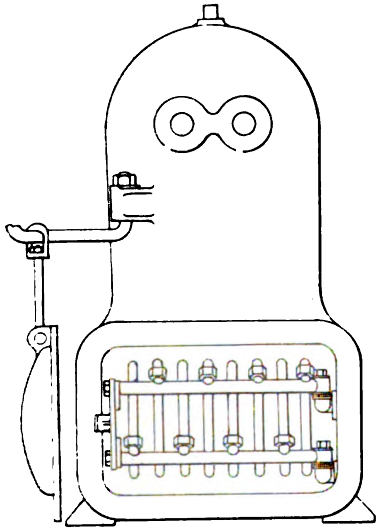


Fig. 11 b.

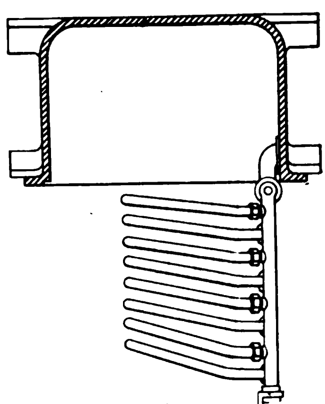


Fig. 11c.

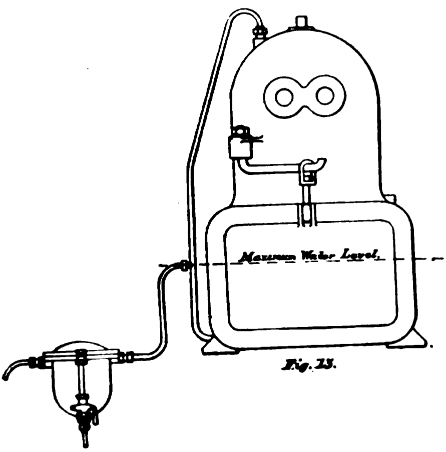


Fig. 15.

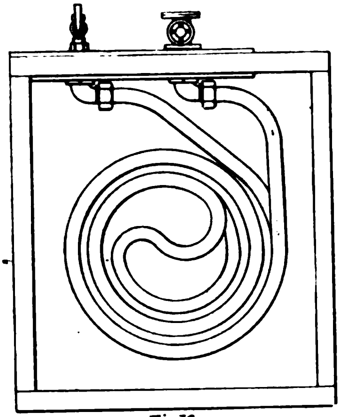


Fig. 16.

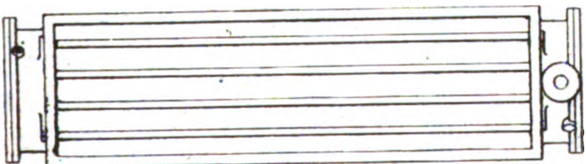


Fig. 17.

Should it be desired to replace a dirty set of tubes with a clean set, two nuts are removed from the plugs, and the inlet and outlet tubes with all the attached coils are lifted off, and the spare set lifted on. There are no flat-sided steam chests or jointed tube plates in this arrangement, all the parts subjected to boiler pressure being tubular, of brass and copper. Testing is also an easy operation, as by opening the steam valve and closing the drain the entire heating surface can be examined, and all the joints being in front are easily accessible for adjustment. In evaporators of large size the heating surface is divided into two sets, each set being independently mounted on the steam hinges or trunnions; the object of the arrangement being that each set of coils can be lifted by one man without the aid of any mechanical appliance.

In all the foregoing evaporators the contained water is simply boiled, but in the Yaryan apparatus the water is delivered in a fine spray through a series of tubes in direct connection with the condenser, and the resulting brine falling into a receiver is withdrawn by a special pump. An evaporator being simply a boiler, the mountings are very similar. Fig. 12, shows a special bye-pass drain cock which admits of continuous brining by an independent adjustment, which is not affected by the complete periodical blowing of the entire contents. Some makers allow the sea water to enter by gravity through a controlling float tank at the inlet, whilst others use a feed pump driven by the air pump-lever. The writer favors the latter plan, as it renders the position of the evaporator in the ship independent of the sea level which, in shallow boats especially, is a distinct advantage. An evaporator naturally requires a little supervision, and is consequently usually placed in a position on the lower platform, readily accessible by the engineers. In the event of it being placed in some out-of-the-way position, and with a view of controlling the level from the starting platform, the arrangement shown in Fig. 13 may be adopted. This regulating device comprises a pipe connected at its lower end with the lower part of the evaporating vessel, where the brine is densest, and, at its upper end, with the steam space; at the desired water level, a branch pipe is taken to a float tank which may be situated at any distance from and below the evaporator.

In these times of severe competition, when every detail on shipboard is viewed from a commercial standpoint, the probable cost of obtaining fresh water by means of an evaporator is a most important consideration. There are several arrangements available; as steam may be taken from the boiler direct, or from the receiver after having done work in the engine, and the steam generated in the evaporator may either be led to the condenser or to the hot well. In order to compare the relative economy of these methods, loss by radiation may be neglected as it is practically a constant quantity; also, for the sake of simplicity, the usual tables on the properties of steam may be taken as applicable to the general conditions.

STEAM SUPPLIED TO THE EVAPORATOR FROM BOILER, AND STEAM GENERATED IN EVAPORATOR DISCHARGED TO HOT WELL.

In considering the method by which steam is supplied to the evaporator direct from the boiler, and the steam generated in the evaporator is condensed amongst the feed water in the hot well or its equivalent, let it be assumed that the pressure in the evaporator is one pound per square inch and that the water fed to the evaporator is taking from the circulating pump discharge at a temperature of 80° F. Experience has shown that evaporators at sea should be worked at a density of from $\frac{3}{32}$ to $\frac{4}{32}$, but for purposes of calculation let us assume $\frac{3}{32}$, and in order to maintain that density in the evaporator one-third of the total amount of water fed to the evaporator must be discharged into the bilge or overboard, consequently to produce one pound of pure steam $1\frac{1}{2}$ pounds of sea water must be supplied to the evaporator, of which 1 pound is evaporated in steam and $\frac{1}{2}$ pound is discharged as hot brine; therefore the total heat required to make 1 pound of pure steam is the sum of the heat in the steam and that in the discharged brine.

The temperature of steam at 16 pounds abs. = 216.3° F.

The heat in 1 pound of steam at a temperature of 216.3 from water at 80° F............... 1099.4 T.U.

The heat in $\frac{1}{2}$ pound of brine at a temperature of 216.3 from water at 80° F. ....68.1 T.U.

Therefore the total heat required to produce 1 pound of pure steam .... $1099.4 + 68.1 = 1167.5$ T.U.

As the generated steam is passed direct to the hot well and is entirely condensed amongst the feed water it gives up the whole of its heat, so the net cost of producing 1 pound of steam is $(1167.5 - 1099.4) = 68.1$ T.U., or, in other words, the actual expenditure of heat is that due to brining.

STEAM FROM BOILERS, GENERATED STEAM TO HOT WELL.

Received by evaporator.	Thermal units.	Discharged by evaporator.	Thermal units.
Heat required to produce one pound of steam at a temperature of 216.3 above 80	1,167.5	Heat given up to hot well. Balance in brine................	1,099 4 68 1
Total........................	1,167.5	Total........................	1,167.5

The heat value of 1 pound of good coal may be taken at 14,500 T.U., and by assuming the boiler efficiency to be 66.7 per cent., which was the average result obtained on the trials of the Research Committee of the Institute of Mechanical Engineers, we have $\frac{14,500 \times .666}{966.6} = 10$ pounds of water evaporated from and at 212° F. per pound of coal, so that 9,666 T.U. will be obtained from the combustion of 1 pound of coal, and the amount of pure steam generated by 1 pound of coal with this arrangement will be $\frac{9,666}{68.1} = 141.9$ pounds, or the amount of coal required to make 1 ton of pure steam $\frac{2,240}{141.9} = 15.7$ pounds.

STEAM SUPPLIED TO EVAPORATOR FROM BOILER, AND STEAM GENERATED IN EVAPORATOR DISCHARGED TO THE RECEIVER OF THE LOW PRESSURE ENGINE.

In this case the generated steam from the evaporator is discharged into the low pressure casing and does work upon the low pressure piston before it is condensed. Again availing ourselves of the data contained in the report of the committee already referred to, we find that in economical triple expansion engines about 17 per cent. of the total heat in the steam is converted into work; for the sake of simplicity, however, consider the efficiency as 18 per cent., and assuming that the power developed in each cylinder is equal, one third of this, or 6 per cent. of the total heat is utilized in each cylinder; it therefore follows that 82 per cent. of the heat is rejected, that the amount of heat entering the low pressure casing is 88 per cent. of the total supplied to the engine, and, of the total heat supplied to the low pressure cylinder, $\frac{6 \times 100}{88} = 6.82$ per cent. is converted.

Let the pressure in the low pressure casing be 7 pounds per square inch and the temperature of the evaporator feed be 80° F., as in the previous case.

Temperature of steam at 22 pounds abs. = 233.1° F.

Heat in 1 pound of steam at a temperature of 233.1° F. from water at 80° F....... 1,104.5 T.U.

Heat in ½ pound of brine at a temperature of 233.1° F. from water at 80° F......... 76.5 T.U.

Heat required to produce 1 pound of pure steam = (1,104.5 + 76.5) = 1,181 T.U.

The equivalent weight of steam if taken from the boiler at 160 pounds pressure and discharged from the evaporator coils at a pressure of 60 pounds abs. or 292.7° F. would be:—

The temperature of steam at 175 abs. = 370.8° F.

Heat in 1 pound of steam at 370.8 above 292.5 = 933.7 T.U..

To produce 1 pound of steam in the evaporator $\frac{1,181}{933.7} = 1.26$ pounds must be taken from the boiler.

Assuming that this steam had passed through the engine in the ordinary manner, and taking the temperature of the hot well at 120° F., the heat in 1 pound of steam at 370.8° F. above 120° F. = 1,106 T.U., so that if instead of being taken to the evaporator it had passed through the engine in the ordinary manner, the amount converted into work would have been 1,106 × 1.26 × .18 = 251 T.U., and of the heat passed from the evaporator to the low pressure, 1,104.5 × .0682 = 75.3 are converted into work, or $\frac{75.3 \times .100}{251} = 30$ per cent. of the total useful heat had it passed through the whole engine; therefore the available useful heat given off by the evaporator is $1,104.5 \times .30 = 331.3$ T.U. To this must be added the heat which is contained in the drain from the coils and which is led to the hot well, viz., $(292.7 - 120) \times 1.26 = 217.6$ T.U.

STEAM FROM BOILERS, GENERATED STEAM TO LOW PRESSURE CASING.

Received by evaporator.	Thermal units.	Discharged by evaporator.	Thermal units.
Heat in 1.26 pound of steam at a temperature of 370 8° F. above 120° F., 1,106.4 × 1.26	1,394	Equivalent value of heat utilized in low-pressure cylinder	331.3
		Heat carried forward to the hot well from coils	217 6
		Balance unaccounted for	845.1
Total	1,394	Total	1,394

The net cost of producing 1 pound of pure steam is, therefore, the balance as above, and the amount of pure steam generated per pound of coal $= \frac{9,666}{845.1} = 11.43$ pounds; consequently the amount of coal required to produce 1 ton of fresh water $= \frac{2,240}{11.43}$ $= 196$ pounds.

STEAM SUPPLIED TO EVAPORATOR FROM INTERMEDIATE PRESSURE RECEIVER AND STEAM GENERATED IN EVAPORATOR DISCHARGED TO HOT WELL.

In this arrangement, steam is taken from the intermediate pressure casing (after having done work in the high pressure cylinder) and employed in the evaporator to produce steam at a pressure of 1 pound above the atmosphere, the evaporator steam being taken direct to the hot well and there condensed amongst the feed water. Let the data in this case be as follows:—steam in the intermediate pressure casing at 50 pounds pressure, temperature of evaporator feed 80° F., and temperature of the hot well 120° F. The heat required to produce 1 pound of pure steam will be the same as in the first example, viz., 1,167.5 T.U. Let the temperature of the discharge from the coils be that due to a pressure of 15 pounds per square inch or (say) 30 pounds abs. = 250.4° F. Temperature of steam at 65 pounds abs. = 298° F.

Heat in 1 pound of steam at a temperature of 298° F. above water at 250.4° F. = 953.9 T.U.

Therefore, to produce 1 pound of pure steam in the evaporator $\frac{1,167.5}{953.9} = 1.22$ pounds of steam must be taken from the intermediate pressure casing. This, on the basis explained in the second arrangement, is equivalent to $1.22 \times \frac{100}{94} = 1.3$ pounds of boiler steam, the total heat per pound of water at 120° F. being 1,106.4 T.U. If, therefore, the heat contained in 1.3 pounds of steam had passed through all the cylinders, 18 per cent. would have been converted into work, 6 per cent. or one-third of the effective heat being utilized in the high pressure cylinder; the equivalent of the total heat is therefore $1,106.4 \times 1.3 \times \frac{1}{3} =$ 479.4 T.U., which represents available useful heat discharged from the evaporator.

There is also the heat in the condensed steam from the coil or $(250.4 - 120)\ 1.22 = 159$ T.U.; and lastly, the steam formed in the evaporator being taken to the hot well and there condensed, it gives up the whole of its heat above 120° = 1,059.4 T.U.

STEAM FROM INTERMEDIATE PRESSURE CASING, GENERATED STEAM TO HOT WELL.

Received by evaporator.	Thermal units.	Discharged by evaporator.	Thermal units.
Heat in 1.3 pounds of steam at a temperature of 370 8° F. above 120° F., 1,106.4 × 1.3	1,438.3	Equivalent value of heat utilized in high pressure cylinder	479.4
Surplus heat after allowing for heat in the brine	259.5	Heat carried forward to hot well from coils	159
		Heat given up by generated steam to hot well	1,059.4
Total	1,697.8	Total	1,697.8

From the above statement it will be seen that there is a reserve of 259.5 T.U. beyond the expenditure of heat in brining. Expressing this in coal, as before, the equivalent is 1 pound of coal for the evaporation of $\frac{9,666}{259.5} = 37.2$ pounds of pure steam; therefore, in producing 1 ton of fresh water, by employing an evaporator in this manner, there is a reserve balance in favor of the evaporator equal to $\frac{2,240}{37.2} = 60.2$ pounds of coal. This theoretical result is based on perfect adiabaticity, and is greater than that which would be obtained in practice, as a large amount of heat naturally disappears by initial condensation.

STEAM SUPPLIED TO EVAPORATOR FROM BOILER, AND STEAM GENERATED IN EVAPORATOR DISCHARGED TO CONDENSER.

In this arrangement it is customary to place a vapor or reducing valve between the evaporator and the condenser; the evaporation will therefore take place at about atmospheric pressure, the feed being at 80° F., as before.

Temperature of steam at atmospheric pressure 212° F.

Heat of 1 pound of steam at 212° F. above water at 80° F. = 1,098.1 T.U.

Heat in ½ pound of brine at 212° F. above water at 80° F. = 66 T.U.

Heat required to produce 1 pound of pure steam 1,098.1 + 66 = 1,164.1 T.U.

As the steam generated in the evaporator is taken to the condenser and there condensed, it forms 1 pound of pure water at the hot well temperature of 120° F., the total heat above 120° F. carried away in the circulating pump discharge at 80° F. being 1,058.1; or 1,098.1 — 1,058.1 = 40 T.U., which represents the amount of useful heat sent to the hot well.

STEAM FROM BOILER GENERATED STEAM TO HOT WELL.

Received by evaporator.	Thermal units.	Discharged by evaporator.	Thermal units.
Heat required to produce 1 pound of steam at a temperature of 212° F. above 80° F.	1,164.1	Heat given up by 1 pound of steam in condenser...	40.
		Balance of heat lost in circulating water............	1,124.1
Total	1,164.1	Total..................	1,164.1

The net cost of producing 1 pound of steam is, therefore, 1,124.1 T.U., whilst the combustion of 1 pound of coal would produce $\frac{9,666}{1,124.1} = 8.6$ pounds, and 1 ton of fresh water would require $\frac{2,240}{8.6} = 260$ pounds of coal.

These investigations show that water may be obtained from an evaporator for a nominal expenditure of coal, or very wastefully, depending entirely on the arrangements adopted. The steam supply from the intermediate pressure casing is more economical from a heat expenditure point of view than a direct connection to the boiler, but there are practical considerations in favor of the latter which will be referred to later. With reference to the steam generated in the evaporator, there is no doubt whatever that discharging direct to the condenser, although a cheap method as regards the cost of fitting up the apparatus on board, is distinctly the most uneconomical which could be adopted, and although a connection to the condenser is sometimes convenient in port, yet at sea it should never be used, as it is simply equivalent to wilfully throwing coals overboard. There is in the hot well a medium, viz., the feed water, which will readily absorb all the heat contained in the steam generated by the evaporator, and in such a manner that none of the heat so absorbed is wasted; consequently, to adopt any other method is sacrificing possible economy.

The condensing of the steam amongst the feed water naturally raises the temperature of the latter, but not to such a point as will influence the working of the feed pumps unless the design is very faulty. If any difficulty occurs, a remedy is often found by making a connection by a ⅜-inch pipe between the top of the feed pump barrel and the condenser. In order to overcome certain objections to evaporating direct into the hot well, the writer has adopted an independent vessel, Fig. 19, which has given good results in practice. The vessel contains two chambers, one of which forms a receiver or well for the feed water on its passage from the hot well to the pumps. Projecting into this well is a nozzle with radial openings through which the steam from the evaporator flows, and by giving the water a centrifugal motion is rapidly condensed; any freed air escapes by an exit pipe, and the heated water overflowing from the receiver is drawn through the suction valve of the feed pump in the usual manner.

The effect of an accumulation of scale in boilers does not come within the scope of this paper, but, considered briefly, the results are:

(1.) Decreased efficiency of the heating surface, causing an unnecessary expenditure of fuel.

(2.) Increased temperatures of the materials forming the heating surfaces, causing collapse or deformation of furnaces and leakage of tubes and joints.

(3.) Increased wear and tear of boilers.

(4.) Excessive boiler cleaning expenses.

The rapid increase in the temperature of the furnace plates, when covered with but a slight coating of scale (especially when it contains oil) is not always fully appreciated until accidents happen, and for this reason a feed water filter is a valuable adjunct to an evaporator. Some very interesting investigations on boiler deposits have been made by Mr. Isaac, the consulting engineer for the Eastern Telegraph Company, who has given the subject careful study on account of the nature of the work of cable laying necessitating boilers being kept under steam for long periods. In one boat, after 110 days steaming, the boiler on being opened out was found perfectly clean and only required the light powder with which the surfaces were covered brushing down and washing out. In another boat, after 103 days steaming, a similar result was obtained. Each boat was fitted with an evaporator and an Edmiston filter, the boilers, of 160 pounds pressure, being worked under Howden's forced draft, and in both cases zinc and soda were used. If boilers were treated in this manner, maximum efficiency would be maintained, the expenditure of fuel, the cost of boiler up-keep and the expenses in scaling and cleaning being reduced to a minimum. An example recently came under the writer's notice, in which a boat brought all her furnaces down, yet the thickness of scale on the heating surfaces was by no means excessive. Subsequent analysis of the deposit gave the following extraordinary result:

Gritty matter and sand	2.69	per cent.
Oxide of copper	1.07	"
" zinc	3.42	"
" iron	24.21	"
" magnesium	16.52	"
" calcium	2 02	"
Oily matter of acid character, combined with oxides of copper, zinc, iron and magnesium	32.02	"
Oil in its natural state, but mechanically mixed through the deposit,	17.98	"
Total	99.93	per cent.

This remarkable deposit contains, therefore, 50 per cent. of oil. The oil on being examined was found to have a vaporizing point of 305 degrees F., and was, therefore, altogether unsuitable for the internal lubrication of high pressure engines.

The efficiency of the heating surface in an evaporator depends chiefly on the steam pressure within the tubes and the thickness of scale on the tubes. With a view of ascertaining the effect of scale, the following experiments were made. Fig. 14 is a vessel open at the top, within which are fitted ordinary condenser tubes terminating at each end in chambers for the inlet steam and outlet water of condensation, the latter being conveyed to a drainer so that full pressure could be maintained within the tubes. Dry steam was supplied to the tubes at a pressure of 45 pounds per square inch, the water to be evaporated taken from the sea, and a density maintained of about $\frac{3}{32}$ to $\frac{4}{32}$ by continuous brining. As the intention was to ascertain the decrease in efficiency due to the formation of scale on a clean tube, every precaution was taken to maintain constant conditions in order that no scale might be cracked off by any variation in temperature.

The trial lasted 48 hours, all water being carefully measured and every provision made for obtaining accuracy. Fig. 15 gives the results; from which it is seen that the evaporation during the first hour was 32 gallons, falling rapidly to 8½ for the twelfth hour, and continuing to decline gradually to 4 gallons for the forty-eighth hour. The initial drop being very rapid, it was suggested that water in suspension passed off with the steam; half the tubes were then taken out and the experiment repeated with

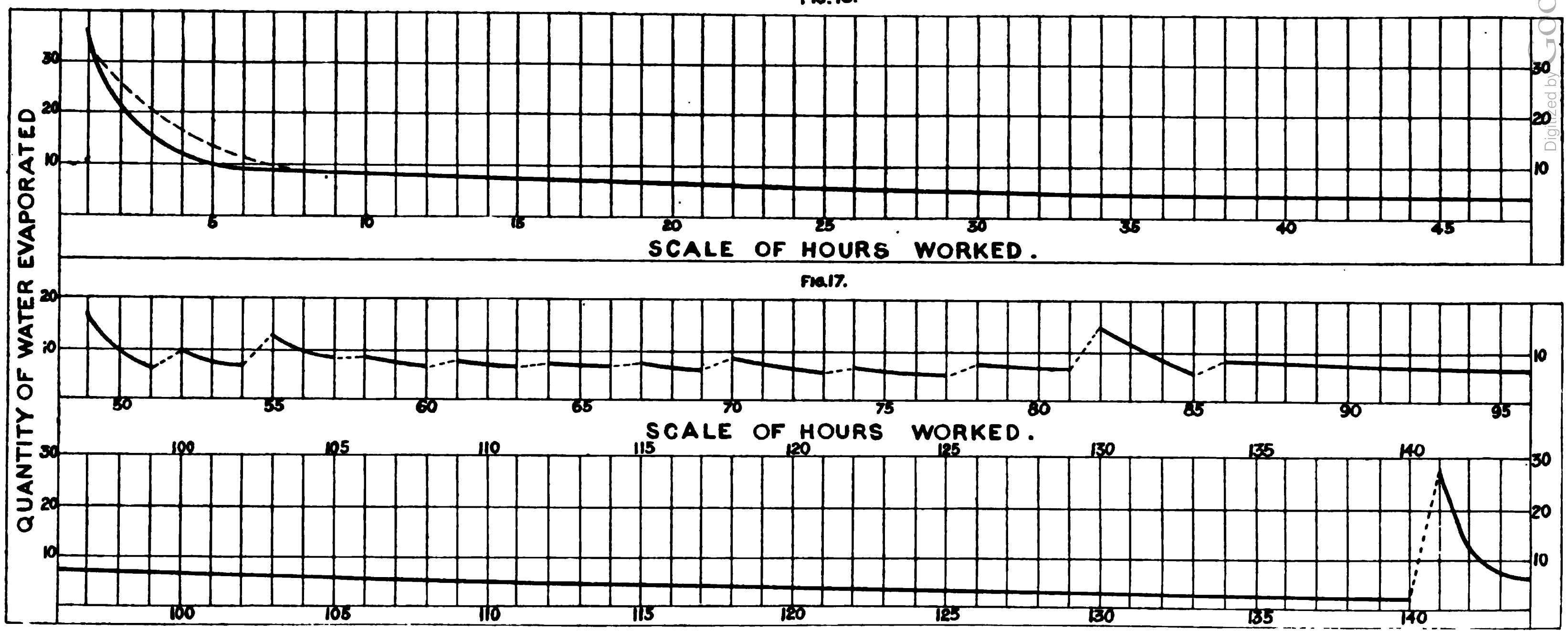

QUANTITY OF WATER EVAPORATED
30
20
10
5
10
15
20
25
30
35
40
45
SCALE OF HOURS WORKED.
20
10
50
55
60
65
70
75
80
85
90
95
SCALE OF HOURS WORKED.
100
105
110
115
120
125
130
135
140
30
20
10

Fig. 15.

Fig. 17.

practically identical comparative results. At the end of the trial, the scale was about $\frac{1}{32}$ inch thick.

Fig. 16 illustrates another vessel, in which the heating surface is in the form of volute coils and with which the same experiment was made with exactly similiar results. The pressure within the coils and the temperature of the water outside being kept constant, there was no tendency for the scale to crack off, and at the end of the trial the coils were covered uniformly with scale $\frac{1}{32}$ inch thick.

It will be noticed that the curves are different on Fig. 15 for the first few hours in the two experiments, this being due to the fact that the first vessel had a larger amount of contained water than the second, therefore the density of the latter rose more rapidly and scale formed more quickly. At the end of the forty-eighth hour steam was shut off, and after the water became cold it was drained away. Sea water was then admitted, and on steam being turned full on a large amount of scale could be seen to crack off and fall to the bottom of the vessel. The effect of this is clearly shown on the diagram, Fig. 17, as, although the evaporation had fallen to four gallons during the forty-eighth hour, yet, after the coils had been subjected to this treatment, the evaporation rose at once to 17.

After three hours working the water was again drained away, sea water admitted, steam turned on and scale thereby cracked off, this process being repeated at intervals until the eighty-first hour, with the result that, although the evaporation had fallen to four gallons during the forty-eighth hour of the continuous trial, yet, after a further thirty-three hours of intermittent working, it had risen to six, which corresponds to the evaporation at the twentieth hour of the continuous trial. At the end of the eighty-first hour the evaporator was blown down, cold water admitted, steam turned on for a few minutes, and then the whole of the water was drained off a second time. The result of this is seen at once in the diagram, Fig. 17, where it will be noticed the evaporation for the eighty-second hour has risen to 15½ gallons.

At the end of the eighty-fifth hour a continuous trial of fifty-five hours duration was made *without* brining in any way, and at the end of that time, that is, for the one-hundred and fortieth hour, the evaporation had fallen to two gallons. On opening the evaporator it was found that a large quantity of salt had been deposited, and that underneath the salt crystals the coils were coated with scale $\frac{1}{16}$ inch thick.

The above method of filling with cold water, admitting steam and draining off, was repeated, and a large portion of the scale cracked off, after which the apparatus was closed up and the experiment continued for a further four hours, with the result that during the first hour the evaporation was 29 gallons, falling to 7 for the fourth hour. The total time therefore, that this trial lasted was 144 hours, and during the whole of this time the coils were not scaled by any mechanical means, the process of blowing down periodically being the only method adopted of maintaining the efficiency of the apparatus.

How long the efficiency could be maintained with this method of working the experiments do not show, but the natural inference is that the decrease in efficiency would be slow, especially if a greater pressure of steam was available; ultimately, however, it would be necessary to scale the tubes by mechanical means. It is for this reason that the writer advocates connecting an evaporator direct to the boiler, as not only is the maximum pressure of benefit if the coils are allowed to become heavily coated with scale, but there is also the advantage of the greater expansion and movement of the coils due to the sudden application of the full pressure, thereby materially increasing the tendency for the scale to crack off.

A double connection to the boiler and intermediate pressure casing is of course the more complete arrangement, as the economy due to the use of receiver steam may be obtained when the evaporator is of ample size, and in fair working condition; whilst if the coils are dirty, or an extra amount of water is required, boiler steam is available.

Repeated instances have come under the writer's notice of where the coils have been encased in a solid block of salt or covered with a scale of exceptional hardness. Both these results are due to the careless working and insufficient attention to brining. It is necessary for success that the density should be maintained from $\frac{3}{32}$ to $\frac{4}{32}$, as if allowed to become too dense, salt will be rapidly deposited on the coils, whilst if the density is kept too low by excessive brining, not only is there a large amount of heat in the discharged water, but the scale formed on the tubes is very hard and difficult to remove. On account of the density of the water and the low pressure of evaporation, there is sometimes a slight tendency to prime, and for this reason a portion of the heating surface is usually kept above the water level in order to break up the bubbles and so prevent water, in the form of spray, passing off with the steam.

A connection to the condenser is very convenient after blowing down, as the vacuum enables the evaporator to be filled from the sea more rapidly when this is being done. Care should be taken to fully immerse the whole of the tubes before turning on steam, the excess water being drained away as soon as the cracking off process is completed. The detached scale should also be cleaned out frequently, as when present in suspension it increases the tendency to prime.

Evaporators are sometimes used as condensers for winches when in port, and certainly seem well adapted for the purpose. The cooling surface required is usually in excess of what is necessary for evaporating purposes, consequently an increased size of evaporator has to be fitted. In order to minimize this increase in size, the writer has designed a combined apparatus, as in Fig. 18, the feature of which is the utilization of the steam space of an evaporator for the reception of a set of condensing coils, such set being a duplicate of the set of evaporating coils in the lower part of the vessel for which they are available when required. In the illustration the coils are divided into three similar sets. When evaporating, two sets are in use and one set available as spare; when condensing, this spare set is fixed in the steam space so that the available surface when used as a condenser is 33 per cent. greater than the surface when used as an evaporator. This extra surface in the steam space is also of value when it is desired to work the evaporator at its maximum, as it vaporizes any water which may be in the steam due to violent ebullition, and would, therefore, be well adapted for warships or torpedo boats where reduction of weight is a great desideratum. On passenger and better class boats, winch condensers or exhaust tanks are a necessity, in order to overcome the delay and inconvenience caused by the escaping steam; but it is the donkey boilers which reap the great benefit, as, in cargo boats especially, they never have a large margin in size, and being fed direct from the sea, thereby causing an ever increasing accumulation of scale, they constitute not the least of the worries on board a steamship. The question of first cost has been the obstacle, however; but now that evaporators are an established necessity, it seems but a natural development that they should, with a little extra outlay, be rendered available for condensing purposes, and so materially add to the general efficiency. The writer had hoped to include the results of experiments with this apparatus, but as they are incomplete he will have pleasure in communicating them to the Institution at a later date.

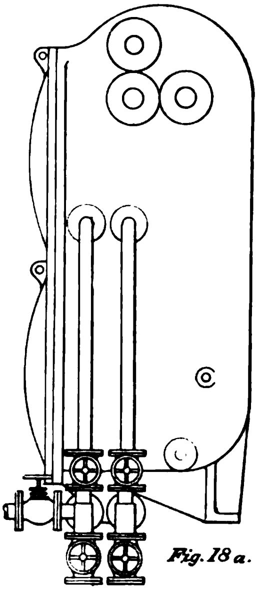


Fig. 18 a.

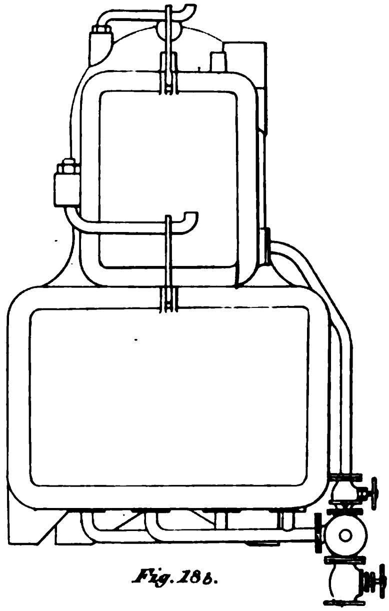


Fig. 18 b.

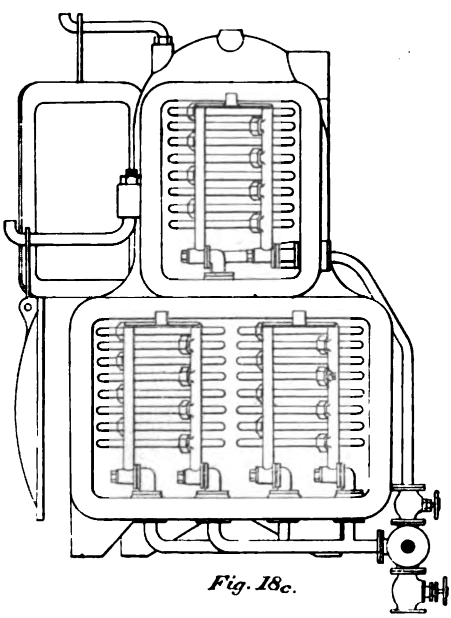


Fig. 18c.

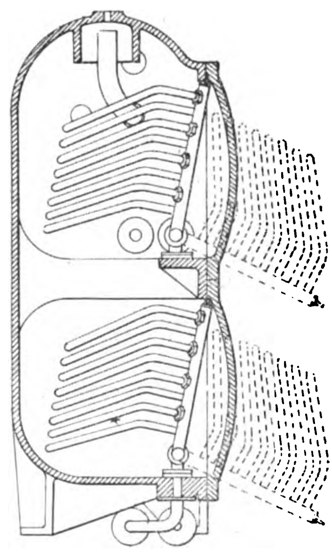


Fig. 18d.

CURVES SHOWING THE RELATION BETWEEN EQUIVALENT HOLLOW AND SOLID SHAFTS.

BY PROFESSOR W. F. DURAND, CORNELL UNIVERSITY.

The general advantages of hollow, as compared with solid shafts may be considered as two in number.

(1.) The greater assurance of soundness and reliability of metal arising from the possibility of inspection on both its inner and outer surfaces, coupled with the removal of the inner core as the part most likely to contain flaws and imperfections.

(2.) The saving of weight for equal strength.

Equivalent shafts are assumed as those which will carry equal turning or bending moments with equal outer fiber stresses.

By the well known methods of mechanics, we have for the general value of the moment of the internal stresses developed by an external torsional moment,

$$M = \frac{\pi k (r_1^4 - r_0^4)}{2r_1}.$$

Where r_1 = outer radius,
and r_0 = radius of hole.

If $r_0 = 0$, and $r_1 = a$, we have for the solid shaft:

$$M = \frac{\pi k a^3}{2}.$$

Hence, equating, we have as the relation between a hollow shaft and the equivalent solid shaft:

$$r_1^4 - r_0^4 = r_1 a^3. \qquad (1)$$

By means of this equation we may deduce a graphical representation of the relation between the internal and external radii of a hollow shaft and the radius of the equivalent solid shaft. Empirical formulæ, or formulæ with empirical constants, are usually arranged for solid shafts, so that in any practical problem we may usually find first the solid shaft which will fulfil the conditions imposed. This representation will then give a wide series of hollow shafts which shall be its equivalent.

In making the necessary computation for the plotting of the curves, it is found preferable to assume for a fixed value of r_1, a regular series of values of a, and thence to derive the resultant values of r_0. These operations being repeated for the range of radii to be included, the values are plotted as shown in the lower part of the diagram, and smooth curves are drawn through all points which, for each curve, give characteristics equivalent to one of the series of values of a.

In the diagram as actually plotted, diameters instead of radii are used.

It thus appears that any curve, as 12—12 fixes the outer and inner diameters for a series of shafts equivalent to a solid shaft 12 inches in diameter. Thus for example a shaft $12\frac{1}{2}$ inches outside diameter with a 7-inch hole is equivalent to a 12-inch solid shaft, and similarly for others.

In the matter of relative weight, it will be convenient to relate everything to the solid shaft as the basis of comparison.

The weight of the hollow shaft is proportional to $(r_1^2 - r_0^2)$, while that of the solid shaft is proportional to a^2, where r_1, r_0 and a have the relations determined above in (1). The ratio of the two weights will, therefore, be:

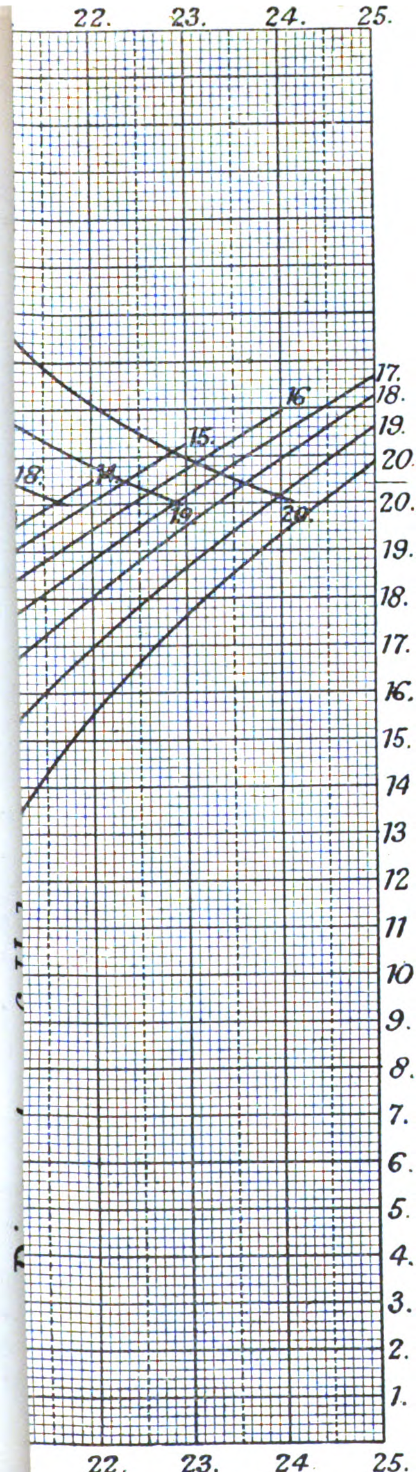
$$y = \frac{r_1^2 - r_0^2}{a^2}. \qquad (2)$$

Eliminating r_0 between (1) and (2), we have:

$$a^4y^2 - 2a^2r_1^2y + r_1a^3 = 0.$$

$$\text{Whence } r_1 = a\left(\frac{1}{4y} + \sqrt{\frac{y}{2} + \frac{1}{16y^2}}\right). \qquad (3)$$

We then give to y a value as .50 and find $r_1 = 1.207\,a$. Hence in the upper part of the figure we take all along the 50 per cent. line points given by 1.207 times the values of a, and similarly for $y = 60$ per cent., etc. After the points are thus laid off, they


22. 23. 24. 25.
17. 18. 19. 20.
16 15. 14. 18. 19. 20.
20. 19. 18. 17. 16. 15. 14 13 12 11 10 9. 8. 7. 6. 5. 4. 3. 2. 1.
22. 23. 24 25.

are so joined as to unite in one curve all relating to the equivalents of the same solid shaft. Thus, the upper curve 12—12 relates simply to the equivalents of a 12-inch solid shaft.

The use of the upper curves is best illustrated by an example.

Taking, as above, the 12½-inch shaft with a 7-inch hole, we pass vertically upward from the corresponding point on the 12-inch curve until we meet the 12-inch curve in the upper series. The corresponding ordinate on the scale of per cent. is 71, showing that a hollow shaft of these dimensions, while the equivalent of the 12-inch solid shaft in strength, will have only 71 per cent. of its weight.

It is readily seen that the relation between hollow and solid shafts is the same for bending as for twisting moment, and that the condition for equivalence will be the same. These curves may, therefore, be used to determine equivalent dimensions relative to either form of stress.

TEST OF WOUND COPPER PIPES.

[Made at the Imperial Dockyard, Wilhelmshaven, Germany, and reported in the "Zeitschrift des Vereines Deutscher Ingenieure" by Chief Engineer Köhn non Jaski.]

TRANSLATED BY WM. WACHSMANN, ESQ., ASSOCIATE.

In the German Navy, steam pipes have always been made of copper, and the thickness calculated so that the stress on the material should not exceed 2,844 pounds per square inch, it being assumed that the thickness is uniform throughout and the material homogeneous. Experience has shown that drawn copper pipes can not be depended upon with certainty, whilst the strength of brazed pipes depends entirely on the quality of the brazing, and consequently on the skill of the coppersmith.

In the careless treatment of pipes in the fire, the material adjacent to the seam to be brazed will be burnt and the strength and ductility considerably reduced. In the German Navy, as elsewhere, experience with brazed pipes has been so bad that their use had to be very much restricted. It is only necessary to recall the pipe explosion on the S. S. *Elbe* of the Royal Mail Co., in 1887, in which it was subsequently proven by test pieces taken from next the brazed seam that the strength of the material had decreased 13 per cent., and tensile specimens taken from near the seam and some distance from it showed a loss in ductility of 70 per cent.

In solid drawn pipes, unsound places are found, in the shape of longitudinal flaws, which are formed during the process of drawing, or are due to impurities in the original ingot; and these defects are only discovered after the pipe has been subjected to a hydrostatic pressure, and generally to a very high one.

To allow for these defects, the thickness of copper pipes for use in the German Navy was formerly determined by the formula

$$t = \frac{pD}{5689} + 0.059,$$

in which

t = thickness in inches,

p = steam pressure in pounds per square inch,

D = inside diameter of pipe in inches,

notwithstanding the fact that, in a pipe designed according to the formula $t = \frac{pD}{5689}$ (the thickness being considered uniform throughout), there was already a factor of safety of 10 with a stress of only 2,844 pounds per square inch on the material.

Isolated cases of copper pipe explosions have, however, given rise to the use of a still higher factor of safety.

As early as 1890, Denny, of Dumbarton, applied bands of round steel to steam pipes, as shown in Fig. 1, in order to increase their strength for very high pressures. They were from 0.236 to 0.314 inch in diameter, and were heated to a red heat before being put on. This practice was brought about by the explosion on the *Elbe*, where nine men were killed, and also by that at the Central Station, Deptford, July 9, 1889. Similar devices were subsequently used by other engine builders, amongst them F. Schichau, of Elbing, in the Austrian torpedo depot ship *Pelican*, and in the new engines and boilers for the Austrian battleship *Tegetthoff*, while the winding of pipes with copper wire was introduced in the English Navy.

In the experiments herein described, the attempt was first made to determine the strength that could be relied upon in drawn copper pipes, after making due allowance for unequal thickness and slight defects in material. For this purpose, pipes provided with flanges were taken from store and tested to destruction by hydrostatic pressure. The results of these tests are given in Table I.

The fractures in tests 1 and 3 occurred in perfectly homogeneous material at *c* and *a* respectively; in test 2, in a small slag place at *c*, and in test 4 in an unsound place at *c*. The fractures were from 3.9 to 12.9 inches long, and 0.27 to 1.18 inches wide. The thickness measured at the lines of rupture should not be compared with that measured at the ends before testing, for, notwithstanding the longitudinal contraction of the pipe owing to the enormous expansion, the thickness was materially reduced. The pipes were presumably ruptured at the thinnest places. The factor of safety in tests 1 and 3 was ample.

The variation in thickness would be fully covered by using the formula,

$$t = \frac{pD}{5689} + 0.059,$$

but only in case there were no unsound places.

How dangerous such defects in material may prove, can be seen in test 4. Here the factor of safety was only about 6, and such pipes would surely burst in case of extraordinary pressures, such as that caused by water hammer, and even at much lower pressure, depending on the size of the unsound place and the thickness of the sound metal remaining.

These tests, as well as explosions which have occurred in practice, emphasize the necessity of increasing the strength of the pipes. Further tests were, therefore, made to determine the efficiency of different kinds of winding.

A pipe of the same dimensions as that used in test 1 was taken and wound with steel wire rope, but in such a way that it alternated with an unwound portion for a distance of 7.87 inches. The data of this test are given in Table II.

A comparison of test 5 with test 1 shows that the safety of a pipe with alternate windings is increased, but that such winding offers no protection against explosion if a defect exists in the material between the windings. From which it follows that only complete windings should be used.

The next thing to determine was the size of the wire rope. The following was adopted as a standard: the stresses due to the steam pressure should be uniformly distributed upon the sides of the pipe and the winding, and a resistance against the winding of at least 2,134 pounds per square inch should be obtained.

FIG. 1.

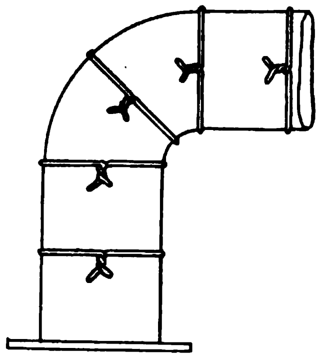


FIG. 2.

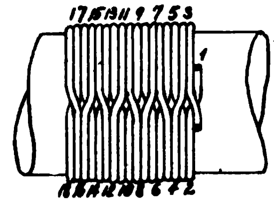


FIG. 3.

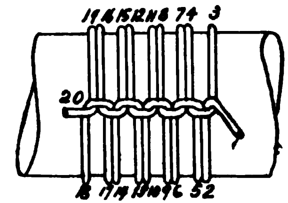


FIG. 4.

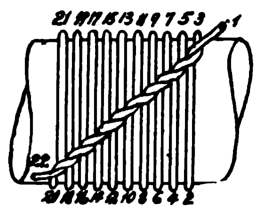


FIG. 5.

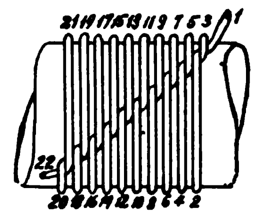
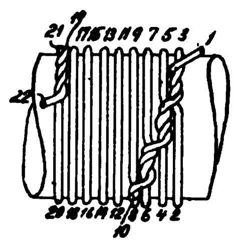


FIG. 6.



In these tests, drawn copper pipes 7.87 and 11.81 inches inside diameter, and 0.295 and 0.413 inch thick respectively, were used. According to the formula $t = \frac{pD}{5689}$, these pipes were suitable for a working pressure of 213 pounds per square inch, and thus a factor of safety of at least 10 was adopted.

The hydrostatic pressure in tests 6 to 11 was only carried far enough to destroy the wire rope used in winding the pipe. The rope was simply coiled around the pipes, which were made to order in Berlin, by C. Heckmann. Twenty test pieces from strips cut from the ends, and in a direction at right angles to the axis, showed an average tensile strength of 31,106 pounds per square inch and an elongation of 25.2 per cent. in a length of 7.87 inches; and after annealing 30,537 pounds tensile strength and 35 per cent. elongation. Cold bending and forge tests gave satisfactory results; so the material of the pipes was of the best quality. The results of these tests, 6 to 11, are given in Table III.

According to the results of test 6, copper wire rope proved too ductile. In spite of the great weight and cost of this kind of winding, the sides of the pipe were not much relieved, and the pipe was much expanded.

Galvanized steel wire rope of 0.1968 inch circumference proved too weak for pipes of 7.87 inches diameter, and steel wire rope of 0.492 inch and 0.7874 inch circumference, used for the 7.87 and the 11.81-inch pipe, was too heavy. The conditions laid down were fulfilled by using galvanized steel wire rope of 0.2952 inch circumference for the 7.87 inch, and 0.3937 inch circumference for the 11.81-inch pipes.

It now remained to determine the best method of winding. Accordingly, the various windings shown in Figs. 2 to 6 were used, and the pipes subjected to a hydrostatic pressure. As a matter of fact, the bights in the different windings were close together, as shown in Fig. 2; in the other figures, they are shown separated in order to make the method of winding clearer. The small figures indicate the direction of winding. Galvanized steel wire rope was used for all windings, except that of test 21, where copper was again used, the reason for which will be explained further on.

After the breaking of the first bight in Fig. 2, the adjacent parts of the same winding were held in place by the other rope, wound in the opposite direction. But as soon as a bight of this second rope broke near the first place, all bights for a distance of 3.9 to 4.7 inches either side of it became loose.

In the winding shown in Fig. 3, the rope was very unfavorably strained, due to the knotting. Though the rope selected was heavier than would have been necessary according to test 10, nevertheless eight adjacent bights broke at a pressure of 1,877 pounds per square inch.

The winding shown in Fig. 4 gave better results. After the breaking of the first bight, the adjacent ones became loose, but after the pipe had expanded a little more, they again became tight.

The winding shown in Fig. 5 acted about the same as that shown in Fig. 4, except that the bights next the place of fracture became looser.

In the winding shown in Fig. 6, the first bight broke at a pressure of 2,418 pounds per square inch, the adjacent bights remaining perfectly tight. After increasing the pressure to 2,560 pounds, other bights broke, but all adjacent ones remained tight. Where the rope broke, the pipe expanded, and a number of other bights broke at a pressure of 1,422 and 1,707 pounds, but all bights which were not broken remained tight around the pipe. In test 17, with the same kind of winding, being a parallel test to 8, the first bight broke at 2,707 pounds. The pressure was then increased to 2,958 pounds, when other bights broke. The behavior of the bights was the same as in the preceding test.

Accordingly, the method of winding shown in Fig. 6 proved to be the most satisfactory, and from its behavior could be designated as thoroughly reliable for use on ship-board.

Tests 18 and 19 were then made with pipes having the same diameter, but less thickness, to determine the influence of these factors on the durability of the winding. As the results show, the expansion of the pipe, with the same internal pressure, was much greater than in the case of pipes of greater thickness, and the steel wire rope broke much sooner. Therefore, to obtain the same safety in case of thinner pipes, the wire rope should be heavier.

As the specimens of pipes tested apparently showed no defects in the material, it remained to determine how a defective copper pipe would behave when wound with wire rope in the most favorable manner and subjected to a high pressure. To obtain this information, a pipe of the same dimensions as that used in test 17 was milled down to about three-fourths its original thickness for a distance of about 7.87 inches, and then wound as in test 17. At a pressure of 2,987 pounds (test 20) the first bight broke at the end farthest from the place where the pipe was weakened. In continuing the test, the pressure fluctuated between 2,133 and 2,347 pounds, while the part where the rope broke expanded and eventually broke at a pressure of 2,347 pounds in perfectly sound material. As the fracture did not take place at the weakest point, the locally decreased thickness had no influence on the strength of the wound pipe. The cause of this favorable result may be looked for in the small amount of yield in the steel wire rope, arresting the expansion of the pipe and thereby preventing the bursting at the weakened place. To verify this assumption, a parallel test, 21, was made with a copper wire rope winding, which had proved to be very yielding in test 6. At a pressure of 1,707 pounds the pipe burst at the weakened place for a distance of about 5 inches without breaking the copper wire rope.

Taking 213 pounds per square inch as the standard internal pressure for the tested pipe, the factor of safety in test 21 would be 8, while in test 20 it was 11, and the gain can only be attributed to the winding with the strong unyielding steel wire, which made the artificially created defect in the material harmless, while the copper wire increased the strength (compare with test 4) but not by any means in the same measure as the steel wire.

As a result of these tests, the following rules were promulgated in the German Navy for the design of copper pipes:

1. The stress in the material of copper pipes must in no case

exceed 2,844 pounds per square inch. In pipes which are wound according to the rules with steel wire rope, the strength due to winding must be eliminated from the calculation. Thickness of such pipes must be at least $t = \frac{pD}{5689}$ inch, and it must never be less than 0.157 inch, so that the flanges can be properly secured. Pipes which are not wound should have a thickness of at least

$$t = \frac{pD}{5689} + 0.059 \text{ inch.}$$

2. Brazed pipes are to be avoided for high pressures, and pipes for such pressures are to be either solid drawn or made of sheet copper with double butt straps and riveted.

3. When drawn pipes of a diameter of 4.72 inches and over are used for steam pressures of 100 pounds and over, they are to be covered with steel wire rope of the following dimensions, and wound in the manner shown in Fig. 6.

Inside diameter of pipe.	Circumference of steel wire rope.
inches.	*inch.*
4.72 to 5.9	0.2952
6.10 to 7.87	0.3937
8.07 to 9.84	0.492
10.03 to 11.81	0.5906
12.00 to 13.77	0.6889
13.97 to 15.74	0.7874

To protect the steel wire rope from corrosion, it must be covered with varnish before being wound around the pipe.

For the sake of completeness, the following rule may be added to which the results of other tests, to be published later, have led.

4. In all main steam pipes of 4.72 inches inside diameter and over, which are to carry a steam pressure of 100 pounds and over, the flanges are to be riveted on, not brazed.

For those who think that the safety required in the foregoing rules is too high, it may be remarked that tests were made at the dockyard in Wilhelmshaven with pipes 5.9 and 12.2 inches diameter, the thickness being respectively 0.19685 and 0.23622 inch. They were partly filled with water so that artificial water hammer might be produced, and steam of 71 pounds pressure admitted, when rupture of the pipe occurred in a similar manner to that which occurs on board ship, and which is usually attributed to water hammer. A pressure as high as 2,133 pounds per square inch was registered on a maximum pressure gauge. These tests were described in the Marine Rundschau, March, 1894.

The increased weight and cost of steam pipes due to winding with galvanized steel wire rope is entirely justifiable, and will have to be accepted until some other mode of manufacture, or other materials which can be used on ship-board, permit such safeguards to be dispensed with.

Tests made at the imperial dockyards with copper pipes made according to the Mannesmann and the Elmore processes have not come up to expectations.

TABLE I.

No. of test.	Inside diameter.	Thickness.	Length before test.	Working pressure according to *	Expansion of pipe. At pressure of	Expansion of pipe. A.	Expansion of pipe. B.	Expansion of pipe. C.	Length after test.	Internal pressure when rupture occurred.	Thickness at point of rupture.	Factor of safety.
	Inches.	*Inches.*	*Inches.*	*Lbs. sq. in.*	*Lbs. sq. in.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Lbs. sq. in.*	*Inches.*	*Pounds.*
1	5.11	.2362	68 3083	196.279	853.39	.1181	.1181	.1574	68.15	2,389	.1574	11.4
					1,706	.2362	.1968	.2362				
					1,920	.3149	.2362	.3149				
					2,176	.5906	.5512	.5512				
					2,389	.8268	.7874	.9848				
2	5.51	.1968	70.15	142.23	853.3	.1181	.1181	.1574	69.05	2,034	.1181	14.3
					1,564.5	.3149	.3543	.3543				
					1,778	.3937	.4331	.5118				
					1,920	.5906	.6299	.7087				
					2,034	.8662	.9843	1.878				
3	9.05	.2756	45.98	136.54	341.3	.0393	.0393	.0393	45.27	1,479	.1771	10.8
					711	.1574	.1574	.1574				
					1,138	.5512	.5512	.5906				
					1,422.3	1.4173	1.338	1.338				
					1,479	2.126	1.732	1.653				
4	9.05	2756	62.67	136.54	341.3	.0787	.0393	.0787	62.56	825	Unsound place.	6.0
					569	.1181	.0787	.1574				
					711	.2362	.1574	.2362				
					825	.2756	.1968	.2756				

* $\delta = \frac{pD}{400} + 1.5$

TABLE II.

No. of test.	Inside diameter.	Thickness.	Length before test.	Working pressure according to*	Expansion of pipe.				Length after test.	Internal pressure when rupture occurred.	Thickness at point of rupture.	Factor of safety.
					At pressure of	 A.	B.	C.				
5	*Inches.* 5 11	*Inches.* .2362	*Inches.* 69.21	*Lbs. sq. in.* 196.27	*Lbs. sq. in.* 1,422.3	*Inches.* .1968	*Inches.* .1968	*Inches.* .1968	*Inches.* 69.09	*Lbs. sq. in.* 2,560.1	*Inches.* .1771	*Pounds.* 13
					1,706.7	.3149	.3149	.3149				
					1,991.2	.5512	.3937	.4724				
					2,275.7	.6299	.5118	.5906				
					2,560.1	.7874	.8268	.7874				

* $t = \frac{pD}{5689} + 0.059$

Fracture at *c* 8.66 inches long and 1.02 inches wide; material, homogeneous.

TABLE III.

Number of test.	Pipes. Inside diameter.	Pipes. Thickness.	Rope work. Material.	Rope work. Circumference.	Rope work. Number of strands.	Rope work. No. of wires per strand.	Rope work. Total number of wires.	Rope work. Thickness of wires.	Rope work. Number of convolutions per foot length of pipe.	Rope work. Weight of wire rope. Per running foot.	Rope work. Weight of wire rope. Per foot of pipe.	Results of tests. Tensile strength of wire rope.	Results of tests. Internal pressure.	Results of tests. Expansion of pipe due to this pressure.	Results of tests. Rope broke at an internal pressure of—	Results of tests. Pressure on the winding.	Results of tests. Pressure on the sides of the pipe.	Weight of pipe per running foot without flanges. Without Winding.	Weight of pipe per running foot without flanges. With Winding.	Increased weight. Due to winding.	Increased cost. Due to winding.
	Inches.	*Inch*		*Inch.*				*Inch*		*Lb.*	*Lbs.*	*Lbs.*	*Lbs. sq. in.*	*Inch.*	*Lbs. per sq. in.*	*Lbs. sq. in.*	*Lbs. sq. in.*	*Lbs.*	*Lbs.*	*Per cent.*	*Per cent.*
6	7.87	.2952	Copper wire rope.	.5236	1	4	4	.0787	67	.0739	11.22	41,250	1,138 2,133 2,276	.03937 3149 .3937	2,560	1,910	650	29.56	40.78	38	34.7
7	7.87	.2952	Galvanized steel wire.	.1968	1	7	7	.0216	155 7	.01008	3.709	34,138	853 1,422 1,849	0 .03937 .0787	1,920	1,849	71	29.56	32.27	12.5	7 4
8	**7.87**	.2952	"	**.2952**	3	3	9	.0196	130.8	.01317	3.870	36,980	1,422 1,707 2,133	.03937 .0787 .1181	**2,276**	1,593	683	29.56	33.43	**13**	**10**
9	7.87	.2952	"	.492	3	7	21	.0248	72 5	.04502	7.391	110,940	1,422 2,560 3,698	.01968 .03937 .07874	......	......	......	29.56	36 95	25	12 4*
10	**11.81**	.4133	"	**.3937**	4	5	20	.0188	94.4	.02183	6.921	62,580	1,422 1,707 2,133	.03937 .07874 .15748	**2,276**	1,294	981	61.82	68.74	**11.2**	**5.5**
11	11.81	.4133	"	.7874	5	4	20	.0413	47.5	.09743	15.6	246,050	1,707 2,133 3,413	.01968 .03937 .11811	......	......	......	61.82	77.40	25	8.7†

* The winding did not break at a pressure of 3,698 pounds.

† As in test 9.

TABLE IV.

No. of test.	Pipes. Inside diameter.	Pipes. Thickness.	Rope work. Manner of winding.*	Rope work. Material.	Rope work. Circumference.	Rope work. No. of strands.	Rope work. No. of wires per strand.	Rope work. Total number of wires.	Rope work. Thickness of wires.	Rope work. No. of convolutions per foot length of pipe	Rope work. Weight of wire rope. Per running foot.	Rope work. Weight of wire rope. Per foot length of pipe.	Results of tests. Tensile strength of wire rope.	Results of tests. Internal pressure.	Results of tests. Expansion of pipe due to this pressure.	Results of tests. Rope broke at an internal pressure of—	Results of tests. Pressure on the winding.	Results of tests. Pressure on the sides of the pipe.	Weight of pipe per running foot without flanges. Without Winding	Weight of pipe per running foot without flanges. With Winding	Increased weight. Due to winding.	Increased cost. Due to winding.
	Ins.	*In.*	*Fig.*		*Inch.*				*Inch.*		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs. sq. in.*	*Inch.*	*Lbs. sq. in.*	*Lbs. sq. in.*	*Lbs. per sq. in.*	*Lbs.*	*Lbs.*	*Per cent.*	*Per cent.*
12	11.81	.4133	2	Steel wire rope.	.3937	4	5	20	.01889	94.4	.02183	22.7	970	1,422 1,707 2,133	.03937 .07874 .15748	2,489	1,294	1,195	61.81	68.73	11.2	5.5
13	11.81	.4133	3	"	.4920	8	7	56	.01377	77.7	.03561	30.42	1675.5	1,422 1,707 1,849	.07874 .1181 .1574	1,877	*	*	61.81	71.08	15.0	6.6
14	11.81	.4133	4	"	.3937	4	5	20	.01889	94.4	.02183	22.7	970	1,422 1,707 2,133	.03937 .07874 .1574	2,560	1,294	1,266	61.81	68.73	11.2	5.5
15	11.81	.4133	5	"	.3937	4	5	20	.01889	94.4	.02183	22.7	970	1,422 1,707 1,991	.03937 .07874 .11811	2,347	1,294	1,053	61.81	68.73	11.2	5.5
16	11.81	4133	6	"	.3937	4	5	20	01889	94.4	.02183	22.7	970†	1,280 1,707 2,418	.03937 .07874 .15748	2,418	1,294	1,266	61.81	68.73	11.2	5.5
17	7.87	.2952	6	"	.2952	3	3	9	.01968	131	.01316	12.69	573‡	853 2,133 2,845	.03937 .07874 .15748	2,702	1,593	1,365	29.56	33.43	13	10
18	11.81	.2952	6	"	.3937	4	5	20	.01889	94.4	.02183	22.26	970	853 1,422 1,849	.03937 .11811 .23622	1,849	1,294	555	43.67	50.46	15.5 ‖	7.4
19	7.87	.1968	6	"	.2952	3	3	9	.01968	131	.01316	12.34	573	1,280 1,707 1,920	.03937 .07874 .11811	1,991	1,593	398	19.28	23.04	19.5 ‖	14
20	7.87	.2952 §	6	"	.3937	4	5	20	.01889	94.4	.02183	15.43	970	853 1,422 2,560	.01968 .03937 .1181	2,987	1,934	1,053	29.56	34.26	16	10.7
21	7.87	.2952 §	6	Copper wire rope.	.5236	1	4	4	.07874	67	.0739	36.81	639	853 1,183 1,422 1,707	.01968 .03937 .1181 .2362	......	910	796¶	29.56	40.78	38.0	34.7

* The distribution of the load on the winding and the sides of the pipe could not be established with any degree of certainty on account of the unfavorable load. † The first bight broke at 2,418 pounds; other bights broke at 2,560 pounds, and after the pipe had been distended at 1,707 pounds. ‡ The first bight broke at 2,707 pounds; other breaks occurred at 2,958 pounds per square inch. ‖ Pipes of small thickness. § The thickness of these pipes at a certain place was decreased to three-fourths of its original thickness for a distance of 7.87 inches. ¶ The pipe burst at a pressure of 1,707 pounds per square inch at the weakened place without damaging the copper wire rope.

REMARKS ON STEAM PIPES.

BY J. T. MILTON, ESQ.

[Read at the Thirty sixth Session of the Institution of Naval Architects, 1895]

The importance of having reliable steam pipes on board vessels cannot be overestimated. There have been a few cases where pipes have fractured with fatal results, which at the time drew attention to the subject; but minor accidents occur, and serious troubles with joints, &c., have to be faced, in which very little interest is taken. For instance, since the accident to the steam pipe of the *Elbe* in 1887, there have been fifteen casualties to the steam pipes of British owned vessels which have been inquired into by the Board of Trade under the Explosions Act of 1882. A list of these cases is given at the end of the paper.

The object of the present paper is to bring forward some points of interest in connection with steam pipes, with the view of eliciting, in the discussion, the opinions of those who make and those who are responsible for the maintenance of these pipes as to the best material of which to make them, and the best means to be adopted to provide for their special requirements in the way of expansion, draining, &c.

With regard to material, by far the greater number of steam pipes have been and are being made of copper, but of late wrought iron has in a few cases been used. Amongst the vessels fitted with wrought iron pipes may be mentioned the *Campania* and *Lucania*. The following list, showing the names of some Liverpool ships in which cast iron steam pipes (and cast iron feed pipes) have been in use for many years, will probably be a surprise to some of the members of this Institution, as it was to me when the information was given to me three years ago by Mr. McGregor, my colleague in Liverpool:

Name of Vessel.	*Age of Steam Pipes. Years.*
Africano,	24
Agia Sofia,	23
Ararat,	24
Arcadia,	20
Bernard Hall,	15
Britannia,	10
Laconia,	7
Lord Clive,	11
Lord Gough,	16
Macedonia,	20
Nieta,	22
Nina,	25
Palm,	21
Plantain,	16
Roumelia,	18
**Andean,*	21
**Australian,*	21
**Haytian,*	19

The almost invariable use of copper for steam pipes for so many years has produced the general impression that it is the only suitable material. It, no doubt, was originally selected on account of its non-liability to corrosion on one hand, and of its great ductility on the other. As regards corrosion, the almost invariable use of cast iron for stop valve chests and safety valve chests, as well as its frequent use for T pieces connecting copper steam pipes, and its invariable use for the slide chests and doors of the high pressure cylinders, shows that cast iron, at any rate, can be used, without misgivings on this point, in parts which, like steam pipes, are always subjected to the full pressure of the steam, while the experience of the eighteen vessels previously mentioned also bears this out. The experience with *Campania* and *Lucania*, so far as it has gone, and also of several other large

*These vessels are now broken up or dismantled, but the cast-iron steam pipes were in use for the periods stated.

vessels in which they have been somewhat longer in use, shows that wrought iron pipes also give no trouble in this respect. It was, therefore, no doubt, mainly owing to the ductility of copper that it obtained, and has since maintained, the preference over other materials for steam pipes.

Steam pipes have to withstand considerable changes of temperature, and their length is consequently liable to continual alterations. Their attachment to the engine may be liable to slight alteration in position, owing to the working or vibration of the engines or vessel; while those to the boilers are also liable to small displacements, due to the contraction or expansion of the boilers from variations of temperatures. All these changes are generally taken up or provided for by the deformation of easy bends in the pipes, or by expansion stuffing boxes where the pipes are straight.

It is evident that whatever forces are necessary to produce the deformation of a length of steam pipes necessary to allow for the expansion of the pipes, or for any possible working of the engines in the vessel, these forces have to be withstood by the necks of the stop valve chests or their attachments to the boilers and to the engines. In the case of pipes of small diameters and small thickness, if the bends are easy, a moderate force may be sufficient; but if the pipes are thicker, even if the diameters and the shapes of the bends are the same, the forces required to be borne by the attachments will increase in proportion to the thickness. The same thing holds good of the flange joints between the different lengths of pipe. These have to sustain the forces brought on the end attachments, and it might, therefore, very well happen that a design suitable for steam pressure of 60 pounds may be altogether unfit for 180 pounds solely on account of the greater thickness required making the pipes more rigid.

It must be remembered that the advance of engineering of late has not only increased the steam pressures used—and, therefore, the temperatures also—but engines are, in general, of much greater size and power than those used years ago. The steam pipes now, therefore, are, as a rule, larger in diameter, much thicker, and are subject to greater changes of temperature and expansion, &c., than formerly. These all make the pipes so much stiffer, or more rigid, that with many pipes, even when made of copper, their rigidity is so great that their yielding or altering form cannot be relied upon to relieve expansion strains, which have, therefore, to be provided for in the same way as they would need to be if the pipes were made of cast iron.

Concurrently with the trouble of providing for expansion, &c., with thick and large pipes, there arises also a difficulty in manufacturing them. The usual method of making pipes of large diameter is to make them, both bends and straights, from copper sheets, the straights, except in very large pipes, having one seam along the entire length, the bends having two seams along the sides, the saddle and back pieces being each worked up from one sheet. The seams are invariably brazed, the edges of the copper being thinned down to form a scarph. Now, the difficulty of satisfactorily brazing a joint of this description increases rapidly with the thickness. The heat has necessarily to be applied from the outside, and has to pass through the thickness of the metal to reach the brazing solder, and thus the risk of overheating the copper on the outside, and consequently burning it, is much greater with thick than with fairly thin copper. There is also a further danger of deoxidizing the copper, both in the brazing and also in the previous annealings to which the copper has to be subjected. To this, further reference will presently be made.

All these considerations have made some of our prominent engineers look with disfavor upon copper as a material for large steam pipes, and to turn their attention to iron or steel.

Endeavors have been made to introduce seamless pipes of large size for these purposes to avoid the risk of brazing. These are made by several firms, and lately, I believe, with a certain amount of success; but amongst some of the earliest of those made some serious longitudinal defects, probably arising from a local defect in the original ingot being drawn out lengthwise in the manufacture of the pipe, caused them to be looked upon with a certain amount of suspicion, besides which the great difficulty of making satisfactory bends with these large pipes has no doubt had some influence in preventing their more general use.

While treating of bending copper pipes, it may be well to mention that the usual practice is to make bends from tubes one gauge thicker than straight pipes of the same diameter. This is, no doubt, correct practice, so long as the radius of the bend does not fall below a certain value, depending on the diameter and thickness of the pipes; but where sharp bends are made from bent tubes, a greater thickness ought to be provided. It is often assumed that in bending pipes the axis of the tube does not lengthen, and that the material of the saddle of the pipe becomes compressed to an amount about equal to the extension at the back of the bend. This is not the case. The compression of the material is not very great, and the pipe bends by extending not only at the back of the bend, but also along the sides; and if it be remembered that the thinning of the metal must be proportional to the extension, it will be found that one gauge thicker is in many cases scarcely sufficient to provide for this.

In Vol. II, page 431, of the Transactions of the Iron and Steel Institution, there is described a method by means of which seamless steel boiler tubes are made in Germany, and it is understood that a somewhat similar process is in use in this country for making seamless copper tubes. In some cases, however, these tubes are still made by repeated drawings from a cast pipe, in which case any original defect in the casting must produce a more serious defect in the finished tube.

The method of manufacturing the Elmore copper pipes has been publicly described, and it has been claimed that it renders the probability of their containing any latent defect very remote.

The results (Table I) of tests made by the Elmore Copper Company upon two tubes made by themselves, and on one seamless tube and three brazed tubes which they procured from other makers, will be of interest.

It will be observed that the seamless drawn, and also the Elmore tubes, showed a high degree of strength, which indicated that they were *hard*, or *unannealed*, a condition in which they would not be used in practice, as steam pipes are always left annealed, or very slightly hardened by planishing.

TABLE I.

Description of pipe.	Diameter inside.	Thickness.	Pressure at which pipe burst.	Stress in tons per sq. in. produced by this pressure.
	Inches.	*Inch.*	*Pounds per square inch.*	
Elmore deposited.....	12.039	.121	930	* 20.65
Ditto..............	9.05	.118	1,100	† 18.8
Seamless drawn.......	7.25	.125	1,520	19.3
Brazed	12.52	From .104 to .144	580	‡ 15.58 § 12.56
Ditto............	9.23	From .125 to .143	750	‡ 12.36 § 11.27
Ditto.............	7.38	From .116 to .126	750	‡ 10.65 § 10.00

NOTE.—All the brazed pipes burst by tearing at the edge of the brazing.

REMARKS.—* Pipe commenced to stretch at about 800 pounds per square inch. † Fractured at flange only. ‡ On thinnest section. § On mean section.

To show the actual strengths of the copper in an annealed condition, twenty-eight test pieces were cut from these pipes and tested in an ordinary tensile testing machine, some of them being annealed, others unannealed. The results of these tests are given in Table II.

From these tensile tests it will appear that Elmore copper, even when hard, has much extension, but that it commences to elongate at much less stress than annealed ordinary copper; while, when annealed, its behavior as to ultimate strength and extension is very similar to that of good commercial copper, but it appears to commence to elongate at somewhat lower stresses than the latter.

While treating of copper pipes it may be well to say a few words as to the qualities of copper. Engineers generally purchase their copper sheets or tubes without subjecting them to rigid tests, relying upon the reputation of the makers for supplying a good article, and not troubling about the chemical composition, &c., so long as it is found to work well. In view of the great ductility of copper, the working of even an indifferent sample of copper may not be sufficient to detect its quality, especially when made into straight or nearly straight pipes.

TABLE II.

SHOWING THE RESULTS OF TESTS OF STRIPS OF COPPER FROM THE SEAMLESS DRAWN, ELMORE DEPOSITED, AND BRAZED COPPER.

Dimensions of Test Piece. Length.	Breadth.	Thickness.	Area.	Fractured Area.	Extension.	Stress at which Permanent Elongation was first observed.	Maximum Stress.	Remarks.
				TESTS FROM SEAMLESS DRAWN.				
In.	*In.*	*In.*	*Sq. in.*	*Sq. in.*	*Per ct*	*Tons per sq. in.*	*Tons per sq. in.*	
7½	1 496	.127	.190	.172	0 8	10.5	21.6	Not annealed.
"	1.494	.123	.184	.165	2.5	13.06	23.4	"
"	1.497	.125	.187	.151	19.8	4.4	14.7	Annealed.
"	1.495	.125	.187	.144	20 7	4.28	15 3	"
				TESTS FROM ELMORE DEPOSITED COPPER.				
9	1.491	.118	.176	.094	22.9	2 39	21.1	Not annealed.
"	1.496	.113	.169	.082	25.6	2.25	21.2	"
"	1 493	.112	.167	.088	43.0	1.20	15.6	Annealed.
"	1.496	.115	.172	.092	43.0	3.00	15.1	"
"	1.496	.113	.169	.084	25.0	2.48	20.9	Not annealed.
"	1 496	.120	.179	.097	25.0	2.78	20.4	"
"	1.495	.117	.175	.084	43.0	1.49	15.5	Annealed.
"	1.495	.120	.179	.091	41.6	1.40	16.2	"
7½	1.495	.084	.126	.078	21.1	3.60	24.3	Not annealed.
"	1 499	.085	.127	.077	20.0	2.70	24.1	"
"	1.494	.085	.127	.068	43.5	2.90	16.5	Annealed.
"	1.498	.088	.132	.066	45.6	2.40	16.2	"
				TESTS FROM THE COPPER FROM WHICH THE BRAZED PIPES WERE MADE.				
9	1.494	.135	.200	.178	19.4	3.90	17.4	Unannealed.
"	1.492	.133	.198	.124	29.8	5.90	17.8	"
7½	1.496	.121	.181	.141	28 9	4.14	16.5	"
9	1 495	.136	.200	.151	32.6	2.25	16.9	Annealed.
"	1.490	.135	.198	.117	38.8	4.10	17.2	".
7½	1.496	.123	.184	.137	31.8	3.80	15.5	"
				TESTS FROM BRAZED PIPES CUT ACROSS THE JOINTS.				
9	1.488	.110	.164	.175	2 4	3.30	14.0	Unannealed.
"	1.490	.135	.200	.126	13.9	3.75	15.35	"
7½	1.492	.121	.180	.144	2.4	3.33	13 06	"
9	1.492	.112	.167	.163	2 8	2.09	14.10	"
"	1.490	.134	.199	.146	20.1	2.56	14.5	Annealed.
7½	1.496	.120	.179	.134	12.9	3.65	12.6	"

All but the last test broke at edge of brazing. The last test broke partly at edge and partly through the brazing.

MEAN RESULTS.

	Tensile strength.	Tons per sq. in.	Extension per cent.
Elmore copper...............	Annealed	15.85	43.3
	Unannealed	22.0	23.3
Seamless drawn.	Annealed	15.0	20.07
	Unannealed	22.5	1.65
Ordinary copper.............	Annealed	16.53	34.4
	Unannealed	17.23	26.0
Brazed joint.................	Annealed	13.55	...
	Unannealed	14.10	...

Commercial copper is practically never pure, the amount of different impurities found in it being probably greater than in the case of any other metal commonly used. Information on this question can be found in the Transactions of Mechanical Engineers, No. 2, 1893, where two papers will be found on the subject, by Professor W. C. Roberts-Austen and Mr. Wm. Dean, respectively. An opinion is generally held by locomotive engineers, coppersmiths, and many others, that the commercial copper of the present day, although chemically purer than that of years ago, is inferior in respect to its lasting qualities, both as regards ability to resist corrosive influences and also to withstand fatigue without cracking. Accordingly, for some purposes, what may be termed impurities are added to the copper for the purpose of improving some of its properties. The papers referred to, and the discussion on them appear to show that arsenic up to a proportion of ½ per cent. is certainly not injurious and is probably beneficial, improving both the tensile strength and ductility of the copper. On the other hand bismuth is objectionable, even small quantities, such as .1 per cent., being sufficient to make the metal absolutely unreliable when heated above the boiling point of water. The following figures extracted from the paper by Professor Roberts-Austen, show these points.

Particulars are given in the Table on the following page for comparison of pure copper and of copper containing arsenic or bismuth, in all cases the copper being as cast, not hammered.

A small quantity of lead, say under .1 per cent., does not appear to be objectionable, but large quantities are not desirable; on the other hand, it appears that nickel and silver are not detrimental, the samples quoted by Mr. Dean as containing the largest proportions of these elements having given satisfactory results in use.

It is rather singular that in all copper made by smelting, oxygen is required in the copper to give ductility; the actual amount required in any case varies apparently with the proportions and amounts of the various impurities present. The precise amount needed is ascertained by frequent tests made during the "poling" process. If less than sufficient oxygen is present, the copper is called "over-poled," and is deficient in ductility, while if the oxygen is in excess, and the copper "dry," as it is termed, ductility also is lost. When the exact proportion is present the copper is termed "tough," or "tough pitch," and is ductile.

	Temperature of copper.	Tensile strength per square inch.	Percentage of elongation.
	Deg. Fahr.	*Pounds.*	
Pure copper	64	18,450	20
Do	64	19,740	35
Copper containing 1.2 per cent. of arsenic	68	24,840	20
Do	266	20,470	16.6
Do	435	16,460	15
Do	511	14,340	4
Do	655	14,860	10
Copper containing 1.5 per cent. of arsenic	59	26,460	20
Do	64	25,400	25 to 50
Do	241	23 460	26
Do	419	19.450	37
Do	500	18,360	Irregular.
Do	586	15,030	0
			Percentage of elongation in 4 inches.
Copper containing .1 per cent of bismuth	59	18,020	20
Do	214	11,510	15
Do	324	5 620	0
Do	390	3.860	0
Do	525	4.940	0
Do	558	2.770	0

A point not generally appreciated by coppersmiths is, that copper of the proper "pitch," that is to say, containing the exact proportion of oxygen to give it its proper ductility, can be made to give up its oxygen and to become in fact "over-poled" by heating it in a reducing flame; that is, a flame not fully charged with oxygen. On the other hand, by heating it in an oxydizing flame, it does not appear to absorb oxygen into the body of the material, the oxygen remaining on its surface, combined with some of the copper, in the form of oxide scale. If, therefore, copper is annealed or brazed, or worked in any way in a reducing flame, it loses its "pitch," and this cannot subsequently be regained by reheating in an oxydizing flame. This matter was strongly impressed upon me by Dr. Watson, of the Broughton Copper Company, to whom I am indebted for much information on copper, and from experiments on this point I am of opinion that many of the so-called "burnings" of copper arise from heating in a reducing flame, rather than from overheating, or being raised to too high a temperature.

Inasmuch as the proportion of oxygen required to produce the proper "pitch" in copper varies according to the composition of the copper, the liability of its losing pitch during working will probably be much greater in some qualities of copper than in others.

It has been stated that the tensile strength and ductility of copper vary according to its composition, but with the same mixture of metal they vary very much more with the mechanical treatment it undergoes. If properly annealed its tensile strength is comparatively low, and its ductility is high. In comparing the qualities of copper, therefore, it is necessary to fix the standard as being thoroughly annealed. To show the effect of annealing and of work the following tests recently made may be quoted. A copper tube was drawn in one operation from 3 wire gauge to 11 wire gauge (a very excessive draw, more than doubling its length). Its tensile strength when drawn was 24.38 tons per square inch, but its elongation was only 3.1 per cent. in 4 inches. After annealing (or possibly only partial annealing) its tensile strength was 16.66 tons per square inch, and its elongation was 44 per cent. in 4 inches. A good average result with annealed copper is 14 tons per square inch, and 40 to 45 per cent. elongation in 4 inches. Some other illustrations of the effect of annealing on tensile strength, &c., are given in the results of the tests made by the Elmore Company, already quoted.

While treating on annealing, it is interesting to compare the difference in the methods adopted in tube works and in ordinary coppersmiths' shops. In the former the tubes are annealed after every draw. They are raised to a temperature of from 800° to 900° C., say from 1,500° to 1,650° F., and are kept at that temperature for some little time, after which they are quenched in water.

The tubes are uniformly heated over their whole length, care being taken that the flame is clear and contains an excess of oxygen. In the coppersmith's shop, both sheets and pipes are heated over open coke fires; the flame may possibly be reducing, that is, may have a deficiency of oxygen, if the fire is a thick one. The sheet or pipe is moved about over the fire, spot after spot being heated, generally to a dull red, and after the whole surface has been thus treated the copper is either quenched or allowed to cool and is considered to be annealed. It thus depends upon the workman's care and judgment to ensure that every part has been heated, and there is considerable probability that some small part may escape full heating. Further, the heating cannot be uniform, nor can any part in general be retained at the red heat for any considerable time, nor is the temperature at any part raised to the same degree as is usual in tube works.

The influence of time upon annealing has, so far as I know, not been much experimented upon, neither has that of the various impurities; but I am informed by Dr. Watson that annealing may be efficiently carried out at lower temperatures than 800° C., but that it requires longer time at the lower temperatures than at the higher.

To show the influence of temperature upon annealing the following experiments are deserving of notice. A sample of copper was found to be abnormal in its behavior, being brittle instead of ductile. Its composition was as follows:

Copper	99.693
Nickel	.260
Iron	.027
Arsenic	Trace.
Silver	.020
	100.000

Six test pieces were cut off it, one was tested unannealed, and five were annealed at different temperatures. The following were the results:

Temperature at which annealing was performed.	Tensile strength, tons per sq. in.	Extension per cent. in 4 in.	Fracture.
Unannealed	14.9	0.0	Granular.
Faintly visible red, about 525° C.	12.13	6.2	"
Dull red, about 700° C.	11.78	3.1	"
Cherry red, about 850° C	13.89	4.7	"
Bright red, about 900° C.	14.2	14.0	Silky.
Approaching yellow, 1,000° C.	15.64	25.0	"

I am not able to say what caused the abnormal brittleness in this case, but after annealing at the high temperature the material regained a fair amount of ductility; and, after subsequent drawing or cold rolling, behaved in a perfectly normal manner. Annealing, however, at red heats left the material brittle. In this case very little time was allowed for annealing, the test pieces having been heated in an open fire and then quenched, the influence of time on annealing not having been so fully appreciated as it should have been.

The following figures, taken from page 310, Vol. II, 1894, of the Transactions of the Iron and Steel Institute, giving the temperatures corresponding with different visible appearances of heated metals are of interest:

	Deg. Cent.		Deg. Fahr.
Incipient redness	525	=	977
Dull red	700	=	1,292
Cherry red	850	=	1,562
Bright red	950	=	1,742
Yellow	1,100	=	2,012
Incipient white	1.300	=	2.372
Bright white	1,500	=	2,732

That copper for large steam pipes is now being looked upon with some distrust is evidenced by the Admiralty having such pipes bound round with wire, whilst in mercantile practice some firms put iron bands round the pipes every few inches, and in some cases the pipes are lapped with fine steel wire ropes.

Turning our attention to other materials suitable for steam pipes, we find, practically, only three, viz: cast iron, wrought iron and mild steel.

Cast iron has the advantage that it can be made in any shape, straight or bent, and that tees or junctions can be made of it.

On the other hand, if the pipes are of the same strength as wrought iron or steel, they are much heavier.

Wrought iron and steel may both be made with a lap welded joint, but, whereas welds in iron are apparently looked upon as trustworthy after a severe hydraulic test, those in steel do not appear to have the same confidence reposed in them, as they generally have a riveted butt strap fitted over them. Apparently, therefore, iron pipes are preferable to steel, unless the latter are made seamless.

With pipes of either iron or steel, manufacturing conditions appear to require them to be of such a thickness that either has a very large margin of strength compared with the pressures now being used, or even with those higher pressures to which marine engineering appears to be tending, so that there is no advantage in this respect in using steel rather than iron.

The question of flanges for iron pipes is important. Most of those hitherto used have had forged iron flanges screwed on, riveted over on the face of the flange, but flanges are now being electrically welded to the pipes in some cases, and welded by machine hammers in others, these plans apparently giving sound results without the chance of leakage which screwed flanges might develop.

Regarding provision for expansion of pipes, whether of copper, iron, or steel, a point sometimes lost sight of is, that it is not sufficient to provide a faucet joint in a straight length of pipe, but provision must also be made to anchor the ends of the length of pipe for the expansion of which provision has to be made, and so compel the movement of expansion to take place in the part provided for it, otherwise the end pressure on the pipes, amounting to several tons in all but the smallest pipes, will cause the joint to slide in the wrong direction. This has occasionally been overlooked in pipe designs. It is always difficult to provide for the expansion of large bends without producing excessive strains, so that, as far as possible, pipes should be made straight.

The only other point to which reference will be drawn is that of providing means of draining steam pipes. More than one fatal accident has been thought to be due to the presence of water in the pipes. In cases where it is the practice to always raise steam in all the boilers simultaneously, the stop valves on the boilers, if opened before steam is raised, may be the best possible drains for the pipes; but where there is more than one boiler in a vessel it may often happen that, even if all the boilers are invariably used for steaming purposes, one only may be used in port for auxiliary purposes, and in this case leakage from its main stop valve will find the steam pipes leading to the other boilers receptacles for the condensed steam, which, if not drained, may be dangerous when opening the stop valves when raising steam in the other boilers. It is noteworthy that more than one of the serious accidents with pipes has occurred at the instant when stop valves were being opened.

Too much attention cannot be paid to the provision for draining steam pipes, and it is considered that it is preferable that these should be automatic, or such as not to require personal attention.

LIST OF CASES IN WHICH INQUIRIES HAVE BEEN HELD BY THE BOARD OF TRADE AS TO THE CAUSE OF CASUALTIES TO STEAM PIPES OF BRITISH VESSELS SINCE THE CASE OF THE S.S. *ELBE* IN 1887.

1888, *Erin.*—Wrought iron pipe connecting top of water gauge to boiler corroded, and burst. This pipe was apparently twenty years old.

1888, *Bryn Glas.*—Intermediate stop valve cover broke, attributed to the wheel for opening the valve being turned the wrong way.

1890, *Springbok.*—Main steam pipe of copper—6 inches diameter, $\frac{3}{16}$ inch thick—broke away from flange next the boiler stop valve, due to faulty construction and to imperfect repairs.

1890, *Jumna.*—Main steam pipe of copper burst at the lap in a bent portion near the boiler stop valve, probably due to defective workmanship in the original brazing.

1891, *Number Three.*—$5\frac{1}{2}$-inch copper steam pipe burst at the brazed joint of the bend near throttle valve. The brazing was thought to be defective, and the accident was attributed to the presence of water in the pipe.

1891, *Greencastle.*—Steam pipe broke at the flange joining throttle valve. An expansion joint was fitted, but it was not so arranged as to take the strain off the flange.

1891, *Rohilla.*—Copper pipe, 14 inches in diameter, failed at the seam, which was riveted and brazed. Accident was attributed to an accumulation of water in the pipe.

1891, *City of Lincoln.*—Copper pipe, 6½ inches diameter, cracked through the solid copper at the edge of brazed seam. Accident was attributed to the presence of water in the pipe, and to the existence of old flaws in the copper.

1892, *Shannon.*—Branch steam pipe of copper, 8 inches in diameter. Accident was attributed to the impact of water in the pipe, set in motion by the admission of steam from an auxiliary boiler.

1892, *Vulcan.*—Main steam pipe, 6 inches diameter, failed at brazed seam, after being in use five years. Probably due to the development of a latent defect, and possibly through want of sufficient provision for expansion, &c.

1892, *Grimsby.*—Main steam pipe, $9\frac{1}{16}$ inches diameter, burst at a part adjacent to the brazed seam. Casualty was attributed to water in the pipe being set in motion when the stop valve was opened.

1892, *Astrion.*—Copper T-piece exploded at the junction of two 6-inch pipes with one of 9 inches. Failure was attributed to the movement of the boilers and to the expansion joint having become set fast.

1892, *Viola.*—Stop valve box (cast iron) burst. Accident was attributed to the accumulation of water in the steam pipe, the draining arrangements having been allowed to get out of order.

1893, *Othello.*—Small steam pipe, 1¼ inches diameter, burst by tearing away from the flange. Attributed to vibration of engines.

1893, *Astrakhan.*—Winch steam pipe broke, due to water in the pipe being set in motion when steam was turned on.

After the reading of Mr. Milton's paper, the Elmore Company expressed surprise and doubt as to the accuracy of the figures given in the paper as representing the elastic limit of their material, and had some tests made by Professor Unwin, in the presence of Mr. Milton, which show that the material supplied by them possesses a high ratio of elastic limit to ultimate strength. The samples tested were what the makers term "soft deposited copper," which, they claim, will stand all the ordinary working of the coppersmith without annealing. The results of the tests, which were published in "Engineering," are given in the following table:

[Copy.]

CITY AND GUILDS OF LONDON INSTITUTE.

Engineering Laboratory, Central Institution, Exhibition Road, London, S. W. Date May 10, 1895.

Report on Specimens of Copper received from W. Elmore, Esq., on May 7, 1895.

Test number.	Marks on specimen.	Dimensions in inches.		Section in square inches.	Stress at elastic limit in tons per square inch.	Maximum stress in tons per square inch.	Elongation in 8 inches.
		Width.	Thick.				
							Per cent.
1650*	C.	1.469	0.187	0.2747	2.275	13.09	45.88
1651	C.	1.485	0.1895	0.2814	15.10	15.48	13.13
1652	C.	1.503	0.185	0.2781	15.28	15 91	14 75
1653	L.	1.500	0.1935	0.2903	15.07	15.67	21.25
1654	L.	1.498	0.193	0.2891	15.56	16.03	17.88
1655*	L.	1.503	0.188	0.2826	1.769	13.13	48 13

* Annealed.

(Signed) W. C. UNWIN,
Professor of Engineering.

FURTHER EXPERIENCE WITH FIRST CLASS BATTLE SHIPS.

By Sir William White, K.C.B., LL.D., F.R.S.

[Read at the thirty-sixth session of the Institution of Naval Architects.]

In the paper read before the Institution last year, "On the Qualities and Performances of Recent First-class Battleships," I summarized the experience gained up to that time with vessels of the *Royal Sovereign* class. In the present communication it is proposed to put on record some results of further experience gained during the past year, and certain facts of great professional interest obtained from rolling experiments made on the *Revenge* at Spithead. The reasons which led to the decision not to fit bilge keels to the *Royal Sovereign* class during construction were stated last year, but may be briefly recapitulated. In ships of these large dimensions and great inertia, it was anticipated, on the basis of previous observation and experiment, that any practicable bilge keels which could be added would have a relatively small steadying effect. The presence of bilge keels, even of moderate depth, necessarily interfered with facilities for docking the ships in some of the docks which they would have to enter. Further, it was estimated, and experience has confirmed the estimate, that in their period of oscillation the *Royal Sovereign* class would approximate to the *Inconstant*, *Hercules* and *Sultan*, which had a high reputation for steadiness at sea. The *Hercules* and *Sultan* had only shallow side keels from 9 inches to 10 inches deep, two on each side, as shown in Fig. 4.

The question was carefully discussed in all its bearings when the design was under consideration. It was realized that some steadying effect would be obtained by fitting bilge keels. But it was finally decided that the balance of advantage lay on the side of omitting bilge keels until experience had been gained at sea.

That stage had been reached when last year's paper was read. I then stated that, as an experiment, the *Repulse* had been fitted with bilge keels so that she might be tried in company with sister ships belonging to the Channel Squadron. These keels are shown in Fig. 4. They are about 200 feet in length and 3 feet deep.

FURTHER TRIALS AT SEA.

The first opportunity for comparative trial occurred in June, 1894, when the squadron was cruising off the west coast of Scotland. A long, low swell was encountered with a length said to vary from 300 feet to 400 feet (crest to crest) and a period estimated at 10 to 12 seconds. For some time this swell was on the quarter, and the speed and course of the ships relatively to the swell were such as produced heavy rolling. This occurred during the night. The reports from some of the ships state that batten observations of the horizon could not be made. Pendulum observations were, therefore, had recourse to, although they are notoriously untrustworthy. After making all allowance for possible exaggeration in the pendulum observations, the facts reported indicated conclusively the very great value of the bilge keels in the *Repulse* in reducing her arc of oscillation. This will appear from the following summary:

The *Resolution* (without bilge keels), by orders from the Admiralty, had been purposely kept in very nearly the same condition of stability as the *Repulse*. Comparing the returns from these two ships, it appears that the *Resolution* on one occasion reached a maximum inclination to the vertical of 23 degrees; whereas the *Repulse* never exceeded 11 degrees. The mean angles of oscillation were, of course, considerably below these maxima, probably about one-half. The *Royal Sovereign* and *Empress of India* were also in company. The condition of coal stowage in these two ships at the time gave them greater stiffness and a quicker period, which, under the conditions of weather and sea, caused rather heavier rolling than in the *Resolution*.

In view of this experience, although the trial was limited and not representative of many conditions occurring at sea, it was decided to fit all the other ships of the class with bilge keels similar to those which had proved so effective in the *Repulse.* This work was completed for the ships of the Channel Squadron during their annual refit last summer; it has since been carried out in all the other ships of the class.

On the cruises of the Channel Squadron which have taken place since bilge keels were fitted, there have been but few opportunities of obtaining proof of their practical value. So far as experience has gone, however, there is a concensus of opinion amongst officers in command that rolling has been greatly reduced by the bilge keels. On one or two occasions, when it has been possible to test their value in rough water, the results obtained have been remarkable.

As an example of many communications which have reached me, I will refer to one having special interest, permission having been given me to do so by the writer, the late Captain Hall, of the *Resolution.* He wrote as follows from Vigo on January 13, 1895:

"We had a rough passage here from Gibraltar, falling in with a strong gale ahead with a heavy sea; waves from 27 feet to 30 feet in height. The difference in the behavior of this ship was marvellous. Had we been without bilge keels, we should have rolled considerably. As it was we hardly rolled at all. No fiddles were required on the table, and, except for the pitching when 'down helm,' one would not have known he was at sea, certainly not in a gale. The ship is now one of the steadiest in the service. The other battleships in the squadron were equally steady."

At our last interview in March (only a few days before his lamented death) Captain Hall told me of another critical trial which he had made with the *Resolution.* while at target practice. The ship was placed broadside on to waves having a height of about 25 feet from hollow to crest and a period approximately synchronizing with her own. The maximum angle of inclination noted under these trying conditions was 6 degrees to 8 degrees on either side of the vertical, and the whole of the guns on the main deck could be fought with perfect freedom. Captain

Hall was of opinion from previous experience that the *Resolution*, without bilge keels, under similar circumstances, would have reached occasionally maximum inclinations to the vertical of 16 degrees to 18 degrees. Further experience will, of course, be gained in the actual service of the vessels now that they have bilge keels. This will enable a more complete estimate to be formed of their behavior when exposed to those conditions of a low and synchronizing swell which occasionally caused heavy rolling in the earlier periods of their service before bilge keels were fitted. All the facts in regard to that earlier experience were given in my paper of last year.

It must be frankly admitted that the steadying effect of bilge keels as fitted on the *Repulse* and her sister ships has greatly exceeded that which we had anticipated from previous experience and experiment.

As I remarked last year, no one has more strenuously urged the utility of bilge keels than myself. The practical question which had to be decided, however, was whether the extent of that steadying effect in the *Royal Sovereign* class was likely to compensate for the inconvenience in docking necessarily resulting from the presence of bilge keels on such large ships. That question was set at rest by the relatively better behavior of the *Repulse* in June, 1894, and by the experience since gained in the Channel Squadron. The broad test of actual experience at sea is, of course, sufficient and conclusive for practical purposes.

ROLLING EXPERIMENTS MADE ON THE *REVENGE*.

For scientific purposes, and for guidance in future designs, much more exact information was required than could be obtained from observations of the behavior of ships under actual conditions of service. There must necessarily be variations of stowage, stability, and other features influencing oscillation, even in sister ships. Ships in company are not always simultaneously exposed to identical conditions at sea. Only long-continued experience, in fact, can suffice to determine the relative behavior of different ships. From the scientific side the problem could only be solved by still-water rolling experiments. It was arranged, therefore, that these should be carried out on the *Revenge*, which had been built and engined by the same firm as the *Resolution*. A careful programme was prepared, and the experiments were conducted by Mr. R. E. Froude. The first series was made before bilge keels were fitted, and the second after that work was completed.

In each series it was proposed, so far as practicable, with some of the equipment weights necessarily not on board, to roll the ship in her condition of maximum stability, and in a condition of stability approximating to the minimum stability likely to be reached on service. In other words, the stowage of coal and water was so varied as to give a metacentric height varying from 3½ feet to a little over 4 feet. Trials were also made after the bilge keels were fitted, with the ship under way as well as with no headway.

During each of the first three trials an inclining experiment was made by running in and out the barbette guns when trained abeam, to determine accurately the metacentric height associated with the several experiments. For the fourth trial the metacentric height was calculated from the known differences in weights carried as compared with previous trials. The oscillations of the ship were produced by training the heavy guns at a suitable rate from side to side, and by running men across the deck in the usual manner. The particulars of the trials which took place at Spithead in deep water with the ship drifting freely and also under way, are set out briefly in the following tabular statement:

	First trial.	Second trial.	Third trial.	Fourth trial
Date of trial	Oct. 3, '94	Oct. 30, '94	Jan. 15, '95	Feb. 13, '95
Mean draught of water, feet and inches	27–6	26–0½	26–0½	27–11½
Displacement, tons	14,300	13,370	13,370	14,620
Metacentric height, feet	3.78	3.25	3.29	3.86
Mean period of single swing, seconds	7.6	8.0	8.4	7.75
Weight of coal and water on board, tons	1,485	572	536	1,782
Number of men for rolling ship	320	0	350	370

Bilge keels were fitted to the ship between the second and third trials. The effect of their addition is allowed for in the mean draught and displacement figures in the table. They were 200 feet long, 3 feet deep throughout their length, tapering away at the ends, about 1,170 square feet in collective area, with a mean radius from the C G of ship of about 41 feet for the third trial, and about 40½ feet for the fourth trial (see Fig. 4). The results of these experiments are shown in Fig. 1 in the form of "curves of declining angles," corresponding to the curves which the late Mr. Froude published about twenty years ago for a number of representative ships of the Royal Navy, and which he then termed "curves of extinction." Each of the curves shown in the diagrams for the *Revenge* without headway gives the mean results of four or more separate sets of observations. For two of the trials, where alone it appeared necessary, they have been corrected by Mr. R. E. Froude, for variations in wind force, on the basis of experimental data obtained during these trials.

Abscissa values correspond to the number (n) of successive "swings," say, from port to starboard, or *vice versa;* which may begin to count at any point in the base line. If the rolling be isochronous, as it practically was in the *Revenge* without bilge keels, if not with them, the abscissa may also be interpreted by a scale of time. Ordinate values represent the extreme inclination (θ) to the vertical for each successive swing. On this diagram also have been shown the corresponding curves obtained by the late Mr. Froude for H. M. ships *Inconstant* and *Sultan.* The curves are so readily interpreted that it will suffice to make a brief statement indicating the *relative losses of swing* sustained by the *Revenge* with and without bilge keels.

Starting from an angle of inclination of 12 degrees to the vertical, it will be seen that in order to reduce the corresponding inclination to 6 degrees, the *Revenge* without bilge keels required to make 18 or 20 swings, and the *Sultan* about 17.

It will be observed from Fig. 1 that there is a remarkable similarity between the curve of declining angles of the *Sultan* and that for the *Revenge* without bilge keels.

Starting from an angle of inclination of 6 degrees to the vertical, it required about 45 to 50 swings in the *Revenge* without bilge keels to reduce the corresponding angle of inclination to 2 degrees; whereas, after bilge keels were fitted, an equal reduction in angle was obtained by only eight swings, indicating the enormous extinctive effect of the bilge keels.

For the *Sultan* and *Inconstant* 32 and 20 swings respectively would be required to produce the same reduction. The comparison between the *Revenge*, with and without bilge keels, may be made in another way. Starting from an inclination of 6 degrees from the vertical, after 18 swings the extremes of inclination reached would be 3¾ degrees without bilge keels and 1 degree with them. Another striking illustration of the extinctive effect of bilge keels is to be found in the comparatively small oscillations impressed upon the *Revenge* after bilge keels were fitted. The ship could be rolled up to an angle of inclination of 13 degrees to the vertical by moving her barbette guns from side to side in due relation to the oscillations of the ship before bilge keels were fitted. After they were fitted, it was found difficult to exceed an inclination to the vertical of 6 degrees to 8 degrees, even with 300 to 400 men running across her decks and acting in conjunction with the movement of guns.

The variations in the "periods of swing" (from out to out) brought to light by these trials are instructive. Without bilge keels the rolling was practically isochronous at the large as well as the small angles. The period for a single swing was 7.6 seconds for the maximum stiffness and 8 seconds for the minimum stiffness, for large as well as small arcs of oscillations. After bilge keels were added, within the range of experiments up to a swing of about 12 degees (6 degrees on each side of the vertical) the period of a single swing decreased as the angle of inclination became smaller. Put into figures it was reduced by one-fifth of a second (about 2½ per cent.) in going from a mean inclination to the vertical of 5 degrees to one of 1 degree. Further, as between the second and third trials—when the conditions of the ship as regards stowage of weights, &c., were practically identical, and when therefore the metacentric heights and radii of gyration of the ship and her lading were appreciably unchanged—there was an increase of about 5 per cent. in the period due to the action of the bilge keels. An increase in period under these circumstances confirms results obtained in similar experiments made by the late Mr. Froude on a model of the *Devastation*, and by MM. de Benazé and Risbec on the *Elorn*. For the *Devastation* the increase in period varied from 7 to 12 per cent.; according as the depth of bilge keels was increased from 1 foot 9 inches to 6 feet. In the case of the *Elorn* (from particulars published in "Naval Science" for 1875) there was an apparent increase of about 7 per cent. in the period; the real increase, after correction for the different metacentric heights on the two occasions (*i. e.* with and without bilge keels) was about 5½ per cent. The bilge keels in this case were about 30 feet long and 1 foot 8 inches deep on a vessel 82 feet long, mean draught about 6½ feet and displacement 100 tons.

The addition of bilge keels, even to as large and heavy a ship as the *Revenge*, does therefore sensibly lengthen the period of oscillation under otherwise exactly similar circumstances. This increase in period, of course, tends to increased steadiness under most conditions at sea.

A feature of great interest in Fig. 1 is to be found in the increased extinctive effect of bilge keels when the ship had headway as compared with their effect when she had no headway.

It will be remembered that this matter was made the subject of experiment by M. Bertin on the *Navette*. The results have been published by M. Bertin, and reproduced in English publications. They are briefly as follows:

Speed of ship.	Value of N.
Nil	.0109
4 knots	.0123
8 knots	.015

To understand these figures it should be stated that, according to the French authorities, the rate of extinction is best expressed by the equation:

$$-\frac{d\theta}{dn} = N\theta^2$$

for angles of inclination (θ) from the vertical exceeding 3 degrees.

The late Mr. Froude also drew attention to the point in his discussion of the behavior of the *Devastation* at sea, although it is understood that no exact measures of the added extinctive effect due to headway were obtained by him in the course of his rolling experiments.

The experiments with headway with the *Revenge* included only one set at each of the two speeds tried; the results under way are therefore probably not so definite as those for the ship without headway. Still they are very suggestive, and confirmatory of the conclusion from previous experience that the rate of extinction is sensibly increased by headway, the ship entering undisturbed water while oscillating, and the inertia of that undisturbed water having to be overcome. For example, starting at 5 degrees from the vertical in each case, the angles of inclination reached after a certain number of swings were as follows:

	Speed of ship.		
	Nil.	10 knots.	12 knots.
After 4 swings, degrees	2.95	2 35	2.2
After 8 swings, degrees	1.95	1.12	1.05
After 12 swings, degrees	1.45	.55	.45
After 16 swings, degrees	1.15	.20	.25

The experimental results are shown in different form in Fig. 2, which contains "curves of extinction" obtained by differentiation from the corresponding curves of declining angles shown in Fig. 1. The equations to these curves of extinction are given in Note I of the Appendix.

Abscissa values here represent angles of inclination (θ) from the vertical in degrees; ordinates represent the extinction value $\left(-\frac{d\theta}{dn}\right)$, or the angle from the vertical lost per swing. In this case also the curves are so easy of interpretation that it is unnecessary to say much respecting them, but they illustrate perhaps more clearly than those of "declining angles" (Fig. 1) the enormously increased rate of extinction with bilge keels. Taking a total swing of 10 degrees (say from port to starboard), we have an abscissa value of 5_2—the mean of the angles of inclination to the vertical at the beginning and end of the swing.

The relative extinction values possessed by the *Revenge*, *Sultan* and *Inconstant*, are given by the following tabular statement. The extinction value of the *Revenge* at deep draught, with no bilge keels, is taken as unity for purposes of comparison.

Sultan	speed of ship, nil,	1.4
Inconstant	" " " "	2.4
Revenge, deep draught, no bilge keels	" " " "	1.0
light draught, no bilge keels	" " " "	1.2
light draught, with bilge keels	" " " "	7.3
deep draught, with bilge keels	" " " "	6.0
deep draught, with bilge keels	" " " 10 knots	8.5
deep draught, with bilge keels	" " " 12 knots	10.3

This comparison is approximately correct for any other angle of inclination within the range of the experiments, except for the *Revenge* under way. The loss of range per swing for moderate abscissa values (up to 6 degrees) will be seen to be about *six times* as great with the bilge keels (whether at deep or light draught) as it was before they were added.

When a ship is rolling permanently through a certain arc, the external forces impress upon her during each swing an amount of energy exactly balancing the energy corresponding to the work done by all the forces resisting her oscillation. This work is expressed and measured by the ordinate of the curve of extinction corresponding to the extent of swing (see Fig. 2).

If for any ship we have two curves of extinction, one with and the other without bilge keels, then for a *given ordinate value*—or energy corresponding to work done by the external forces resisting oscillation—the respective abscissa values corresponding to that ordinate on the two curves, will of course differ. That is to say, the abscissa value (or swing) for a given "extinction" will be less for the curve with bilge keels than for the curve without them. The difference of the abscissæ may be taken, therefore, as a measure of the probable reduction in swing from the vertical due to the addition of bilge keels under the action of external forces capable of producing the larger swing without bilge keels.

Applying this to the case of the *Revenge*, and extending upwards her curves of extinction without bilge keels (by using the appropriate equations), let it be assumed that some external forces—say a series of regular co-periodic waves—could produce a permanent swing of 18 degrees on each side of the vertical. Then the same external force applied to the ship with bilge keels would only produce a swing of about 6 degrees. The addition of bilge keels, therefore, roughly speaking, would reduce the swing to one-third of its former amount. This ratio is practically constant for angles less than 18 degrees, as may be readily seen on referring to Fig. 2.

This is an extreme comparison for the conditions of maximum steady rolling, viz: a series of regular co-periodic waves which are seldom met with, and do not obtain for any length of time. Any slight disperiodicity is accompanied by a rapid decrease in the magnitude of the swings, as was demonstrated by the late Mr. Froude. Into this branch of the subject it is impossible to enter at present, and it is unnecessary for purposes of illustration of the great extinctive effect of bilge keels demonstrated in the experiments on the *Revenge*. The results of these experiments have added greatly to our knowledge of the subject of bilge keel resistance, but they must necessarily be supplemented by much fuller investigation and experiment before the subject can be considered to be exhausted. It is proposed that this question shall be followed up in all its details by Mr. R. E. Froude, in whose hands we may be sure it will receive most able and thorough treatment.

ESTIMATE FOR EXTINCTIVE EFFECT OF BILGE KEELS MADE PRIOR TO ROLLING EXPERIMENTS ON *REVENGE*.

In justification of the opinion which we had formed previously to these experiments, in regard to the probably small steadying effect of bilge keels on a ship of the *Royal Sovereign* class, it appears desirable to add a brief statement. The best information hitherto accessible on the subject of keel and bilge keel resistance to rolling is undoubtedly to be found in the papers published by the late Mr. Froude in *Naval Science* (1872–'74).

In his calculations for several typical ships which had been made the subject of still water rolling experiments, Mr. Froude had occasion to estimate the work of the resistance to a flat surface (such as a bilge keel or a portion of the deadwood) oscillating harmonically in water. For this he adopted, as applicable to the case in question, a coefficient of 1.6 pounds per square foot with a mean velocity of 1 foot per second. This coefficient, Mr. Froude stated, was based upon experiments made with a powerful pendulum apparatus carrying a plane so deeply submerged as to be clear of all wave making action. The purpose which Mr. Froude then had primarily in view was to authenticate the opinion that wave making resistance was a most potent factor in fluid resistance to rolling. That position he thoroughly established.

In his analysis of the total work represented by the observed extinction of oscillation in certain typical ships, he showed incidentally that the use of this coefficient of 1.6 pounds per square foot for deadwood and keels, in association with his estimate for frictional resistance on the immersed surfaces of the ships, did not fully account for the experimental facts. On the other hand, in the case of the *Sultan* the agreement between Mr. Froude's estimate, based upon the use of this coefficient, and the experimental facts was very close indeed.

Another valuable contribution to the subject is to be found in the appendix to a paper contributed by Mr. Watts to the "Proceedings of the Institution for 1883." In this paper Mr. Watts endeavored to estimate the area of bilge keels required to secure a given rate of extinction in a certain ship. For this purpose he employed experimental data obtained by the late Mr. Froude from the *Greyhound*, with and without bilge keels. From the figures published by Mr. Froude in "Naval Science," for the *Volage*, *Inconstant* and *Sultan*, Mr. Watts obtained certain approximate values for the coefficients of normal pressure on bilge keels when oscillating, on the assumption that the whole difference in the work of extinction between that estimated by Mr. Froude and that deduced from the experiments on typical ships might be credited to a virtual increase in the coefficients of resistance per unit of surface of the bilge keels. Taking the *Volage* and

Inconstant for example, Mr. Watts estimated that, instead of the coefficient 1.6 pounds per square foot for a mean velocity of 1 foot per second, the respective coefficients would become 8.7 and 7.2 pounds respectively. In the case of the *Sultan*, however, the coefficient thus derived from the rolling experiments was shown to be as nearly as possible 1.6 pounds. The *Sultan* was fitted with duplicated shallow side keels (as shown in Fig. 4), and that fact probably had much to do with the close agreement of the estimate and the experiment.

Our difficulty in dealing with the question of probable bilge keel effect on the *Royal Sovereign* class before experiments were made was twofold:—

(1) We did not know the character of the curve of extinction for the ships without bilge keels.

(2) We were uncertain as to the coefficient to be used in estimating the additional resistance due to bilge keels of a specified length, depth, area and mean radius of oscillation.

The first difficulty might have been met by recourse to model experiments. It was not considered necessary, however, to carry out such experiments, since the addition of bilge keels at a later stage was a simple matter, should they prove necessary. Moreover on the basis of experience with ships like the *Inconstant*, *Hercules* and *Sultan*, it appeared reasonable to expect that the *Royal Sovereign* class, under most conditions of sea, would be steady ships, apart from bilge keel resistance.

In regard to the coefficient to be used for estimating the probable extinctive effect of bilge keels, it was decided after careful consideration to adhere to the late Mr. Froude's figure of 1.6 pounds per square foot for a mean velocity of 1 foot per second. This, as above explained, had been actually found by experiment to hold good in the *Sultan*, which was the only large ship that had been rolled having approximately similar form and period to those of the *Royal Sovereign* class. This action is shown to have been reasonable by the close correspondence since experimentally demonstrated between the curves of declining angles for the *Sultan* and *Revenge* without bilge keels (see Fig. 1).

We next proceeded to calculate the probable extinctive effect due to bilge keels of about the dimensions which have since been added to the ships; assuming that the work due to fluid resistance on the bilge keels could be expressed by the formula used by the late Mr. Froude. Embodying the selected value of the coefficient of resistance, it was an easy matter to approximate to the probable additional loss of range per swing which the keels could effect, if the ship without the keels had reached a certain angle of oscillation under the influence of external forces. Taking an extreme case, and supposing the ship was rolling to 20 degrees on each side of the vertical, then this method of calculation showed that the addition of bilge keels 200 feet long and 3 feet deep would increase the extinction value by not quite 2 degrees (see Appendix, Note II).

It may be interesting to state, in passing, what would be the value of the coefficient for bilge keel resistance if the whole increase of work, shown by the experiments to result from the fitting of bilge keels, were credited to the bilge keel area. For an angle of swing of about 10 degrees, instead of the coefficient being 1.6 pounds per square foot of bilge keel area, it would be about 11 pounds. For a swing of 4 degrees (when the oscillation is nearly ceasing), the coefficient would reach as high a value as 15 to 16 as against 1.6. The details of the calculation appear in the Appendix, Note III.

It will be understood that these values of the coefficients for bilge keel resistance, deduced from the experimental data, are in no way put forward as truly representative of the actual resistance experienced per unit of area on the bilge keels. They simply represent, as before stated, what this coefficient would be if the assumptions held good—(1) that the whole of their work of extinction was equated to the area of the bilge keel; and (2) that their resistance varied as the square of the angular velocity.

The curves of extinction for the ship with bilge keels do not follow exactly, and throughout their whole length, the law which the late Mr. Froude laid down for such curves twenty years ago, viz:

$$-\frac{d\theta}{dn} = a\theta + b\theta^2.$$

But excluding very small oscillations of the ship, curves can be drawn (as shown in Fig. 3), whose equations obey this law, and which closely approximate to the experimental curves for values of θ from about 2 degrees to the largest angles obtained when the ship was rolling. The equations to these approximate curves, and to the corresponding curves without bilge keels, are given in the Appendix, Note I. From these equations it will be seen that (within the limits of swing for which the equation approximately fits the curve of extinction) the addition of bilge keels involves an enormous increase in those terms of the fluid resistance which vary as the *first power* of the velocity. This is indicated by the greater value of the a coefficient.

If the increase in the b coefficient (which is a measure of the work done by that portion of the resistance which varies as the square of the velocity) be assumed to represent the value of the bilge keel area coefficient, it will be found to be about 6 pounds per square foot, at one foot per second mean velocity, instead of 1.6 pounds. The details of the calculation appear in Note III of the Appendix.

Further investigation may, of course, show that this form of equation for curves of extinction will have to be definitely abandoned in some cases. But, as the matter at present stands, it would appear that the *Revenge* experiments point to a possibility which is also indicated by the results given by Mr. Froude in 1874. It appears that when bilge keels are added to a ship they must become effective, not merely as flat surfaces oscillating with the ship, and experiencing direct resistance, but by indirectly influencing the stream line motions which would exist about the oscillating ship if there were no bilge keels. It also seems possible that the existence of such keels as were fitted to the *Revenge*, even so deep below the surface (see Fig. 4), may be effective in producing a marked increase of surface disturbance, and so adding to the extinction. As pointed out long ago by the late Mr. Froude, a wave of insignificant dimensions, only a few inches in height, would be sufficient to account for all the work to be attributed to surface disturbance. Such waves might easily escape detection. For an estimate of the height of such a wave to fit the case of the *Revenge*, see Note IV in Appendix.

The facts obtained also suggest that for the very limited range and mean velocity of motion which is experienced by bilge keels, even when oscillating through arcs of 10 degrees or 12 degrees, the resistance upon them may vary, as Rankine and some other of the earlier writers supposed, as the first, and not as the second, power of the velocity. In such a case the curves of extinction, shown in Fig. 2, for the ship with keels would more nearly approach straight lines. For the *Revenge*, when performing a swing of 12 degrees, the bilge keels sweep through a distance of about 8½ feet in 8.4 seconds, with a mean velocity of about 1 foot per second.

INFLUENCE OF BILGE KEELS ON STEERING AND SPEED.

Independently of their steadying effect, the addition of bilge keels to the vessels of the *Royal Sovereign* class has had a sensible influence in another direction. These large ships have always had a good repute for handiness and steadiness in steering. Their tactical diameter without bilge keels was found to be about five times the water line length when both screws were going ahead, and about three and a half times with one screw reversed.

Reports from the ships state that since bilge keels have been added the tactical diameter has been reduced sensibly, and the steadiness in steering improved. Trials made with the *Revenge* after she was fitted with bilge keels gave a tactical diameter of 525 to 550 yards with both screws going ahead, or about four and a quarter times the water line length; and 350 yards with one screw reversed, or about two and three-quarter lengths. Similar trials in *Resolution* gave 500 yards as the tactical diameter with both screws ahead, and 300 yards with one screw reversed. These results are remarkable, and they completely dispose of the statements so often made, that large ships are necessarily unhandy and difficult to manœuvre.

As regards the influence of bilge keels on speed, the practical test of actual service proves that there is no sensible reduction in speed for power, or material increase in coal expenditure for a given speed; at a given draught, and with the bottom in similar condition.

CONCLUSION.

The facts set forth in this paper, besides their value in regard to a large and important class of battleships in the Royal Navy, will be of service to Naval Architects generally when dealing with the extinctive effect of bilge keels in vessels of the largest size and longest period. The experiments made on the *Revenge*, with and without bilge keels, had been preceded, it is true, by others; and notably by those of the late Mr. Froude on the *Greyhound*, and of the French experimentalists mentioned above. Mr. Froude also worked out in the most thorough manner the method of model experiments on rolling, applying it especially to the cases of the *Devastation* and *Inflexible*.

APPENDIX.

NOTE I.

The differential equations to the curves of extinction, shown in Figs. 2 and 3, are as follows:—

C.–*Revenge*, light draught, no bilge keels $-\frac{d\theta}{dn}=.015\theta+.0028\theta^2$

D.– " deep " " " $-\frac{d\theta}{dn}=.0123\theta+.0025\theta^2$

A.–*Inconstant*, ... $-\frac{d\theta}{dn}=.035\theta+.0051\theta^2$

B.–*Sultan*, ... $-\frac{d\theta}{dn}=.0267\theta+.00166\theta^2$

For curves G and H in Fig. 3, which conserve the form—

$$-\frac{d\theta}{dn}=a\theta+b\theta^2$$

and which also approximate best to fit curves E and F in Figs. 2 and 3, for values of θ exceeding two degrees, the equations are:

G.—*Revenge*, light draught, with bilge keels $-\frac{d\theta}{dn} = .084\theta + .019\theta^2$

H.— " deep " " " $\frac{d\theta}{dn} = .065\theta + .017\theta^2$

In the text of the paper the extraordinarily large variations in the coefficients of the equations with and without bilge keels are discussed.

For the *Greyhound*, Mr. W. Froude obtained the following equations:—

	Period in Seconds.	Differential Equations.
Without bilge keels, .	About 4.35	$-\frac{d\theta}{dn} = .044\,\theta + .0032\,\theta^2$
With bilge keels, ..	4.33	$-\frac{d\theta}{dn} = .035\,\theta + .05\,\theta^2$
" " " ..	3.88	$-\frac{d\theta}{dn} = .0198\,\theta + .0462\,\theta^2$

In this case the bilge keels were fitted for experimental purposes, and were of great proportionate depth and area for the size of the ship.

NOTE II.

Following the method of the late Mr. Froude (see "Naval Science," October, 1872), the relation between the decrement of roll (loss of range per swing) and the normal pressure on bilge keels of specified dimensions and given position on a ship is obtained thus:—

W = displacement of ship in pounds.
m = metacentric height in feet.
T = period of ship in seconds for a swing from out to out.
A = area of bilge keel in square feet.
r = mean effective radius in feet of the normal pressure on bilge keels from the axis of oscillation. (It will be sufficiently correct if, at any point in their length, the radius be measured from the mid-depth of keel to the middle line axis through the ship's center of gravity.)

C = coefficient of normal pressure in pounds per square foot of bilge keel area oscillating with a mean velocity of 1 foot per second.

θ = mean of the extreme angles of inclination from the vertical at the beginning and end of a swing.

$d\theta$ = extinction or angle from the vertical lost per swing.

If θ_n and θ_{n+1} be the angles of inclination from the vertical at the beginning and end of the n^{th} swing, then—

$$2\theta = \theta_n + \theta_{n+1}, \qquad \text{and } d\theta = \theta_n - \theta_{n+1}.$$

The work of resistance of bilge keels during any swing can only be done at the expense of an equivalent amount taken from the energy possessed by the ship at the commencement of that swing, and will be measured by the loss of dynamical stability during the swing.

Hence after integrating the resistance work function over, say, the n^{th} swing, and equating this to the corresponding loss of dynamical stability, we obtain for values of θ within limits for which the curve of stability is practically a straight line—

$$\frac{Wm}{2}(\theta_n^2 - \theta_{n+1}^2) = \frac{2}{3}\frac{\pi^2}{T^2}.\, C A r^3 (\theta_n^3 + \theta_{n+1}^3)$$

which is approximately

$$Wm\,.\,\theta\,.\,d\theta = \frac{4}{3}\frac{\pi^2}{T}\; C A r^3 \theta^3. \qquad (1).$$

In estimating the loss of range per swing ($d\theta$) for the *Royal Sovereign* class, taking the ships under average conditions, $W = 32{,}000{,}000$ pounds; $m = 3.75$ feet; $T = 7.75$ sections; $r = 40.5$ feet; $A = 1{,}170$ square feet (both bilge keels), we get by substitution in (1) above, on the assumption that C is $= 1.6$ pounds, for the case of $\theta = 20°$, or $\frac{\pi}{9}$ in circular measure.

$$d\theta = .0285, \text{ or } 1.63 \text{ degrees}.$$

Where greater accuracy is desired, and in most cases where the angle of inclination from the vertical exceeds 10° to 12°, it would be better to take the value of $G Z$ obtained from the curve of stability in place of $m\theta$, and to measure the dynamical stability by the corresponding area of the curve of stability.

NOTE III.

To find the value of the coefficient for normal pressure on the bilge keels of the *Revenge*, on the assumption (*i*) that the whole of the observed increase in extinction value due to their addition may be credited to the work of their resistance whilst oscillating; (*ii*) that the resistance varies as the square of the mean velocity. The observed increase in extinction value will be measured by the ordinate intercept between curves *C* and *E*, or between *D* and *F*, according as ship is at her light or deep draught respectively.

Assumption (*ii*) implies that the bilge keel extinction value at any angle (θ) is a term with some b coefficient, say—

$$-\,d\theta = b_1\theta^2. \qquad (2).$$

Combining this with equation (1) of Note II, viz:

$$Wm\,.\,\theta\,.\,d\theta = \frac{4}{3}\frac{\pi^2}{T^2}\cdot C\,.\,A\,r^3\,\theta^3,$$

we get, on substitution of (2) in (1), and reduction, remembering that (2) is in degrees, and (1) in circular measure—

$$b_1 = \frac{\pi^3\,.\,C\,A\,r^3}{135\;W\,.\,m\,.\,T^2}. \qquad (3).$$

Hence, if at any angle (θ) we take the ordinate intercept between, say, curves *C* and *E*, and divide it by θ^2, we shall get a b_1 value which may be substituted into (3).

An angle of swing of about 10° corresponds to an abscissa value of 5 in Fig. 2, where the intercept between curves *C* and *E* measures .62, and that between *D* and *F* .76. These divided by 25 (that is, θ^2) give a b_1 value of .0248 and .0304 respectively.

From the table of particulars given in the paper (page 5), we have for—

Revenge (deep), $W = 32{,}750{,}000$, $m = 3.86$, $T = 7.75$, and $r = 40.25$.

Revenge (light), $W = 29{,}950{,}000$, $m = 3.29$, $T = 8.4$, and $r = 41$.

For both conditions $A = 1{,}170$.

Substituting in equation (3), which may also be written—

$$C = \frac{135\ W . m . T^2 b_1}{\pi^3 A r^3} \qquad (4).$$

we get—

$$C = 10.7 \text{ (deep draught),}$$
$$C = 11.3 \text{ (light draught).}$$

If the intercepts for an abscissa value of 2 (that is, a swing of 4°) be similarly treated, the corresponding values of C will be found to be 15.3 and 16.4 respectively. For a swing of 14° its value will be rather less than 8.

Instead of crediting the *whole of the increased extinction value* to the bilge keel area coefficient, (*iii*) we may assume for purposes of calculation that the bilge keels are responsible only for that portion of the increased extinction represented by the excess in the value of b in the approximate equation to the curve of extinction for the ship with keels over the value of b in the equation of the corresponding curve of extinction for her with no keels.

In the equations for the *Revenge*, light draught, given in Note I, these b values are .019 and .0028—their difference, .0162. For *Revenge*, deep draught, they are .017 and .0025—their difference, .0145.

Substituting in formula (4) above, these values are found to be—

$$C = 6.25 \text{ (deep draught),}$$
$$C = 6.1 \text{ (light draught).}$$

These values are, of course, constant for all angles of swing between those limits within which the approximate equations to the curves of extinction are deemed sufficiently accurate.

With the first assumption made (viz: (*i*) above) this coefficient varied with the magnitude of the swing, and, within the range of the experiments, its value varied from less than 8 to about 16; with the second assumption (viz: (*iii*) above) its value was over 6, and constant up to about the largest angle reached in the ship.

It will be understood that these results are not given as even approximate values of the true coefficients for bilge keel resistance. They are derived from certain assumptions as to the values the coefficients must have, if the whole or part of the observed extinction were referred to the bilge keels.

NOTE IV.

In any estimate of the extent of wave making disturbance produced by an oscillating ship, we must equate the work of that portion of her extinction value (or loss of range per swing), which varies as the single power of the velocity, to half the total energy of the two half waves (*i. e.*, one on each side created at the surface each swing. The wave system maintained only travels at half the speed of the individual waves, the ship has therefore only to supply energy for half a wave per swing.

In this case—

$$-d\theta = a\theta.$$

The work due to loss of range per swing, as in Note II —

$$= W.m.\theta.d\theta \text{ foot pounds}$$

becomes, therefore—

$$Wma\theta^2 \text{ foot pounds.}$$

Following the method of the late Mr. Froude (see *Naval Science*, July, 1874) let—

h = height in feet from hollow to crest of wave created.

l = its length in feet, from crest to crest.

s = its width in feet along the crest. This must approximately equal the length of the ship.

The total energy of a complete wave = $16\,lsh^2$ approximately.

Hence, we must have—

$$Wma\theta^2 = 8\,lsh^2, \qquad (5)$$

to fulfil the conditions stated above.

The length of a wave is approximately $5\frac{1}{8}$ times the square of its period, and since the waves are created by swings of the ship, they will be co-periodic—that is, the period of the wave will be identical with the period of the ship for a double swing from out to out and back again. Hence—

$$l = 20.5\,T^2.$$

substituting in (5), we get $Wma\theta^2 = 164\,h^2sT^2$.

that is

$$h = \frac{\theta}{T}\sqrt{\frac{Wma}{164s}} \qquad (6).$$

From the particulars for the *Revenge*, say, at deep draught, given above, we have

$$\frac{m}{s} = \frac{1}{100} \text{ approximately.}$$

$T = 7.75$. $W = 32,750,000$. $a = .0123$ (no bilge keels).
$a = .065$ (with bilge keels).

Substituting in (6), we get— $h = .64\,\theta$ (no keels).
$h = 1.48\,\theta$ (with keels).

In the *Revenge* experiments with no keels, the greatest angle from the vertical reached was about 13 degrees, that is, $\theta = \frac{9}{40}$ in circular measure; with keels the angle was about $5\frac{3}{4}$ degrees, that is, $\theta = \frac{1}{10}$. These give $h = .145$ (no keels), or .148 with keels. For the *Revenge* at light draught the corresponding values of h are .135 and .138.

We thus see that a wave less than 2 inches in height will account for the whole of the surface disturbance indicated, even at the greatest angles reached, by the experiments with the *Revenge*, either with or without bilge keels.

The "shoring ribbands" on the sides of the ship, entering and leaving the water with each swing, caused some surface disturbance which would have certainly masked, and so interfered with the detection of these small waves, less than 2 inches in height, as we see, even if it had been otherwise possible to observe them in open tidal waters. The immersion and emersion of the shoring ribbands, no doubt, caused some increase of fluid resistance to rolling. Whatever the extinctive value due to them may have been, these ribbands were operative throughout all the experiments.

FIG. 1.

CURVES OF DECLINING ANGLES

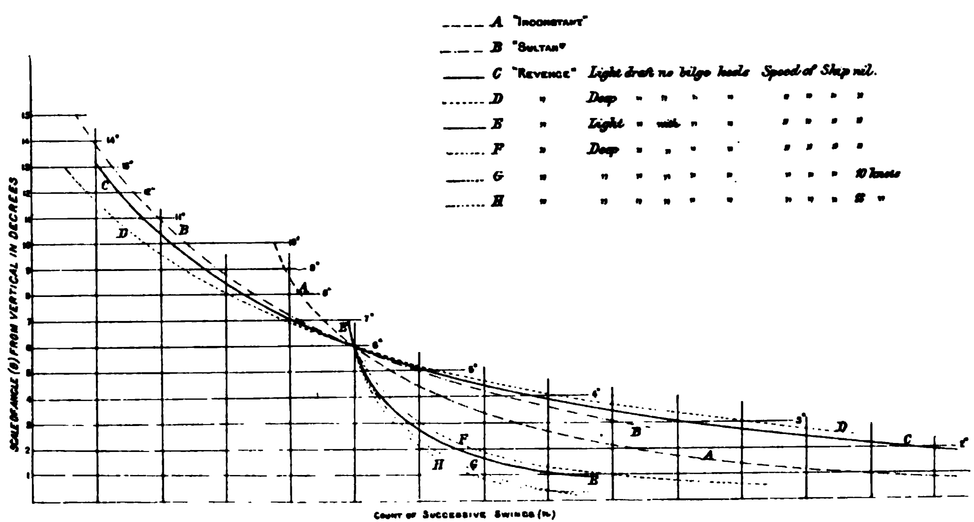


FIG. 2.

CURVES OF EXTINCTION

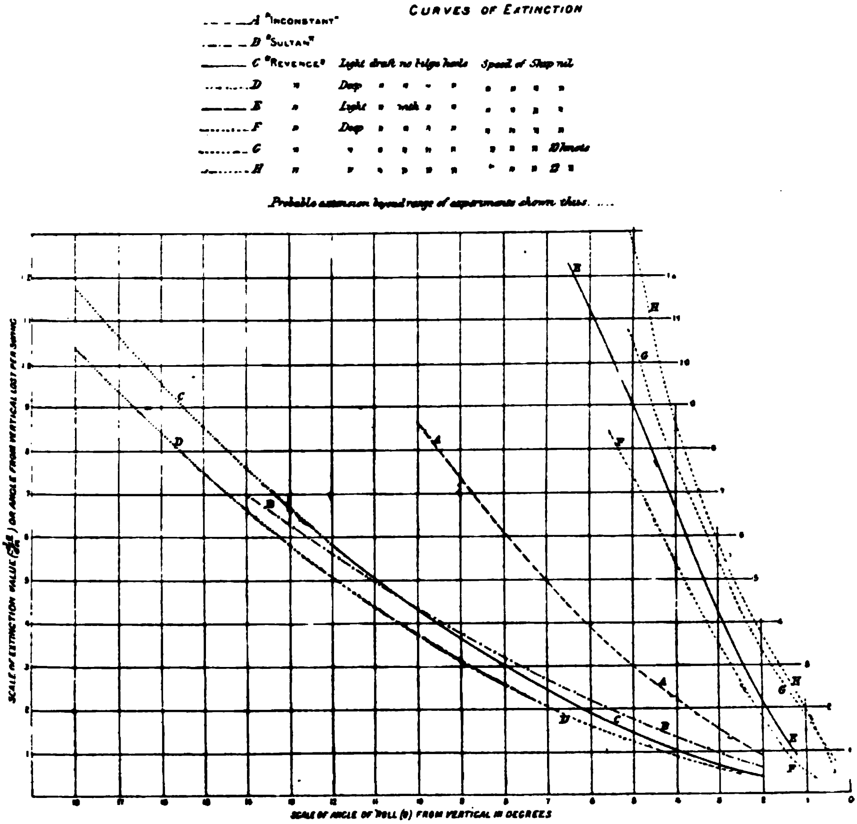


FIG. 3.

CURVES OF EXTINCTION FOR "REVENGE"

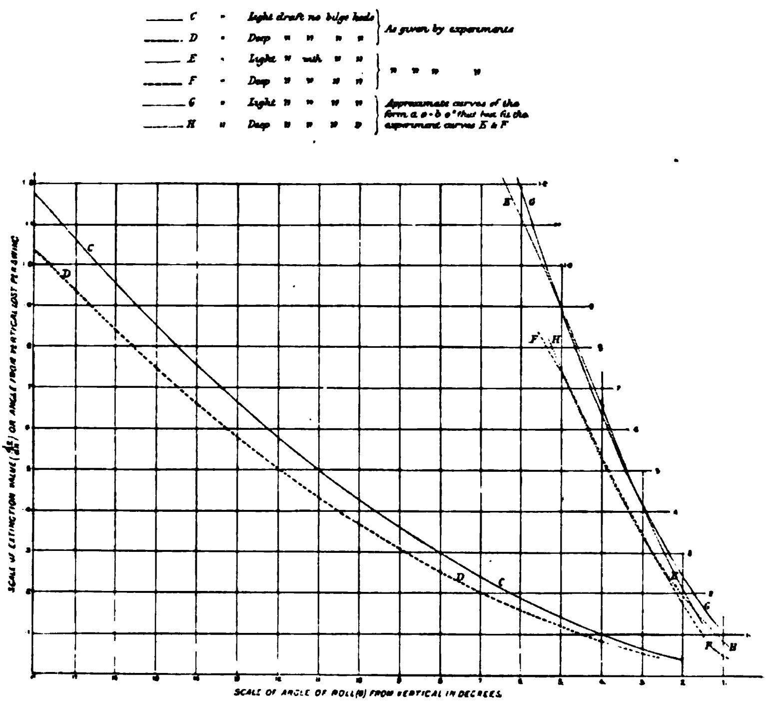
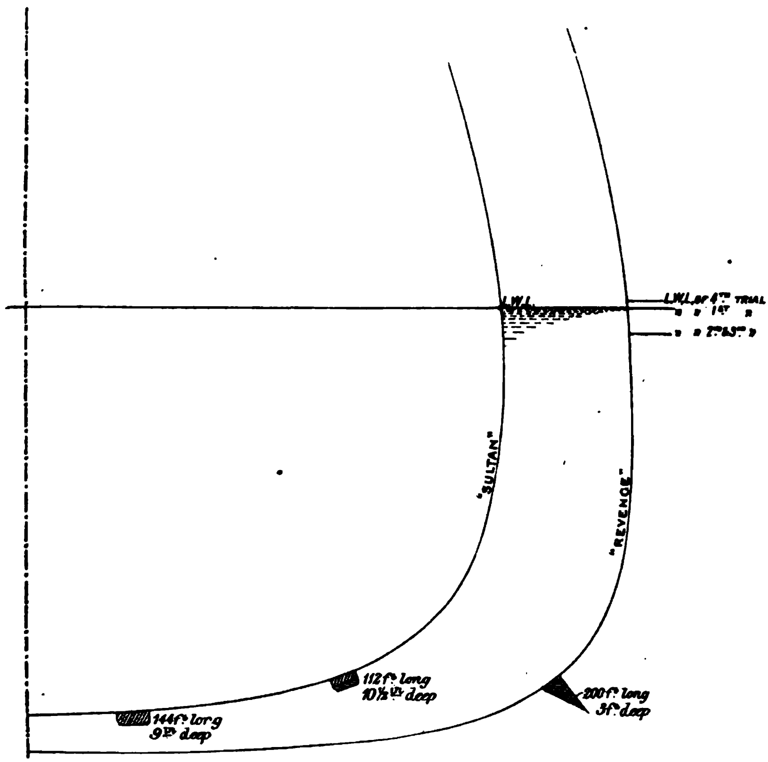


Fig. 4.

Midship Sections, Showing Size and Positions of Bilge Keels.



NEW REVENUE CUTTERS.

BY FIRST ASSISTANT ENGINEER CHAS. A. MCALLISTER, U. S. R. C. S.

On June 26th bids were opened at the Treasury Department for the construction of two first class revenue cutters, one for service on the Great Lakes, to be stationed at Milwaukee, Wis., and the other for service on the New England coast, to be stationed at Boston, Mass. The contract for the construction of the Milwaukee cutter has been awarded to the Globe Iron Works of Cleveland, Ohio, at their estimate of $148,700, and the Boston cutter will be built by the Atlantic Works of East Boston, for $159,951. The general dimensions of both boats are: Length over all, 205 feet; length between perpendiculars, 188 feet; breadth of beam molded, 32 feet; depth of hold amidships, 17 feet. The Milwaukee cutter will have a displacement, at a mean draught of 10 feet 9¾ inches, of 906 tons; the Boston cutter will displace 980 tons at a mean draught of 12 feet 3 inches. The general design is practically the same for both boats, with the exceptions that the Boston cutter is of composite build and brigantine rigged, whereas the Lake vessel will be built entirely of steel and schooner rigged. It may be noted that the new Boston cutter will be the first modern vessel for this Government to be of composite build. The following are some of the details of her construction: In addition to the flat keel plate, of 20 pounds per square foot, there will be a main wooden keel of yellow pine or Oregon fir sided, 14 inches by 14½ inches in depth, the lower edge of the rabbet for the garboard strake being 7 inches above the bottom of keel; there will also be a false keel of white oak, 14 inches in width and 3 inches thick, fastened to the main keel by 6-inch composition spikes. The lower parts of the stem, stern post, rudder post and the rudder frame will be of manganese bronze. The upper parts of the stem, stern and rudder posts will be of the best hammered iron, and scarphed and riveted to the lower parts of the same. The planking will extend from the keel to about two feet above the load water line, amidships. It will be of the best quality of yellow pine or Oregon fir, and will have a thickness, with the exception of the garboard strake, of 5 inches. At the keel the garboard strakes will be 7½ inches thick, tapering to 5 inches at the outer edge. The upper edge of the top strake will be protected by a beveled angle bar, 3 by 3 inches, of 7 pounds per foot, worked from stem to stern and calked water tight to the outside plating. The fastenings will be of bronze bolts and nuts, $\frac{15}{16}$ inch diameter at the shank. The heads of the bolts will be let into the planking about ⅞ of an inch, the recess over the heads to be filled either by plugs or Portland cement. The steel plating for both vessels will be of the best quality of mild open hearth steel, the requirements for which are that it shall have a tensile strength of not less than 55,000 pounds per square inch, and an elongation, in a length of 8 inches, of not less than 25 per centum.

With the exception of a small forecastle deck, both vessels will be flush decked; the captain's and officers' quarters will be located aft, on the berth deck, and will be roomy, and fitted up with all conveniences. The petty officers' and crew's quarters will be forward. In the house on the main deck will be the ship's galley, officer's lavatory, executive officer's office, engineer's workshop, boatswain's locker and lamp room. The pilot house and chart room will be located on top of the main house.

Through the stem of each vessel there will be a 15-inch torpedo tube, to be used for launching torpedoes, in case these revenue cutters should be used as auxiliaries to the Navy in time of war. Their regular armament will consist of one 6-pounder rapid fire gun mounted on the forecastle deck, and two 1-pounders mounted on the rail just abaft the mainmast. Each cutter will carry four boats, including a 30-foot steam launch. It is expected that the new vessels will be able to maintain a cruising speed of 16 knots an hour; for short runs, they will, no doubt, make as high as 17½ knots. There is no contract requirement for speed, and consequently no premiums will be awarded. The specifications require that the engines shall be able to make a successful run of at least eight consecutive hours, working off at 160 pounds pressure all the steam the boilers will make with clean fires, using free steaming coal, to be selected by the superintending engineer.

The propelling machinery for these vessels will be of the same design, with the exception of the manner of securing the sea and injection valves to the hull. Although the lake vessel will be in fresh water, the possibility of her being transferred to the coast at some future date, has caused every appliance, such as surface condenser, distilling apparatus, zinc protection, etc., to be specified for her machinery. The total indicated horse power of the main engine, air and circulating pump engines will be about 2,000, when the main engine is making about 160 revolutions per minute. There will be one vertical, inverted cylinder, direct acting triple expansion engine, with a high pressure cylinder, 25 inches, an intermediate pressure cylinder, 37½ inches, and a low pressure cylinder, 56¼ inches in diameter, with a common stroke of 30 inches. The high pressure cylinder will be forward and be fitted with a piston valve; the intermediate and low pressure cylinders will each be fitted with a double ported slide valve. The framing of the engine will consist of three wrought steel columns at the front, each 6 inches in diameter, and three cast iron columns at the back, the latter forming a part of the three sections of the main condenser. The valve gear will be of the Stephenson type, with double bar links; the intermediate eccentrics will be worked on the coupling of the two sections of crank shaft. The engine bed plate will be of cast iron, in one section, and be supported on a foundation built up from the frames of the ship; a feature of this foundation is that it will be extended aft under the thrust bearing, the top plate of the foundation being ⅝-inch steel plate. In addition to this, the thrust bearing will be secured to the bed plate by means of lugs cast on the same. The crank shaft will be 10½ inches in diameter, forged solid and in two sections. All the shafting, as well as the piston rods, connecting rods, eccentric rods, valve stems and reversing shaft will be of the best mild open hearth steel. The main condenser will be cast in three sections, securely bolted together and forming a part of the framing of the engine. The total cooling surface will be about 3,000 square feet, measured on the outside of the tubes. The tubes will be 1,253 in number, ⅝-inch outside diameter, No. 18 B.W.G. in thickness, and 14 feet 5 inches long between tube sheets. There will be one vertical, independent, single acting, twin air pump worked by two steam cylinders. The diameter of the steam cylinders will be 9 inches, of the pump cylinders 20 inches, and a common stroke of 12 inches. The pump cylinders will be of cast iron with composition linings. The circulating pump will be independent, and of the centrifugal type, having a discharge nozzle 10 inches in diameter. The pump will be driven by a vertical engine, 8 inches in diameter and 8 inches stroke. The main and auxiliary feed pumps will be of the vertical duplex type, having steam cylinders, 8 inches in diameter, water cylinders, 5 inches in diameter, and a stroke of 12 inches. The water ends of these pumps will be entirely of composition, Naval standard, and be provided with water pistons of composition. A special fire pump will be provided, of the vertical duplex type, having steam cylinders 14 inches in diameter, water cylinders 8½ inches in diameter, and a stroke of 12 inches. There will be a complete distilling apparatus, capable of producing 3,500 gallons of potable water every twenty-four hours.

The propeller will be four bladed and of maganese bronze. The engineer's workshop will be on the main deck and will be equipped with a lathe, planer, drill press and shaper; all to be run by an independent engine. The electric light plant will be located in the upper engine room and will be complete in every detail. The dynamo will be of 10 kilowatts capacity, working at 80 volts. The engine will connect direct to the dynamo and make about 500 revolutions per minute. There will be 140 fixed lights of 16 candle power each in the various compartments of the vessel.

A powerful search light will be erected on top of, and be controlled by a hand wheel within the pilot house.

Steam will be supplied by four single ended boilers of the horizontal, return fire tube type. Each will be 11 feet 6 inches, outside diameter, and 10 feet long over all. The total heating surface will be about 5,200 square feet, and the total grate surface, 168 square feet; each boiler will have two corrugated furnaces, 42 inches internal diameter. The shell of each of these boilers will consist of two plates only. Each plate of the shell will be about 18 feet long and 9 feet 6 inches wide. Although it will take nearly a 10,000 pound ingot for each plate, no trouble has been found in placing the orders for this material. All plates used in the construction of the boiler will be of the best mild open hearth steel. Longitudinal specimens cut from the shell plates must show a tensile strength between 58,000 and 67,000 pounds per square inch and an elongation in a length of 8 inches, of not less than 25 per cent. The elastic limit shall in no case be less than 29,000 pounds per square inch. The tensile strength of furnace and flange plates must be not less than 50,000, nor greater than 60,000 per square inch, and the elongation in a length of 8 inches not less than 28 per cent. The boiler tubes will be of the best charcoal iron, 2½ inches in external diameter. The ordinary tubes will be No. 10 B.W.G. in thickness, and the stay tubes No. 6 B.W.G. There will be one athwart ship fire-room. The uptakes from the four boilers will unite to form the base of the smoke stack, which will be double and 6 feet 9 inches in external diameter. The closed fire room system of forced draft will be used and arrangements will be made to make the fire room as nearly air tight as possible. There will be two fire room blowers of the Sturtevant type, provided with air ducts from the two 19-inch ventilators and discharging directly into the fire room.

In addition to the above cutters, plans and specifications are now being prepared for a cruising cutter intended for use on the Pacific Coast at a cost not to exceed $200,000, and a small cutter for use in San Francisco harbor, at a cost not to exceed $50,000. The Pacific Coast cutter will be about 220 feet long over all, 200 feet long on the water line, 32 feet 10 inches extreme beam, 12 feet 3 inches mean draught, and have a displacement of about 1,000 tons. She will be a single screw vessel, having a triple expansion engine capable of developing 2,000 horse power. The San Francisco boat will be 110 feet long, and have a triple expansion engine capable of developing about 500 horse power. There are also in construction for this service the revenue cutter, *Windom*, for the Baltimore station, the steam launch, *Tybee*, for Savannah harbor, and two 65-foot launches for service in Puget Sound.

NOTES.

THE RUN OF THE *COLUMBIA*.

In order to test the ability of the *Columbia* to maintain high speed along the trade route of the North Atlantic, the Navy Department ordered that, after being docked at Southampton and having her bottom cleaned, she proceed to New York under all boilers and her three engines, using natural draft except during the last 24 hours, when mild forced draft was to be used. Her departure from Southampton was somewhat delayed on account of slight straining she received when docked, the report on which will be found at the end of this account.

She left Southampton at 12·30 P. M. on Friday, July 26, passed the Needles at 2 P. M., and arrived at Sandy Hook at 8·59 A. M. on Friday, August 2, having made the run of 3,090 miles in 6 days 23 hours and 49 minutes, or at an average rate of 18.41 knots.

The daily runs were 405, 460, 462, 450, 455, 453 and 405 miles to Sandy Hook lightship.

The entire run was made under natural draft, as it was found impracticable on the last day to transport coal from the distant bunkers rapidly enough to supply the furnaces. The coal burned was limited to 200 tons during the first two days, and to 225 for the four succeeding days. The total amount burned was 1,475 tons, or at the rate of 212 tons a day for all purposes. The auxiliaries consumed about 11.33 tons per day.

When she started, the *Columbia* drew 26 feet 3 inches forward and 25 feet 6 inches aft, with the after trimming tanks full, thus being down by the head, from which cause she shipped considerable water from time to time. On her arrival at New York, the draught was 20 feet 10 inches forward and 24 feet 4 inches aft.

The mean draught for the run was, then, 23 feet 14¾ inches, corresponding to a displacement of about 8,152 tons. The displacement on her acceptance trial was 7,350 tons.

The weather was generally fair, with westerly winds, except on the 30th of July, when it became necessary to slow down for four hours on account of fog and heavy weather.

The following is a brief summary of the log for the several days of the run:

Friday, July 26.—Passed the Needles at 2 P. M., and the Lizard at 9.50 P. M.; making from 18 to 19 knots in the Channel. Light westerly wind.

Saturday, July 27.—Moderate sea; light to fresh northerly wind. Distance run to noon, 405 miles. Coal, 196.25 tons. Average revolutions of engines: Starboard, 97.2; port, 97.3; center, 96.6. Leaky tubes in one boiler rendered that boiler useless for seven hours.

Sunday, July 28.—Gentle breezes, smooth sea. Distance run, 460 miles. Coal, 201.25 tons. Average revolutions: Starboard, 104.1; port, 103.9; center, 103.7.

Monday, July 29.—Smooth sea, fresh S.S.W. wind. Distance run to noon, 462 miles. Coal, 225.50 tons. Average revolutions: Starboard, 105.8; port, 105.8; center, 105.7.

Tuesday, July 30.—Fresh breeze from W. by S. Distance run to noon, 450 miles. Coal, 229.75 tons. Average revolutions: Starboard, 103.2; port, 103.3; center, 102.6; Slowed for four hours on account of fog and heavy sea.

Wednesday, July 31.—Fresh breeze from W.S.W. Distance run to noon, 455 miles. Coal, 230 tons. Average revolutions: Starboard, 105.9; port, 105.9; center, 105.1.

Thursday, August 1.—Fresh breeze from W.S.W. Distance run to noon, 453 miles. Coal, 230 tons. Average revolutions: Starboard, 105; port, 104.9; center, 104.4.

Friday, August 2.—Passed Sandy Hook lightship at 8.59 A. M. Distance run since preceding noon, 405 miles. Coal burned to 9 A. M., 221 tons. Coal on hand at noon, 328 tons.

From the Needles, England, to Sandy Hook, N. Y.—

	1	2	3	4	5	6	7
Distance run	405	460	462	450	455	453	405
Coal burned for steaming purposes, tons	168.9	189.9	214.7	218.5	218.6	218.6	211.1
Steam pressure at boilers	140	134	131	128	135	133	128
Revolutions—Starboard	97.2	104.1	105.8	103.2	105.9	105	104.4
Port	97.3	103.9	105.8	103.3	105.9	104.9	104.4
Center	96.6	103.7	105.7	102.6	105.1	104.4	102.3

This run of the *Columbia* must be considered a remarkable one for a man-of-war, and demonstrates that the two vessels of this class are capable of maintaining, under natural draft, over long distances at sea, a speed inferior only to that of a few of the "ocean greyhounds," and almost equal to that of vessels of her class in foreign navies on their forced draft trials.

The maximum speed for any one hour of the run was 20.6 knots, and for four hours, 80.5 miles.

It will be of interest to compare this run with the *best* runs of the transatlantic steamers going over the same course.

	D.	H.	M.
Fürst Bismarck	6	10	32
Normannia	6	12	30
Paris	6	16	43
New York	6	17	14
Augusta Victoria	6	20	22
St. Louis	6	18	47
U. S. S. *Columbia*	6	23	49

The time of the first trip of the *St. Louis* was 7 days 7 hours and 11 minutes.

Extract from the report of the Board appointed to examine the hull of the *Columbia*:

"In general, the actual damage is slight, it being confined to loose and leaky rivets and a few leaky butts and seams in the flat keel plates and to dents in the flat keel plates and garboards. These dents occur evidently where the ship rested on the keel blocks at Southampton, and are all located at the outer edges of it on the flat keel plate and in the seam of the keel plates and garboard, or at an average of 17 inches from the vertical keel.

The starboard side has suffered markedly more than the port. The damage to the keel and garboard is greatest at the fore end, just abaft the buckle, where the keel begins to cut up, and noticeably decrease aft, until all damage, even to the cement, disappears forward of the engine room. Forward of the knuckle nothing has been injured. Five of the seven long stanchions in the fire room, reaching from the protective deck to the inner bottom, are buckled, the worst having a permanent set of 1½ inches. No plates or angles are cracked. Four rivets are sheared sharp off, which secure a floor bracket to the frame bar within the double bottom.

"Two brackets, two floor plates, two water tight floors and the vertical keel are buckled, none of them seriously. We find no damage to the machinery has been sustained.

"We find that the cause of the damage and injury sustained by the hull of the *Columbia* by the docking at Southampton was generally careless and unskillful docking, as shown by apparent neglect of most elementary precautions to secure the uniform support of the keel of the ship. The immediate cause of the dents and bruises to the bottom plating of the *Columbia* was that the keel blocks in Southampton were not properly aligned, and did not bear equally, and that each block was not squared off to give support to the flat and level surface of the flat keel. On the contrary, the keel blocks had been repeatedly used, and by bar keel vessels, so that they were crushed down in the center to such an extent that, when examined, as soon as the water was out of the dock at Southampton, a considerable number showed no bearing whatever on the flat part of the keel, and only bore on the outer edges on the bottom plating. Wedges were driven between the keel and the center of these blocks at the request of the officers of the *Columbia*. A vessel was floated out of the Southampton dock just before the *Columbia* was taken in.

"A serious contributory cause to the damage was that the keel blocks were not built up forward, where the forefoot is cut away from a point 107 feet abaft the forward perpendicular. This very considerable proportion of the length of the ship was left entirely unsupported, and was only shored up some time after the dock was pumped out, at the request of the officers of the ship, an ineffectual method of taking the weight, if promptly and properly done. No bilge blocks were used, and the bilge shores were only put in when requested.

"The following repairs are recommended:

"Loose rivets to be cut out and redriven, leaky butts and seams to be caulked and reriveted where necessary, bent bracket frames to be straightened and reriveted, broken and cracked cement to be replaced. The estimated cost for this labor is $475, and the material $50; a total of $525, and the total time required, twelve days.

"It will be noted that the fire room stanchions showed slight increase in buckling after the ship was docked on the 12th instant, although the ship rested equally on fair, true blocks, built up forward to a point 46 feet from the forward perpendicular, therefore we recommend that these stanchions be renewed when opportunity occurs after the ship is afloat. Estimated cost of six new stanchions is: Labor, $275; material, $200; time required, eight days."

U. S. S. *NEW YORK.*

The following table gives the results of the recent run of this vessel from Southampton, England, to New York:

Date	May 18–28, 1895.
Running time, hours *	242.42
Average revolutions of engines, per minute	78.60
steam pressure, at boilers, in pounds per square inch	144.3
vacuum, in inches of mercury	24.72
revolutions, double strokes, of air pump	17.47
coal burned, in pounds per hour, for steaming purposes	7,170
speed, in knots, by patent log	13.77
indicated horse power, including air and circulating pumps	2,991
displacement, in tons	8,550
Propellers: Diameter, 16 feet; mean pitch, 21 feet; total helicoidal area of one propeller, 69.093 square feet.	
Number of engines in use during run	2

* For 22 minutes of this time the engines were backing.

THE ACCIDENT TO THE TORPEDO BOAT *ERICSSON*.

The following notes were prepared by Assistant Engineer Edw. L. Beach, U. S. N., Inspector of Machinery for the *Ericsson*.

It will be recalled that during a trial run in 1894, a dowel pin of the starboard low pressure piston rod, connecting piston and rod, worked loose and fell to the bottom of the cylinder. At the next stroke of the engine the piston rod broke at the lower face of the piston, the latter being then thrown up with great force, breaking the top of the cylinder, also the low pressure steam chest, which is part of the same casting as the second intermediate cylinder. No one was injured at this time.

New cylinders were cast by the builders, and one new piston rod was made. When fitting up the new machinery, the piston rod which had been in use in the port low pressure engine was placed in the starboard engine. The superintendent of the works informed the writer that this was done because it would be easier to fit. This is to be remembered, as it had a most important bearing upon the disastrous catastrophe.

For the trials held in 1895 the builders of the *Ericsson* secured the services of Mr. Geo. F. Coleman (as chief engineer), who is well known in connection with the trials of the *Maine*, and is also under contract to run the trials of the *Texas*. Mr. Coleman was empowered to hire what men he chose, and he was able to get experienced men as his assistants. The machinery and pipes were all re-erected under his supervision, and, after numerous preliminary contractors' trials, it was decided, July 17, to make a full power speed trial preparatory to running over the trial course which had been laid out. The boat left its dock at about 8·45 A. M., July 17, ran between the two lightships outside of New London, Conn., turned around and started to run back. She passed the second lightship, and about eight minutes later was enveloped in a cloud of steam, and the men came tumbling up out of the engine room. The main stop valves on deck were immediately shut, the safety valves of the boilers being opened at the same time; this necessarily occupied an appreciable length of time. At the same moment the boat gave a wide sheer to starboard, showing that the starboard engines were stopped. There were five men at the time in the forward part of the engine room attending to the main engine, and three in the after part at the air and feed pumps. These last three were able to get out without burns, save a few trifling scalds on the hands and face of one. The five men in the forward part all succeeded in getting out through the hatch over the condenser. They were all frightfully scalded.

Records taken a moment before the accident showed the engines to be making about 400 revolutions a minute. Steam pressures were as follows: Boiler, 240 and rising; first intermediate receiver, 115; second intermediate receiver, 55; low pressure receiver, 20. Vacuum, 27 inches.

After the engine room was cool enough to enter, it was discovered that the upper part of the starboard low pressure cylinder and steam chest was broken and thrown up a distance of 2 or 3 inches.

A pass-over steam pipe connects the main steam pipe with the low pressure steam chest, and this pipe was carried up by the broken part of the steam chest. This pass-over pipe broke *inside of its valve* just where it is connected by an elbow and nipple to the main steam pipe, the elbow of cast steel, standard, 1½ inches, breaking in its turn, and thus allowing boiler steam to pass from the main steam pipe through the nipple and broken elbow into the open space of the engine room. The elbow was situated a little to port of the middle of the part of the engine room forward of the condenser. As soon as possible the nipple was removed from this main steam pipe, the hole plugged up, and the boat started to return with the port engine running with steam from one boiler only; soon the condenser became hot, as did also the engine room, and it was observed that the exhaust steam from the port low pressure cylinder passed to the top of the condenser, then up through the starboard exhaust pipe to the broken cylinder, and from there to the engine room space. It was necessary to stop the port engine, take down the starboard exhaust pipe, and blank the joint on the condenser; when this was all done the *Ericsson* proceeded on her way with the port engine, running to the dock at New London. No valves are fitted to these exhaust pipes because of the extra weight involved.

On the next day the broken parts of the machinery were taken out. Examination showed the cylinder and steam chest to be broken below the flange, the piston before taken out being cock billed in the cylinder. The piston rod was broken at the lower face of the piston. The low pressure valve was cracked, and the piston, cylinder head and low pressure valve stem were ruined. All these parts must be replaced by new ones. The surfaces of piston and cylinder were absolutely free from any indentation, showing that no foreign piece of metal had got in to cause the break. It has been stated that this piston rod had previously been used in the port low pressure cylinder at the time of the previous accident. At that time the rod was bent and strained and badly distressed about 1 inch below the piston, probably up to, if not beyond, its elastic limit. This rod was then straightened, which further distressed it, and after regrinding, it was placed in the starboard low pressure engine for use. It is believed that the cause of the break was the using of this rod by the contractors, instead of fitting a new one, as should have been done. The strength of the rod itself was ample for all direct loads that could have been put on it, it being of forged steel, $2\frac{1}{8}$ inches in diameter. The broken metal of the cylinder castings gave a combined area of about 112 square inches. If this cast iron had a tensile strength of 20,000 pounds to the square inch, the blow that broke this must have had a striking force of 2,240,000 pounds, or 1,000 tons.

The piston itself was rather loose in the cylinder, there being a play of between $\frac{1}{64}$ inch and $\frac{1}{32}$ inch all around; the fact that the piston was found in a cock billed position shows that it was not tight. The piston itself, though unquestionably strong enough, appears frail and light to one conversant with ordinary engines. When running at the high piston speed of 1,100 feet per minute, with a pressure of 20 pounds per square inch on one side and a vacuum of 27 inches on the other, the piston must have had a movement of its own which might be likened, though greatly exaggerated, to the opening and the shutting of an umbrella. Now, the piston being loose on its sides, and having some play of its own, would it not have a bending effect upon the piston rod? And, after a great number of strokes, might not the strength of the rod be seriously impaired, so that it would unexpectedly break at the ordinary working load?

Again, this cylinder works under conditions entirely dissimilar to the low pressure cylinder of engines generally. At high speeds the latter will make perhaps two double strokes to the second, whereas the *Ericsson* piston will make seven double strokes to the second, so that there will be much more frequent and violent changes of temperature in the low pressure cylinder of the *Ericsson* than in the others. It is to be hoped that the remains of the piston rod will be put in a testing machine, and its strength tested at different parts.

A comparison of the *Cushing* with the *Ericsson* may be of value. The *Cushing* has five cylinder, quadruple expansion engines, there being two low pressure cylinders, each 22½ inches in diameter. The piston rods in this case are 2 inches in diameter. The engines work at the same steam pressure. The combined area of the *Cushing's* low pressure cylinders for one engine is about 800 square inches, and that of the *Ericsson* 707 square inches. The combined area of the *Cushing's* corresponding two piston rods is 6.28 square inches, which for one rod would be equal to a diameter of 2.8 inches. The *Ericsson* has only one rod 2⅛ inches in diameter, the work done in the cylinder being nearly the same.

If the piston has any motion of its own in the cylinder, stiffness and rigidity are much in favor of the *Cushing's* engines, for on the *Ericsson* is the piston of 30 inches in diameter, of nearly double the area, and doing twice the work, with a diameter of piston rod of 2⅛ inches, to the 2-inches diameter rod of the *Cushing* in a 22½-inches cylinder. If there is any such working on the piston rod, due to the spring and motion of the piston, it would be much greater in the case of the *Ericsson*, because this may be said to be a couple in which the arm or lever is longer, and the power applied greater, to withstand which it has a rod only ⅛ inch greater in diameter, or .4 square inch more in area.

Some thoughts have arisen in the mind of the writer, caused by being a witness of the late catastrophe on the *Ericsson*, which are impressed so strongly upon him that he deems them worthy of consideration by those who are to design the torpedo boats which will in time form a very important branch of our Navy.

To begin with, the pipe that was broken was not in the design of the *Ericsson's* machinery, as first sent out by the Bureau of Steam Engineering, and was only allowed after special request by the contractors. This is the first point to note about this pipe; the second point, and one which should never be forgotten, is that this pipe was absolutely never used while the boat was underway. The lesson to be drawn from this is to avoid pipes to be used for remote contingencies; far better to imagine they are remote to occur; get along with one pipe for many services, and avoid many pipes for one service.

2d. As soon as the accident was made apparent the closing of the main stop valves was immediately commenced on deck; during the time this went on, boiler steam was pouring into the engine room. Had there been fitted an automatic valve, which would have immediately shut off steam from the boiler rooms, there need not have been a death resulting, nor anything but trifling scalds. Or, if such an automatic valve could not be depended on in every case, a man might be stationed on deck during trials, who, on the first sign of an accident, could throw down a lever, which would shut a butterfly valve situated in the correct position in the main steam pipe. If one or the other of these plans is adopted, it ought to be conducive to life saving in the future.

3d. A closed engine room will confine steam let loose in it, carrying death and destruction with it. There should be a hatch, open over the whole length of the engine room, the necessary structural strength being given by beams athwartship. A cover could be designed to such a hatch, to be carried always, and to be securely fastened by bolts when the boat is going to sea for ordinary cruising, and which could be left off when on trial trips or running at great speeds for short distances. At the time of the accident to the *Ericsson* the forward middle plate of the engine room had been left off, size 4 feet 8 inches by 2 feet 10 inches.

A great quantity of steam came out of this opening and the two small hatches aft of this. All the steam pipes are at the top of the engine room, just under the deck. Had there been such an open hatch over the *Ericsson's* engine room the steam would not have been confined, and there is reason to believe no lives would have been lost.

4th. Although only an inch and a half steam pipe broke, allowing steam at a pressure of 250 pounds to the square inch to escape into a comparatively small and confined space, in which at the time were five men, yet each of these men was successful in getting out of the engine room, though they had to climb over the circulating pump to the top of the condenser, and thence up a vertical ladder to the deck. In doing this they fell over each other and impeded each other in getting out. With an open hatch, and ladders more conveniently placed, this might not have occurred. The last man out, Strinskey, conceived it his duty to stop the starboard engine before he left. This he did, and this extra delay in all probability caused his death.

The point to be remembered is that all five men got out. The second and third men out both died, not from their scalds and burns, but from the inhalation of steam. The fourth man out was the most seriously scalded, and is now considered out of danger, because, as he informed the writer, he " had sense enough not to breathe steam."

At either end of the engine room are boiler rooms filled with compressed air. Suppose the man stationed on deck, in case of a broken steam pipe, had another connection to his lever so that the latter would not only jam shut the butterfly valve on his end of the engine room, but would also uncover an opening through the lower part of the fire room bulkhead. Would not the lower part of the engine room then become filled with fresh air, and the steam forced up through the open engine room hatches? With such an arrangement the men below, having air to breathe instead of steam, would have much more of a chance for life.

One more point: All engineers will agree that frequent examination is vital to the safety and good care of machinery. For reasons patent to all, this will apply much more to torpedo boat machinery than to ordinary man-of-war engines. And yet the *Ericsson* is so constructed that it will be impossible to examine her cylinders except by taking down about all the steam piping there is in the engine room. There is no good reason why holes over the cylinders should not be cut in the deck overhead, and plates fitted to be securely bolted over these holes. By these means, the engineer would be enabled to examine the machinery under his charge, and would have that confidence which must necessarily be lacking under the present conditions.

RECORD OF AN EXPERIMENT TO DETERMINE THE EVAPORATIVE EFFICIENCY OF A BRAND OF FRENCH BRIQUETTES.

The following record was transmitted by Past Assistant Engineer Howard Gage, U. S. N., under whose supervision the experiment was made.

The briquettes used were obtained by the U. S. S. *Ranger* from a French steamer at Guayaquil, Ecuador. They were made in Havre, France, of Welsh coal slack. Their age was not known. The dimensions of each briquette were 11½ inches by 8⅝ inches by 4½ inches; approximate weight, 17.6 pounds; specific gravity about 1.27. The word "Havre" and an anchor were stamped on one face of each briquette.

It requires about double the time to properly stow bunkers with these briquettes that it does with coal that will run.

The briquettes, at the rate of combustion used in the experiment, burned freely with little flame and almost no smoke; burning to a fine white ash mixed with a moderate percentage of slaggy clinker that formed a partial coating over but did not cling to the grate bars.

Before making the experiment, the sea suction valves to the feed pump were tested and found to be tight. All discharge connections of the feed pump, leading to other than the feed valve of the boiler, were blanked off.

The feed water was taken from the river Guayas. A small barrel, filled from the ash hose, was placed on a platform scale, and each barrel of water used was weighed and then emptied into a larger barrel, from which it was taken by a suction pipe of the feed pump.

The coal was weighed as it came from the bunkers.

The ashes were weighed while in a dry state.

At the beginning of the experiment the heights of the water in the boiler and in the larger barrel were noted, and also the condition of the fires. At the end of the experiment the water in the boiler and in the barrel was brought to the same levels as at the beginning, and the condition of the fires was made as nearly the same as could be judged.

During the experiment, which was carried on while distilling, the steam pressure, pounds of coal consumed per hour, and height of water in boiler were evenly maintained.

The boiler was a cylindrical one with two plain internal furnaces joined to a common combustion chamber, the tubes returning above the furnaces. Material of boiler and tubes, steel. Built in 1892 at the Navy Yard, Mare Island, California. It was tight and clean. The following are the important dimensions:

Diameter of boiler, feet	9
Length of boiler, feet and inches	8–5
Number of furnaces	2
Diameter of furnaces, inside, feet and inches	2–10
External diameter of tubes, inches	2½
Length of tubes, feet	6
Length of grate, feet and inches	5–4
Width of grate, feet and inches	2–10
Grate surface in boiler, square feet	30
Area through tubes, square feet	4.6
Area through smoke pipe, square feet	19.63
Total heating surface in boiler, square feet	736.26
Ratio of grate to heating surface	1 to 24.54
Ratio of grate surface to area through the tubes	6.5 to 1
Height of chimney above grates, feet	45

Results of experiment:

Duration of experiment, 24 hours. (From 1·15 P. M., July 25, 1895, to 1·15 P. M., July 26, 1895.)

COAL.

Total pounds consumed	2,788
of refuse	461
of combustible	2,327
Per cent. of refuse	16.5
Pounds of coal burned per hour	116.1
combustible burned per hour	97
Pounds of coal per square foot of grate, per hour	3.87
combustible per square foot of grate, per hour	3.23

FEED WATER.

Total number of pounds pumped into boiler	19,437.75
Mean temperature of feed water, degrees Fahr.	80
Steam pressure, per gauge, mean, pounds.	22
Mean number of pounds of water vaporized per pound of coal from the temperature of feed water at the temperature of boiler steam	6.97
Mean number of pounds of water vaporized per pound of combustible	8.35
Mean number of pounds of water vaporized per pound of coal from and at 212 degrees	7.96
Mean number of pounds of water vaporized per pound of combustible	9.54

SHIPS.

UNITED STATES.

Battleships Nos. 5 and *6.*—The general features and dimensions of these two battleships, authorized by the last Congress, are as follows:

Length between perpendiculars, feet	355
on load water line, feet	368
Beam, extreme, feet and inches	72–2½
Draught, mean, feet (normal)	23–6
Displacement at this draught, tons	11,500
Speed, knots	16

There will be two balanced double turrets, oval in shape, at each end, the lower part of each turret containing two 13-inch guns, and the upper part two 8-inch guns. The four guns, with their turret, will be revolved together. There will be fourteen 5-inch rapid fire guns on the main deck, protected by casemate of 6-inch armor, and twenty 6-pounder rapid fire guns mounted above and below the main deck, besides ten machine guns.

The engines will be twin screw, triple expansion, and of 10,000 I.H.P. when the engines are working at 120 revolutions per minute, with a steam pressure of 180 pounds per square inch. The general arrangement of machinery will be similar to that of the U. S. S. *Iowa.*

Gunboats 10, 11, 12 and *13.*—Four of the composite vessels authorized by the last Congress. They will be single screw vessels, barkentine rig, spreading 11,000 square feet of canvas, and have been designed specially for distant cruising. Their particulars are:

Length on water line, feet	168
Breadth on water line, feet	36
Draught, normal, forward and aft, feet	12
Displacement on above draught, tons	1 000

Coal carried on above draught, tons	100
Bunker capacity, tons	238
Indicated horse power	800
Speed, knots	12

The framing will be of steel from the keel up to and above the water line ; the upper edge of the wood plank will lap the top side plating about three feet. Plank of Georgia pine will be worked on the frames, secured thereto by composition bolts in such manner as to prevent galvanic action. The outside surface of the plank will be coppered.

No plating will be worked on the under water body of the vessel, except the keel plates, a strip of plating on each side of the keel plates under the boilers to form the lower portion of a water tank and narrow strips for the plates under the longitudinals and bilge keels. The entire top sides will be plated as on steel vessels.

Throughout the machinery space, an inner bottom of plating will be worked, giving added strength to this part of the vessel.

The controlling idea in the design of the machinery has been to secure economy under cruising conditions, and efficiency for long periods; and less attention has, therefore, been paid to reduction of weight than to the attainment of these objects.

The engines are of the vertical triple-expansion type, with cylinders 15½, 23½ and 36 inches in diameter, and a stroke of 20 inches, and have been designed to run at 150 revolutions per minute at full power. The condenser is cylindrical, and contains 1,120 square feet of cooling surface. The air and bilge pumps are worked from the L.P. crosshead, and there is also a connection for running the flushing pump from the engines; the circulating pump is of the centrifugal type. A disconnecting coupling is provided, so that the screw may revolve freely when under sail alone.

The boilers are two in number, of the cylindrical, return tubular type, and are placed in a compartment forward of the engine with a bunker between the engine and fire rooms. They are 10.5 feet diameter and 10.5 feet long, each with two corrugated furnaces 36 inches in diameter, and have a combined grate and heating surface of 78 and 2,500 square feet respectively. The tubes are 2½ inches diameter. Moderate forced draft will be used, the air to be supplied by two blowers delivering through the back of the boiler into closed ash pits.

The battery will consist of six 4-inch, four 6-pounders, and two 1-pounders, and will be disposed in this order: Four 4-inch on the gun deck amidships, two on either side, and two 4-inch on the main deck, one forward and the other aft; two 6-pounders forward on the gun deck, one on either bow, and the other two amidships between the 4-inch guns; the 1-pounders on the main deck.

Gunboats 14 and *15*.—These are two remaining gunboats authorized at the same time as the preceding ones, and differ from them chiefly in having twin screw engines and steadying sail only. The system of construction and the battery are the same as in the single screw boats. Their particulars are:

Length on water line, feet	174
Beam at water line, feet	34
Draught, mean normal, feet	12
Displacement at above draught, tons	1,000
Coal carried on above draught, tons	120
Bunker capacity, tons	250
Indicated horse power	800
Speed, knots	12

From the dimensions above given, it will be seen that the twin screw boats have not as fine lines as the single screw ones.

The engines will be vertical, of the triple-expansion type, and will be placed in a common water tight compartment. The cylinders are 12, 18½ and 28 inches diameter, and have a stroke of 18 inches. The revolutions at full power are intended to be 200. There is one condenser common to the two engines, and of the same size as that in the single screw boats, and the arrangement of pumps and boilers is the same. The grate surface is 78, and the heating surface 2,500 square feet.

Torpedo Boats Nos. 6, 7 and *8*.—These boats are similar in general design and construction to *Torpedo Boats Nos. 3, 4* and *5*, described on page 152 of the current volume of the JOURNAL, but are larger, and have been designed for greater speed. Their particulars are:

Length on water line, feet	170
Breadth at water line, feet	17
Draught, mean, feet	5.5
Displacement, tons	180
Indicated horse power	3,200
Speed, knots	26

The engines are arranged as in the previous design of torpedo boats, each in a separate water tight compartment. They are of the inverted-cylinder, direct-acting, triple-expansion type, with cylinders 14½, 23 and two of 26 inches diameter, and a stroke of 18 inches, and have been designed to run at about 400 revolutions per minute at full power. The valves are of the piston type, one for the high and two for the intermediate and low pressure cylinders, and are worked from a counter shaft geared to the crank shaft. The propellers will be about 6 feet diameter and about 7.5 feet pitch.

Steam at 250 pounds pressure will be furnished by three water tube boilers, two of which will be placed in a compartment forward of the forward engine, with a common fire room between them, and the other in compartment abaft the after engine room.

The total weight of machinery with water, spare parts, etc., is not to exceed 92 tons.

The appropriation for the construction of each of these boats, including armament, is limited to $175,000.

The trial will be of two hours' duration, during which the speed must average 26 knots, with a penalty at the rate of $10,000 a knot down to 25 knots.

ENGLAND.

Terrible.—The first class sheathed cruiser, a few of the particulars of which were given on page 197 of the last volume of the JOURNAL, was launched from the works of Messrs. James and George Thomson, Clydebank, on the 27th of May. The following details are from the "London Times" and "Engineering":

Length over all, feet	538
between perpendiculars, feet	500
Breadth, extreme, feet	71
Depth to upper deck, feet	43.25
Draught, mean, feet	27
Displacement, tons	14,200
Coal capacity, tons	3,000
I.H.P., natural draft	25,000
Speed, knots	22

The hull is built on the double bottom principle, the outer and inner skin being carried up to the level of the protective deck, which is also supported on bulb beams and on the water tight bulkheads. The two bottoms are 4 feet apart at center and 2 feet 6 inches at the bilge, increasing to 4 feet at the protective deck level. In the region of the machinery the depth is increased to 8 feet and the section strengthened. A series of plate girders bind the bottoms together with thwartship intercostals. There is no center line keel, the external keel being the central strake, consisting of two thicknesses of plates. The stem, weighing 15 tons, and the sternpost and A frames, of 50 tons, are of phosphor bronze. To the details of construction we may refer in a subsequent article.

The shell plating is of mild steel. The ends of the plates are secured by double riveted butt straps, and the edges of the plates by double riveted lap joints, the rivets being of steel, and generally $\frac{7}{8}$ inch in diameter. As is now usual in war vessels intended to keep the sea without docking for a great length of time, the steel plating of the hull is sheathed on the outside with 4-inch teak planks which are securely fastened to the steel plates by gun metal screw bolts, the heads of which are let in below the surface of the teak plank to the extent of 1 inch, and this is filled in with Portland cement, to preclude any metallic action between the copper sheathing and the steel shell. The width of the teak planking is about 12 inches, and the spacing of the bolts about 2 feet 6 inches. The seams are caulked thoroughly water tight, and "payed" with pitch, the wood sheathing being finally covered with tarred paper before the copper is nailed upon it. Bilge keels have been fitted, in accordance with the experience with recent battleships. These keels have a depth of about 3 feet and extend for a length of 224 feet. They are formed of solid logs of teak, V-shaped in section, secured to the shell plating of the vessel by 1-inch gun metal screw bolts screwed through the plating of the outer bottom, and fastened with nuts. The surface of the bilge keels is covered with rolled brass plates, which, at the base of the keel, abut against the copper sheathing, and form a continuation of it. These brass plates are secured by ½-inch wood screws.

The ship has been built specially strong along the machinery space. The bar keel plating forming the central strake is 1¾ inches thick, and the longitudinal girders are here 8 feet deep, although they are only 4 feet deep in other parts of the ship, while the web plates are increased from 20 pounds to 25 pounds per square foot. The sole plate of the engines is bolted to plates 1¼ inches in thickness. These are worked horizontally upon the upper edges of the longitudinal girders. The protective deck beams are 9 inches deep, of angle bulb section, and the 4-inch protective deck is in three thicknesses. The upper frames of Z-bar section, are 14 pounds weight per foot, with plate frames at 10 feet intervals.

The stem, sternpost, rudder, and the brackets for carrying the screw shafts are all made of phosphor bronze, the twin screw propellers being of manganese bronze. The total weight of bronze used is 120 tons, excluding the weight of the twin propellers, which are each 21 tons. The stem weighs 15 tons. It is of the usual ram form now universally adopted by the Admiralty. The ram projects 15 feet beyond the perpendicular line of the bow. The rudder is partly balanced, and has an area of 250 square feet. The rudder frame is also of bronze, and weighs 21 tons. The open spaces between the arms of the frames are filled in with pine, and on each side the rudder is plated over with rolled brass plates.

There is no side armor, but the protective deck has a greater rise of arch than in any cruiser yet built. The crown of the armored arched deck is 3½ feet above the water line at the center of the vessel, while at the sides the edges of the deck join the hull 7 feet below the water level, whereas it is usually only 5½ feet. The rise of the arch is thus 10½ feet, and the deck is 4 inches thick, except towards the fore and after end, where it is 3 inches. It is formed of three layers of mild steel plates riveted together. In this case, moreover, the machinery, although of a vertical type, is wholly under the protective deck, the length of stroke and of the connecting rods of the propelling engines having been reduced, so that the cylinders would not, as in most previous cruisers, project above the deck, and thus necessitate armored protection round the cylinders. Further protection is afforded by coal bunkers extending for the length of the machinery above and below the protective deck, a distance of 252 feet of the central portion of the vessel, or about one-half of the total length. These bunkers form, when filled with coal, a solid belt. The coal thus carried totals 3,000 tons, giving the cruiser a good radius of action. The bunkers are subdivided by water tight transverse bulkheads, so as to limit the loss in buoyancy caused by a shot entering the side of the vessel. Again, the hull is divided into 236 water tight compartments. Some, of course, are of small size, while others, such as those containing the boilers and engines, are of considerable capacity. The space given up to machinery—252 feet long—is divided by a middle line longitudinal bulkhead and several transverse bulkheads into ten compartments, of which two are utilized for the twin set of triple-expansion four-crank engines, and eight for the 48 Belleville boilers. The bulkheads and longitudinal division walls for the coal bunkers are utilized as much as possible for the supporting of the protective deck, in addition to the beams already referred to.

The armament consists of two 9.2-inch, 22-ton guns, twelve 6-inch rapid fire, sixteen 12-pounders, nine machine guns, and four torpedo tubes. One of the 9.2-inch guns is mounted on the forecastle and one on the poop, 32½ and 37 feet respectively above the load water line. They are mounted in barbettes, and are protected by dome shaped armored shields revolving with the gun. Of the 6-inch guns, eight are on the main and four on the upper deck, two on each deck firing ahead and two astern. Two of the 12-pounders also fire ahead and two astern. The 6-inch guns will be most effectively protected by Harveyized steel armored casemates, 6 inches thick, completely surrounding the gun, while the shot and powder are conveyed along passages immediately under the protective deck, and surrounded by the coal bunkers, which form a belt of great depth along the machinery spaces. From this passage to the inside of the casemates the ammunition is raised in an armored tube, so that in no case is it for any time exposed to the enemy's fire.

The conning tower, which is located on the forecastle deck, is circular in plan, having an internal diameter of 9 feet 6 inches, and is formed of 12-inch steel faced armor. The aperture for entry to the tower is protected by a heavy steel shield. All the pipes, wires, etc., passing from the conning tower to below the protective deck, are in a strong armored tube 9 inches in internal diameter and of steel 9 inches thick.

The protective deck is chiefly utilized for the stowage of coal, and also provisions, stores and water. On the main deck, which is the next above the protective deck, and the first above the water line, are mounted eight 6-inch quick firing guns, while the remaining four 6-inch guns are on the upper deck, and the two 9.2-inch 22-ton breach loading guns in barbette on the level above, on the forecastle and poop. The whole of the remainder of the main deck is devoted to the cabins for the officers and the messing and sleeping quarters for the crew, the total complement of officers and men being about 900 all told. Above the main deck is the upper and chief structural deck of the ship, on which are situated commodious quarters for the admiral and captain and their numerous staff at the after end of the vessel below the poop, while at the forward end under the forcastle there is additional accommodation for seamen. The topmost deck, as already stated, is called the boat deck, and has a width of only 16 feet along each side of the ship.

There is a bridge over the top of the conning tower. On the bridge is a chart house, with binnacle, another steering wheel, and the engine telegraphs, &c. At each side of the bridge is also a powerful searchlight. On the top of the chart house again is a flying bridge, this latter navigation platform being 52 feet above the load water line.

Immediately aft of the bridge is the foremast, which carries two fighting tops. In each there will be mounted two quick firing guns, while above this again there is a platform on which a search light is to be mounted. The mainmast carries one military top and a search light platform above. The masts are 36 inches in diameter, and are tubular, with hoists for the ammunition supplies. Each mast is to carry a derrick for lifting in and out the boats. The derrick on the main mast is specially strong, of steel, 18 inches in diameter, for lifting in and out small torpedo boats. Two powerful crab steam winches are fitted on the upper deck for working the after derrick. The largest boat carried has a length of 56 feet. Each mast has two yards, which are not for setting sails, but for hoisting signals. Between the two masts wire rope jack stays are stretched for hoisting additional signals, and there is a second stay on which a traveler can be mounted for lifting the covers of the four funnels, ventilators and heavy weights on the deck.

The steering gear is of the screw type, and is placed immediately under the protective deck and aft over the rudder, which is of the balanced type, and has an area of 250 square feet. The gear consists of a double-threaded right and left-handed screw on an 8-inch shaft, which carries a nut on the right-handed and another on the left-handed portion of the screw. The revolution of the shaft causes the nuts to approach or recede from one another. The motion of the nuts is transmitted to the cast steel crosshead on the rudder stock by means of heavy steel rods 10 inches in diameter and 10 feet long. The rudder stock is cast in one piece with the rudder frame, and is of manganese bronze 24 inches in diameter, but with a 9-inch hole cored in it to reduce the weight. A brass stuffing box has been placed at the point where the rudder stock passes through the sternpost, to maintain water tightness. The weight of the rudder is taken up on a series of eight gun metal rollers 6 inches in diameter, working on a roller path bolted to the sternpost. The steering gear is actuated by two powerful steering engines, each having two vertical cylinders 13 inches in diameter by 10-inch stroke. The engines are in duplicate, to avoid the chance of a breakdown. They are placed in the engine room, and the power is transmitted to the gear by hollow shafting 6 inches in diameter carrying the spur gear. The vessel can also be steered by four handwheels 6 feet 6 inches in diameter placed on the same shaft as the nuts, the gear being connected or disconnected to the steam engine or handwheels at will by a powerful screw clutch.

The whole of the wheel gearing throughout the entire system has been machine cut, so as to reduce backlash and noise to a minimum. The motion of each of the steam steering wheels corresponds to that of the ordinary hand steering wheels, and they are carried on gun metal pedestals, having indices to show the position in degrees of the rudder to starboard or port. In addition to the brass dials, those on the upper deck are fitted with glass segments and lanterns for illuminating the inside at night, and have the necessary figures and the information burned into these glass segments.

The engines are of the four-cylinder triple-expansion type, developing a total power of 25,000 indicated horse power under natural draft conditions. Each set of engines is separated by a longitudinal water tight bulkhead, which extends the whole length of the machinery space. The diameters of cylinders are: high pressure, 45 inches; intermediate, 70 inches, and the two low pressure cylinders, 76 inches, the length of stroke being 4 feet. The high pressure cylinders are placed at the forward end, and are fitted with piston valves of the inside type, having improved adjustable packing rings, while the other cylinders are fitted with treble ported flat valves, having a special type of relief frame to relieve them of steam pressure, and the weight of all the valves is suitably balanced in order to reduce the strain on the valve gear as far as possible.

The cylinders, which are entirely independent castings, are bolted together to provide sufficient longitudinal stiffness; and, to further increase their stability in case of ramming, &c., strong struts are fitted between the high pressure cylinder and the forward structure of the vessel, as well as transversely between the respective cylinders in each engine room. Each cylinder is supported on four cast steel columns. The barrels of all the cylinders are made of special close grained cast iron, and are steam jacketed. The valve gear is of the double eccentric link motion type, and is reversed by means of a double cylinder engine attached to one of the cast steel front columns at the level of the starting platform and beside the starting handles. Each of the reversing levers is provided with screw gear, so that the valves of each cylinder may be linked up independently.

The pistons, cylinder covers and steam chest doors are of cast steel. The pistons and connecting rods are of Siemens Martin steel, and metallic packing has been employed for all the stuffing box glands of the piston rods and valve spindles of the main engines, as well as for all of the auxiliary engines throughout the vessel. The crankshafts are hollow, and each consists of four interchangeable pieces, 20 inches in external diameter at the journals, and 10 inches in internal diameter. The crank arms are cut away as much as possible for lightness and for convenience in fitting the centrifugal lubricators. The thrusts are of the horseshoe type, each with eight collars. The thrust shafts and propeller shafting are also hollow, the shafting being 18½ inches in diameter inboard and 20 inches in diameter outside the ship. As the vessel is copper sheathed, the portions of the shafting aft of the stern tube stuffing box have been cased with gun metal, as described in a previous article. The propellers are three bladed, 19 feet 6 inches in diameter, and work inwards, recent experiments made by the Admiralty warranting this departure. The bosses are of gun metal, and the blades of manganese bronze, secured to the bosses by large forged naval bronze pins.

The tube casings as well as the ends of the condensers are built up entirely of naval brass plates riveted together. The minimum weight possible is thereby secured, and this condition is of the greatest importance, as a combined cooling surface of 25,000 square feet is required in the *Terrible*. The steam is condensed outside the tubes, which are ⅝ inch in external diameter by .05 inch thick, the circulating water passing through them.

The water is supplied by four large 24-inch Gwynne's centrifugal pumps, each being driven by an independent engine. The pumps, with steam of 150 pounds pressure, are capable of discharging 1,500 tons of water per hour from the bilge.

In addition to the two main condensers, there are two for auxiliary purposes having a combined cooling surface of 3,000 square feet. The circulating water is supplied by two 9-inch centrifugal pumps.

Besides the auxiliary engines already noticed, a double cylinder reversible engine is conveniently placed above the starting platform, on one of the aft columns which support each of the aft low pressure cylinders, for the purpose of turning the engines. This is effected by a set of compound worm gearing, the worm-wheels having machine cut gun metal teeth, the main worms being of manganese bronze. These engines are capable of turning the main engines completely round in eight minutes with a steam pressure of 150 pounds, and a hand gear has also been arranged for the same purpose.

There are two air pumps for each main engine, one worked from the high and the other from the forward low pressure cylinder.

The propeller shafts are carried in brackets or A-frames of the form usually adopted by the Admiralty. In the case of the *Terrible* the shaft projects through the side of the ship, overhanging to the extent of 50 feet. The A-frame is pear shaped on plan, the thinnest edge being placed aft, in order to avoid eddy making. The longest axis of the section is 3 feet 9 inches, and the shortest 12 inches. The ends of the A-frame, after passing through the side of the ship to the interior, are flattened out into broad palms, which are secured to strong plate steel girders by steel rivets. The water tightness of the arms where they pass through the shell is maintained by angle iron collars, both inside and outside the shell plating. The A-frames weigh about 50 tons. To guard the shaft against hawsers, etc., there is around it a casing or tube of rolled brass plates, stiffened by longitudinal angle bars.

The platform and orlop decks, being below the protective deck, are utilized for the stowage of ammunition and torpedoes, and also for the steering gear, capstan engine, ventilating and air compressing engines, and for some of the dynamos. Being essential to the fighting efficiency of the ship, these are necessarily put below the protective deck. At each end of the vessel on the orlop deck is a torpedo compartment, each containing two tubes for the discharge of 18-inch Whitehead torpedoes. The fact of the tubes being below the protective deck, and the weapons being discharged below the water level, overcomes the possibility of explosion by the enemy's shell before being ejected. The ammunition magazines are also below the protective deck, and an interesting departure has been introduced in providing an ammunition passage on either side of the ship immediately below the protective deck and right through the lower coal bunkers, that is to say, there are coal bunkers on either side and below the passage, with the protective deck immediately above, and over that again more coal bunkers. The powder and shell for the 6-inch guns on the main and the upper decks will be taken from the magazines and conveyed on trolleys along this ammunition passage until below the gun, where the powder and shot will be hoisted through a protected tube into the armored casemate in which the gun is mounted. Thus the powder and shell are never without protection from the enemy's fire. There is also an ammunition passage on the protective deck on either side of the ship for serving the 12-pounder and smaller guns.

There are in all 48 boilers for the *Terrible*, of seven and of eight elements, located in eight boiler rooms, and arranged symmetrically on each side of the central longitudinal water tight bulkhead. The four after spaces on each side of the vessel contain eight boilers, respectively arranged in three groups, the forward and after groups each consisting of two boilers placed side by side, and the center group of two pairs of boilers placed back to back and fired from awthartship stokeholds.

The remaining 16 boilers are placed in four forward boiler rooms, situated likewise in pairs on each side of the central bulkhead, and fired from longitudinal stokeholds. This difference in arrangement is necessitated by the fineness of form of the vessel at this part. The funnels are four in number, of oval section, one to each transverse division. They are of different cross dimensions, to suit the number of boilers leading to each, but the longitudinal dimensions have been kept the same in all four, in order to accord with the general symmetry of the ship. The height of each funnel from grate is 80 feet. To supply the air required for suitable deflection of the furnace flames and for admixture with the gases for insuring complete combustion, eight air compressing engines are supplied and fitted in the boiler rooms, there being one double cylinder compressor for each of the four large compartments, and a single cylinder compressor for each of the four smaller forward spaces. The air is injected into the furnace from a nozzle box placed on the front of the boiler immediately above the furnace doors, and extending the whole width of the fire grate. This air is discharged over the fire through small nozzles, which divide it into thin streams. The total grate surface is 2,200 square feet, and the total heating surface 67,800 square feet, which should give an ample margin of boiler power even when compared with merchant service proportions. The working pressure in the boilers is 260 pounds and is reduced to 210 pounds in the high pressure steam chest.

In the case of the *Terrible's* boilers, the junction boxes are malleable cast iron, $\frac{5}{16}$ inch thick, and the tubes, mild steel lap-welded, 6 feet 8 inches in length, $4\frac{1}{2}$ inches outside diameter, and varying in thickness from $\frac{3}{8}$-inch for those of the lower, to $\frac{3}{16}$-inch for the uppermost rows. The tubes are screwed into the back boxes, the pitch of the screw on the tube being very slightly different from that of the box, so as to form a metallic joint between them. A jam nut is added for greater security. A similar device is employed for the front ends, with this exception, that, instead of both tubes entering the box, one is connected by means of a screwed coupling nut to a projecting nipple. This arrangement is adopted to facilitate the removal of the tubes which form the elements. The casings which inclose these elements are particularly deserving of notice, from the careful manner in which they have been designed so as to secure the requisite stability, together with a minimum of weight. The radiating surfaces of these casings, as well as of the steam collectors, have been covered with a layer of asbestos 3 inches thick, which is in turn protected by thin plates securely and neatly fastened. The length of pipe in each element is 120 feet.

The main steam pipes are of mild steel, as are also the receiver pipes. On each side of the central longitudinal bulkhead through the machinery space, there are three lines of piping from the boilers to the engines, making four in all.

There are three feed pumps in each engine room and six in the stokeholds, making twelve feed pumps in all.

To effect the efficient ventilation of those portions of the ship underlying the protective deck and of the engine and boiler rooms, 18 steam fans of large diameter are employed. Two fans, 6 feet in diameter, are placed forward of the machinery space, and by means of two large trunks, air is led to the submerged torpedo room air compressing space, and to the capstan engine room, all these compartments being on the orlop deck. Where these trunks have occasion to pass through water tight bulkheads, vertical and horizontal automatic valves are fitted over the opening, so that, in the event of a compartment being flooded, the adjacent compartments are kept intact.

Two fans of the same dimensions as those forward are also placed on the orlop deck abaft of the machinery space, with air trunks extending through the auxiliary machinery space, ammunition passages, 12-pounder and 6-inch shell rooms, submerged torpedo room, and steering compartment, in which latter space the trunk stops. Branches are carried down to the platform deck aft as well as forward, and after supplying the engineers' store rooms, branch trunks are led to the 6-inch magazines, 3-pounder and small arms magazine, torpedo head magazine, gunners' store rooms, and finally to the 9.2-inch shell rooms. The hold is supplied in a similar manner to that already described for the forward compartments. Branches with louvres are led along shaft passages, port and starboard, supplying the 12-pounder and the 9.2-inch magazines. Provision is also made for thoroughly ventilating the double bottom.

An equally efficient service of exhaust trunks is fitted throughout the ship, by which means the foul air is carried aloft. In each of the engine rooms a steam fan 7 feet in diameter has been placed for the purpose of extracting the heated and vitiated air. In connection with the inlet apertures of these fans a system of air trunks has been led to those parts of the engine room where heated air is likely to lodge, so as to draw it off and expel it overboard. In connection therewith, screens, suitably placed in the engine room hatch, are employed to direct the down coming fresh air to the more important positions from which the engines are started or manœuvred. The remainder of the fans are placed in the boiler rooms, two in each of the four after, and one in each of the four forward compartments. These are 6 feet 6 inches in diameter and are double breasted, with a diaphragm plate in the middle, and may be regulated from either the fan platforms or the stokehold floors. The discharge apertures and trunks of these fans have been arranged to insure a uniform supply of air throughout, and in the event of the boiler rooms being closed these can maintain an ample supply of air to all the furnaces.

The air compressing machinery for charging the torpedoes consists of four complete sets of air compressing engines and pumps, and eight sets of air reservoir tubes with separators and charging columns. Two engines are placed in the forward part of the vessel, and the other two in the after end. Each has three air pumps of large size, and all the parts of these engines, as well as of all the other auxiliary engines throughout, are designed to work at the full boiler pressure of 260 pounds per square inch, which will be the pressure ordinarily employed. The air pressure employed is 1,700 pounds per square inch, the tubes for the separators, charging columns, and air reservoirs being made of the best open hearth steel, great care being taken to secure them of a perfectly cylindrical form and of a uniform thickness throughout. Some indications may be given of the excellence of the workmanship employed in the manufacture of this class of machinery, so as to secure perfect tightness of the joints at each of these tube ends, 50 of which form but one air reservoir, and also of the joints of the intermediate pipes connecting them to the air pumps, as well as of the various valves and fittings of the pumps themselves. The whole of the installation was tested to the working pressure of 1,700 pounds per square inch, and allowed to stand under this pressure for 24 hours, when it was ascertained that the loss of pressure was under 6 per cent. To attain this result only the very best materials can be employed, and the greatest care has to be exercised in selecting the copper, as well as in obtaining the most suitable alloys of this metal.

The electric machinery for generating the current for internal lighting, search lights, motors, etc., consists of three large sets of condensing engines and dynamos. The engines are of the open fronted compound type, mounted on the same bedplate, and coupled direct to dynamos which are of the direct current type, self regulating, and each capable of maintaining on continuous running 600 amperes, with an electromotive force of 80 volts, at 300 revolutions per minute. Two of these sets are placed in a compartment adjacent to the main engine room and under the protective deck, the third set being placed on the main deck amidships. The electric light installation consists of about 800 50-candle power and 16-candle power lamps, laid out on the double wired, water tight distributing system. In addition to the lighting up of the interior spaces, including coal bunkers and magazines, the decks will be illuminated by powerful lights suspended from the rigging. The compasses, telegraphs, masthead, side lamps, signal lanterns, semaphores, and military tops are all separately lighted and under the immediate control of the officer on deck. Six search lights of about 50,000-candle power each, are fitted up—two on the forward bridge, two on the after bridge, and one on the top of each mast. Each of these powerful lamps can project a beam of light right round the horizon. Electric motors are to be used throughout in lieu of the usual hydraulic appliance—and this applies not only to the training and elevating of the large guns, but also for the ammunition hoists, etc. Submerged torpedoes will also be fired by electricity from the torpedo director house and conning towers.

The remaining pieces of auxiliary machinery may now be briefly noticed. Amongst the more important are the boat-hoisting winches, which are two in number. The barrels are each arranged to take about 240 feet of wire rope, capable of lifting 17 tons; and the coal hoisting engines, two in number, which are situated on the upper deck. Twelve double cylinder ash hoisting engines, with brake apparatus and automatic stop-gear, are also fitted for removing ashes from each of the stoking platforms and for discharging them overboard. The engineers' workshop is fitted with a double cylinder engine and a complete complement of machine tools, comprising two large and one small lathe, punching and shearing machine, shaping machine, drilling machine, and grindstone, together with a number of benches fitted with vises, the whole making a very complete repairing department. The vessel is also fitted with mechanical telegraphs, and reply gongs between the engine room and the steering positions and to the stokeholds, revolution indicators and counters. Tell-tales, for indicating the direction of rotation and number of revolutions which each of the main engines is making, and a complete system of voice pipes between the engine room and the important stations throughout the vessel are also to be fitted, together with a system of electric bells, pushes and indicators.

The following is a list of the separate engines in the ship:

	Sets.
Main engines	2
Reversing engines	2
Turning engines	2
Main circulating pumps	4
Auxiliary circulating pumps and air pumps	2
Main feed pumps	6
Auxiliary feed pumps	8
Fire and bilge pumps	4
Drain tank pump	1
Distiller pumps	2
Air compressors for air jets in Belleville boilers	8
Fan compressors for stokeholds	12
engine rooms	2
ship ventilation	4
Electric light engines	3
Air compressors	4
Steering engines	2
Boat hoisting engines	2
Coal " "	2
Ash " "	12

	Sets.
Engine for workshop	1
Capstans, fore and aft,	2
Total engines on board	87

Powerful.—A sister ship to the *Terrible* was launched from the works of the Naval Construction and Armaments Company, Barrow, on the 24th of July. Her construction does not differ from that of the *Terrible*, but there are some differences in the engines, the cylinders of which are 45, 70 and 76 inches in diameter and 48 inches stroke, their total length being 45 feet. The engine columns and bedplates are steel castings of box section, instead of H-section, as in the *Terrible.*

The cylinders are all separate in themselves, but are attached to each other at their tops by cast steel connecting pieces. They have thin cast iron liners, which will be adjusted when hot. The pistons are of cast steel, with deep cast iron junk rings, and the cylinder covers are of steel. The high pressure steam chest cover is of steel, and the other covers are of cast iron. There is a piston valve on the high pressure cylinder, and ordinary flat valves, which have the usual relief at the back, for all the other cylinders. The link motion is of the ordinary description, with steam and hand reversing gear, the steam engine for this purpose being placed on one of the intermediate engine columns. Each valve is capable of being linked up independently by means of a screw and block.

The four-throw crankshaft is in four separate pieces, each of which is interchangeable with any other, and this applies to the cranks in both sets of engines. The main and crankpin brasses are of ordinary Admiralty mixture, lined with white metal. The top end brasses, or crosshead bearings, are of a special mixture of hard metal; the crossheads are Swedish iron; the piston and connecting rods and main bearing caps are of forged steel. As is now usual, the large steam pipes are of steel. They have welded seams, over which there is riveted a butt strap. The turning engine is on the end low pressure standard. The worm-wheels of this are of bronze, and the worms of forged steel. There are two air pumps, one worked from the high pressure and one from the forward low pressure engine by means of side levers. The thrust bearing consists of one large steel casting, with horseshoe collars and water service as usual. The propellers are three bladed, about 19 feet in diameter. They are of Admiralty gun metal, with blades bolted to the boss.

The *Powerful* was more complete at the time of her launch than are many vessels of this class when placed in the water. All the armor was in place, and also the gun pedestals and a great deal of the cabin fittings, so that the launching weight was brought up to 7,300 tons. In order to take this weight with safety, the ways had been built out a long distance into the channel, and had been made with 5 feet bearing surface on each side, which is a good deal beyond the average width. The cradle had also been very much strengthened forward, dockyard practice having been followed in its general construction. A built up plate of steel, several feet long fore and aft and $\frac{3}{4}$ inch thick, was passed under the ship's keel, being hooked over the poppet heads —the poppets were almost upright—on each side of the cradle. The whole structure was further consolidated by a large number of turns of heavy chain. The interior of the ship was also strutted more than is usual, even for the big and comparatively light scantling ships of this kind. In the neighborhood of the forward part of the cradle this was especially noticeable.

Sultan.—This single screw third class battleship has been given a thorough refit. New decks, cabins and top sides have been fitted, military masts and fighting tops have been substituted for her former sail carrying equipment, a complement of quick firing guns has been added to her original armament, and she has been supplied with modern inverted triple expansion engines, designed and constructed by Messrs. J. and G. Thomson, of Clydebank, Glasgow. Steam is supplied by eight single ended boilers, which are placed in two separate water tight compartments. They are of the marine return tube pattern, 15 feet $2\frac{3}{4}$ inches in mean diameter and 10 feet long, containing four furnaces each. Siemens-Martin steel was used throughout for their construction, and they are designed for a working pressure of 155 pounds per square inch.

Her trials were carried out on the 29th and 31st of May, but the ship was not at her load draught, the mean draught being 23 feet 2½ inches. The results were:

	Natural draft.	*Forced draft.*
Steam pressure	147.7	151
Vacuum	25.5	25.9
Revolutions	88.7	93.8
Air pressure	...	.36
I.H.P	6,531	8,244
Speed by patent log	14.6	15.3

Pelorus.—The contract for the machinery of this new third class cruiser, whose dimensions were given in the last number of the JOURNAL, has been given to Messrs. J. and G. Thomson, Clydebank. The engines are to be of 7,000 I.H.P., under natural draft, and the speed under these conditions 20 knots. Steam is to be furnished by Normand boilers. Her displacement will be 2,135 tons.

Torch.—The trials of this sheathed gunboat, whose dimensions are given on page 203 of the last volume of the JOURNAL, has been completed, with the following results:

	Natural draft.	*Forced draft.*
Duration of trial, hours	8	4
Steam pressure	150.4	153
Revolutions per minute	186 6	203.4
Vacuum	...	27.4
Air pressure, inches of water	...	1.2
I.H.P.	1,163	1,457
Speed by patent log	13	13.4

Sharpshooter.—Trials of the boilers.—On account of the opposition in England to the adoption of the Belleville boiler for the *Powerful* and *Terrible*, and the questions raised as to its reliability, the Admiralty decided to subject the *Sharpshooter* to a series of trials to determine the behavior of her boilers under ordinary conditions at sea. For this purpose, the trials determined on were four in number, the first consisting of four runs of 1,000 miles each, at 1,530 I.H.P.; the second of two similar runs at 1,800 I.H.P.; the third of three runs at 2,000 I.H.P.; and the fourth of one run of 1,000 miles at 2,150 I.H.P., or until the coal abreast the boilers has been used.

The first and second series were carried out without difficulty with the boilers, but doubt was expressed as to the ability to complete the last trial on account of the excessive vibration of the vessel.

Sturgeon.—This torpedo boat destroyer, whose trials were noted in the last number of the JOURNAL, after having been repaired, succeeded in completing her official trials, her speed on the mile being 27.6, and that for three hours, 27.25 knots.

FRANCE.

Rapid Cruisers Nos. 1 and *2.*—The French Government has recently entered into contract with private establishments for the construction of two triple screw cruisers (*croiseurs corsaires*) to have a speed of 23 knots, and to carry enough coal to steam 7,500 miles at 12 knots. The preliminary scheme contemplated vessels of about 8,500 tons displacement, not more than 425 feet long, and draught aft not to exceed 24.5 feet; but the plans on which awards have been made are for vessels of about the size of the *Columbia* and *Minneapolis.*

The main battery, composed exclusively of rapid fire guns, comprises two 6.5-inch mounted amidships, one forward and the other aft; six 5.5-inch, two of which are on the upper deck with ahead and astern fire, and four in redoubts on the battery deck, two forward and two aft. All are protected by 2.12-inch shields. For the guns which fire ahead, the regulation allowance of ammunition is provided for in the weights; for the others it will be reduced one-third, but the magazines are to be large enough to stow the full amount, and, if possible, one-third more.

The secondary battery consists of ten 47-mm. guns mounted on the superstructure.

The protective deck will be 1.26 inches thick on the flat and 1.75 inches on the slope, and will be 2.6 feet above the water line amidships and 4.6 feet below it at the sides.

The conning tower will have 7.87 inches of Harveyized armor.

She will have no automobile torpedoes and will not be provided with torpedo nets.

The requirements for the machinery are that the engines shall be vertical, of either the triple or quadruple expansion type, and strong in construction; that the boilers shall, if possible, be of the water tube type; and that the speed of 23 knots shall be attained with a mild forced draft in closed fire rooms. The endurance of 7,500 miles, at 12 knots, is to include the coal necessary for running the auxiliaries, distilling water, &c.

In the construction of the hull, special attention is to be given to the strength and shape forward, in order that they may be driven into a sea at high speed. As far as possible, wood work will be prohibited, especially in the upper works.

There will be a double bottom below the machinery space, and trimming tanks forward and aft.

The rig will be two pole masts without yards, but with light platforms for search lights.

Stowage will be provided as follows: For provisions, 90 days; for water, 20 days.

Masséna.—This triple screw battleship, designed by M. de Bussy, was launched from the Chantiers de la Loire, St. Nazaire, on the 24th of July. Her dimensions are:

Length on water line, feet	363.5
Breadth, feet	66.6
Draught, aft, feet	26.8
Displacement, tons	11,760

She is designed to make a speed of 16 knots on 9,300 I.H.P. with natural draft, and 17.5 with assisted draft on 13,500 I.H.P. The engines are triple expansion, and the boilers, 24 in number, of the Lagrafel-d'Allest type.

She has a complete armor belt varying in thickness from 9.8 to 17.7 inches, and the armor of the large turrets is 13.8 inches on the moving and 15.7 on the fixed portion. The protective deck is 3.5 inches.

The battery comprises two 12-inch guns in central turrets, one forward and the other aft, two 10.6-inch in side turrets, eight 5.5-

inch in broadside turrets, and eight 3.9-inch on the superstructure, besides thirty 47 and 37-mm. rapid fire guns and five torpedo tubes. The 5.5-inch guns are protected by 3.9 inches of armor.

Bouvines.—A sister ship to the *Jemmapes*, described on page 805 of the last volume of the JOURNAL, completed her trials in June and July last. The full power trial lasted two hours, the I.H.P. being 8,680, and the speed 16.05 knots. About a week afterwards she had another trial with twelve boilers in use; this lasted twelve hours, and the results are said to have been satisfactory, both as regards I.H.P. and economy, but the temperature of the fire rooms was very high, trouble of the same kind having been experienced on the former trial. Her boilers are of the D'Allest type, as stated in the last number of the JOURNAL.

Her final preliminary trial was made in March, with 115 revolutions of the engines and 8,200 I.H.P.

GERMANY.

Aegir (formerly "*T*").—A fourth class battleship of the *Siegfried* class has recently been added to the German Navy. Her dimensions are:

Length on water line, feet	236.2
Breadth at water line, feet	50.52
Depth, feet	35 56
Draught, mean, feet	17.39
Displacement, tons	3,542

She has an armor belt of nickel steel 8.66 inches thick, backed by 7 to 8 inches of teak, and extending about half her length, the citadel above being 4 inches thick on sides and the bulkheads 8 inches. The gun turrets and ammunition shafts also have 8-inch armor. A cork belt 31 inches thick extends from the ends of the armor belt forward and aft.

The battery consists of three 9.45-inch, ten 3.4-inch, eight machine guns, and four torpedo tubes, two of which are submerged.

The engines are twin screw, triple expansion, with cylinders 26, 40 and 63 inches in diameter, and 29.5 inches stroke, and are designed for 2,400 I.H.P. each with 175 pounds boiler pressure.

The air pumps are independent, and have three steam and two water cylinders for each main engine. The propellers are 11.5 feet diameter and 12 feet pitch. Steam is furnished by eight Thornycroft boilers of the old type, having a combined grate surface of 274 square feet.

Her bunker capacity is 223 tons.

ITALY.

Aquila.—The following account of the accident on board this torpedo boat is given by a Spezia correspondent of the London "Standard."

"Early on the morning of the third of July the *Aquila* received orders to put to sea to undergo full speed steam trials, with the object of ascertaining if she could be utilized as a torpedo chaser. Consequently, the speed and head of steam under which she was going at the time of the catastrophe must have been excessive, for a breakdown occurred in the reversing gear of the forward engines, a portion of what is called Stephenson's link snapping from the violent vibrations of 300 revolutions per minute. The crown of the furnace collapsed, dragging with it the fore part of the boiler, together with the tubes. The explosion blew down the bulkhead leading into the torpedo room, killing the fireman on duty, and suffocating a sailor who was sleeping there. The steam also forced its way into the engine room through an opening in the bulkhead, over the heads of the engineering staff, severely burning all, and blowing one overboard, together with a ventilator, which broke the ribs of the officer second in command, who was on deck. The Chief Engineer, though severely injured, had the presence of mind to have the fires of the after boiler drawn by two firemen, who remained uninjured, to prevent further accidents, there being no one to superintend the working of the other pair of engines. The survivors signalled to the Semaphore, and also sent a small boat to the nearest village on the coast for assistance, and on the news reaching Spezia two tugboats, with doctors and medical appliances, proceeded to the disabled boat, and towed her to Spezia, landing on their way the most severely injured at the Naval Hospital at Portovenere. Of the survivors, three have since died, and five or six others are not expected to live. The body of the missing engineer blown overboard was picked up by fishermen at Riomaggiore, terribly burnt about face and head. The steam trials of the *Aquila* were being superintended by Signor Oltremanti, Staff Engineer of the Reserve Squadron, now at Spezia, who happened to be looking down the engine room at the time of the accident, and was severely scalded about the face and head. The *Aquila* was built by Schichau, of Elbing, in 1888, and had a speed of twenty-six miles per hour."

PORTUGAL.

Adamastor.—Orlando Brothers, Leghorn, Italy, have recently received a contract from the Portuguese Government for the construction of a cruiser of the following dimensions:

Length on water line, feet	242.7
Breadth, extreme, feet	35.1
Draught, mean, feet	14
Displacement, tons	1,771

Her battery consists of two 5.9-inch guns, one forward and the other aft, four 4-inch, two 47-mm. and four Nordenfelt machine guns, besides three torpedo tubes, one fixed forward, and two pivoted in broadside.

There will be vertical twin screw triple expansion engines of 3,000 I.H.P. natural draft, when making about 115 revolutions, and of 4,000 I.H.P. under forced draft. The speed expected under the two conditions is 16 and 17.3 knots respectively. The boilers will be four in number, of the gunboat type, and will have three furnaces each.

RUSSIA.

Sokol.—A torpedo boat destroyer, similar to the *Havock* of the British Navy, is building by Yarrow & Co. for the Russian Government, under a guarantee to make 29 knots an hour. Her dimensions are:

Length on water line, feet	190
Breadth, feet	
Draught, mean, feet	7
Displacement, tons	240

She will have twin screw triple expansion engines of 4,500 I.H.P., steam for which will be furnished by eight Yarrow water tube boilers.

Her armament will comprise one 75-mm. rapid fire gun forward in the conning tower, two 47-mm. forward for ahead fire, and one 47-mm. aft, besides two torpedo tubes on deck.

New Cruiser.—The Russian Government has recently entered into a contract with the Forges et Chantiers de la Mediterranée at Havre to build a protective cruiser having the following characteristics:

Length on water line, feet	331.40
Breadth extreme, feet	42.65
Depth to upper deck, feet	35.11
Draught, aft, feet	18.76
Displacement, tons	3,767
Bunker capacity, tons	394
I.H.P.	8,400
Speed on measured base at Cherbourg, knots	20

Her battery comprises six 15-cm., ten 47-mm. rapid fire guns, and four torpedo tubes.

The protective deck is 1 inch thick on the flat and 2 inches on the slope, and the conning tower 4 inches thick.

There will be two four-cylinder triple-expansion engines, working with an initial steam pressure of 170 pounds, and designed to make 128 revolutions when running at full power. Steam will be furnished by eighteen Belleville boilers, in three groups, working under a pressure of 242 pounds. The air pressure to be used on trial is not to exceed ½ inch of water.

Samoyede.—The Thames Iron Works, London, has just completed an armed transport for Russia, whose construction entire has been done in three months from the date of signing the contract. Her dimensions are:

Length on water line, feet	170
Breadth, feet	33
Depth, feet	16.6
Draught, mean, feet	12
Displacement, tons	1,050

She has a single screw vertical engine with cylinders 20, 32 and 50 inches diameter and 24 inches stroke, designed for 1,050 horse power on a piston speed of 600 feet per minute, and a boiler pressure of 160 pounds. She has two main and one auxiliary boiler, the former being 12 feet 3 inches diameter and 10 feet long, and containing 105 square feet of grate and 3,000 of heating surface; the auxiliary boiler is 10 feet diameter and 9 feet long, and works at a pressure of 100 pounds. Her speed is intended to be about 12 knots.

Her battery consists of two 47 and two 37-mm. rapid fire guns.

MERCHANT STEAMERS.

St. Louis.—A general description of this steamer of the "American Line" has already been given in Vol. VI, p. 811, of the JOURNAL.

The *St. Louis* sailed on her first voyage from New York for Southampton on Wednesday, June 5, 1895, and made the voyage in 7 days 3 hours and 53 minutes, at an average rate of speed of 18.37 knots. On her return voyage, the voyage was made in 7 days 7 hours and 11 minutes. The best speed made on the first voyage was 19½ knots, the I.H.P. being a little more than 16,000 with 85 revolutions. The engines were at no time pushed.

The second voyage back from Southampton was made in 6 days 18 hours and 47 minutes. It will be seen that so far no "record-breaking" attempt has been made, such as would be fully and fairly representative of her qualities and power.

The following description and data of the machinery were taken from "Engineering:"

"The main engines are of the quadruple expansion type, but with six cylinders working on four cranks, an arrangement patented by Mr. John Thom, who is associated with the technical staff of the American Line as a consulting engineer. There are two high pressure cylinders, and each of these is placed over one of the two low pressure cylinders. The tandem cylinders are at the forward end, the arrangement being high pressure and low pressure working on the first crank, the same working on the second crank, the second intermediate on the third crank, and the first intermediate on the fourth crank. Steam, of course, is passed from the two high pressure cylinders into the one first intermediate, then to the second intermediate, and thence into the two low pressure cylinders. The diameters of the respective cylinders are: Two high pressure 28½ inches, first intermediate, 55 inches; second intermediate, 77 inches; two low pressure, 77 inches. The stroke in each case is 5 feet. The cylinders are each separate castings, and are supported on A-frames at back and front, the condenser and its pumps being separate and placed in the wings of the ship. The supporting frames are cast in two parts, each part having three sides only, with flanges to the outside for bolting together. The inside is thus entirely open, so that the soundness of the casting is apparent. The cylinders are braced longitudinally by cast iron girders of box section, which also extend between the forward and aft cylinder and the ship's bulkhead, so that there is little tendency to work. These bulkheads are specially stiffened by girders 2 feet deep, built of plates and angle bars. Each high pressure cylinder is carried 24 inches above the low pressure cylinder on cast iron frames on either side, and this clearance enables a manhole to be provided on the top of the low pressure cylinder to admit of examination, &c. The main stop valve is in the engine room, on the same level as the high pressure cylinders; and the inlet to the high pressure cylinder valves is controlled by a balanced piston throttle valve on the main pipe. The steam pipes, it may be said, are all of steel, lap welded, with double riveted flanges, and the largest is 20 inches in diameter.

Piston valves of the Thom's balanced type are fitted throughout, and they are operated by the usual double eccentric link motion, the bent rod being for the astern motion. The eccentric straps are of cast steel filled with Parson's white metal. There are two valves for the low pressure cylinders. Frequently the guide brackets for the crosshead for valve spindles in such cases are insufficient, and the little slackness resulting tends to twist either spindle and snap it. In this case the guides have been brought out on either side to within 10 inches of the valve spindles. Cast brass guide blocks are fitted to the quadrant piece, the guides consisting of a cast steel bracket bolted to the low pressure cylinder. Special arrangements have been made for adjusting any wear. The spindle of the high pressure cylinder valve is worked from the low pressure valve crosshead through a bellcrank lever. And here it may be said that the starting and reversing is done by gearing not dissimilar to Brown's, but without any hydraulic cylinder. There is a steam cylinder 24 inches in diameter by 30-inch stroke, and the cushioning is by the adjustment of the valve, and also by a spiral spring on the guide spindles.

The cylinders are of cast iron; the second intermediate and the two low pressure cylinders only have jackets, and these drain into water traps which discharge into the hot well tank. Outside all the cylinders are coated with asbestos, hair felt, and covered with sheet steel. Cramps' metallic packing is used throughout. It is somewhat similar to the United States packing, with cast iron rings compressed by a spiral spring. The clearance in the cylinders is on the top of the pistons $\frac{1}{2}$ inch, and below $\frac{5}{8}$ inch. The piston rods of the high pressure cylinders are 6 inches in diameter, and in the other cylinders $8\frac{1}{2}$ inches. The connecting rod is fully twice the length of stroke, 11 feet 3 inches centers, and is $8\frac{1}{2}$ inches in diameter at top, and 10 inches at bottom. The connecting rod at top is not forged with the usual U end for the crosshead pins. The crosshead connection is built up. The top of the rod is squared to a T piece, with a hole bored through the two heads. On the bottom of the crosshead itself, at either side, there is forged a projection, which is screwed and passed through the holes and bolted. In other words, the crosshead brasses have a steel T piece with pin forged to the bottom which passes through the holes on the top of the connecting rod. Slipper guides for the crosshead are fitted to one side of the framing. There is a steel flange fitted on either side of the column face, and the slipper works inside it. Between the back of the crosshead and the other frame there is a small gangway to admit of inspection, and to economize weight a hole is bored through the crosshead brasses, which also have the usual piece for adjustment. Lubrication is from a separate tank at the top of the engine skylight, whither the oil is pumped from a supply tank, and whence it passes by gravitation in a series of pipes to the different parts of the engines, the supply being controlled at each delivery by a needle pointed valve.

The crankshaft is 21 inches in diameter, the crankpins 22 inches, the bolts being 5 inches at the bottom of the thread. The cranks themselves are 16 inches broad, the length of pin being $31\frac{1}{2}$ inches, and there is a 6-inch hole through the cranks and pins. The bearings are 26 inches long, and are of cast steel filled with Parson's metal. They are bolted down with 4½-inch bolts, and in the bottom water is circulated. Here it may be stated that the bedplate is of cast iron box section, 3 feet 4 inches deep and 4 feet 7 inches at the center, the center part, instead of being flat, being dished to the extent of 1 foot. The bases of the standards are fitted to the dished part of the bedplate as well as the flat portion, so as to tend to obviate the radial "working" which sets up torsional vibration and strains.

The ship, it may be said, has a center keel line 4 feet 9 inches deep, from which the side framing rises. This framing is of channel section, 7 inches by 3½ inches by ½ inch, spaced 32 inches apart, every third frame being of web construction 30 inches deep, with face plates running longitudinally and 30 inches broad.

The thrust shaft is 21 inches in diameter and solid, the diameter over thrust rings being 33 inches. There are 13 horseshoe collars, each 2½ inch thick, and the surface on the ahead side is 6,616 square inches. The length of the thrust shaft is 14 feet, and it is secured to the bedplate of the engines. The horseshoe rings are adjustable by a horizontal screw with two nuts for each side, which greatly facilitates the removal of any ring. The turning wheel is immediately aft of the thrust shaft. The engine has two cylinders, 8 inches in diameter by 8-inch stroke. The thrust shaft, by the way, is placed in a recess, and over it, with entrance from an upper platform, is the dynamo room.

The propeller or line shaft is 19 inches in diameter, also solid. It is fitted in lengths of 23 feet, with bearings 14 feet apart. These bearings are 2 feet long, and have cast steel bodies, filled with Parson's white metal. There is fitted to the after length of the shaft a portable coupling. It is in halves, and through each half there is a longitudinal feather 5 inches wide and 2¾ inches deep. The ten bolts were put through the coupling when at a high temperature, the subsequent contraction giving greater binding to obviate slip. This arrangement, which is not usual, is to facilitate the drawing of the shaft for repair. The feathers running longitudinally through each half of the coupling would not have prevented the shaft from backing out when the engine was going astern, and to overcome this possibility, grooves 1 inch deep were turned in the shaft, forming collars, which engage in collars and grooves on the coupling. There is no outboard shaft, the framing and plating of the ship being bossed out in the same way as in most high speed twin screw merchant steamers now. The stern shaft, which is 21 inches in diameter, is covered with a liner 1½ inches, working in lignum-vitæ bearings, constructed in the old style in strips 3½ inches broad and 1 inch deep, the division between the strips allowing water to circulate. The stern gland is light, but is packed with Tupper's machine plaited flax packing. The bosses of the propellers are of steel, with three blades of Parson's bronze, and these, for the present, are set at a pitch of 27½ feet.

The condensers are separate from the main engines. They are 7 feet 2 inches inside diameter, and the tubes, which are of seamless brass, are ¾ inch in diameter and 16 feet 8⅝ inches long. There are six stay rods, and the tubes are supported at two intermediate points between the tubeplates. The total condensing surface is 26,170 square feet. The air pumps are also placed in the wings of the ship. There are four for each condenser, and they are of the Worthington type, with steam cylinders 26 inches in diameter and 20 inches stroke. There are 8-inch valves to each of the four buckets. On the voyage across these worked at about 20 double strokes per minute, giving a vacuum of 26½ inches. The air pumps discharge into the hot well tank, which also receives the drainage from all the water traps in connection with the jacket of the cylinders, and with all the auxiliary machinery, and all is subsequently passed into the feed. The centrifugal pumps for the condenser are also of the Worthington type. They are driven by engines with 12-inch cylinders by 14 inches stroke. The discs are 3 feet 6 inches in diameter, with a 6½-inch inlet and 3¾ inches discharge. The water, after it has been used for condensing, instead of being run overboard, is forced up to a tank on the topmost or boat deck, where, at a temperature of 115 degrees, it is stored in a tank available for use in baths or for galley or pantry use. There is also a cold salt water tank on the same deck.

The feed water is passed through Worthington's feed heater, being raised to 210 degrees, while the same company's vertical feed pumps are in use. The evaporator and distiller are on Quiggan's system, while the installation of general pumps for sanitary duty, for the hot sea water to baths, and for bilge duty, is on the Worthington system; and here it may be stated that all the auxiliary machinery exhausts into a separate condenser.

We come now to the boilers, which work at 200 pounds pressure, having been tested to 300 pounds by water pressure. There are six double ended and four single ended boilers, each 15 feet 7½ inches in diameter, while the former are 20 feet long, and the latter are 10 feet 4½ inches. The shellplates are 1 9/16 inches in thickness, and are quadruple riveted with 1½-inch rivets. The front plate is flanged inwards. There are four furnaces in each end, and these have each separate combustion chambers. Thus there are in all 64 furnaces. These are of Fox's corrugated type and, in accordance with latest practice, they are slightly reduced in diameter towards the back, so that they may be readily withdrawn for repairs without injuring the front of the boiler. The flues are 3 feet 3 inches in diameter, of 19/32 inch thickness of metal, and the furnaces, which have the ordinary fire bars, are 6 feet 10½ inches long. There are 416 tubes in the single ended, and 832 in the double ended boilers, the total number of tubes in all boilers being 6,656. The number of stay tubes is 328 in each double ended boiler. The fire tubes are 2¾ inches in external diameter, and the thickness of metal 11 B.W.G., while the stay tubes are 2¾ inches in diameter and ¼ inch thick, the distance between the tube sheets being 7 feet. The tubes, by the way, are fitted with spiral retarders which have given good results in causing the hot gases to pass in a helical course through the tubes, and thus insure prolonged contact with the surface. The tube plates are ⅝ inch thick. The diameter of the combustion chamber stays at the smallest base is 1¾ inches for the outside row, and 1⅝ inches for the inside row, by 7 inches pitch. The total grate area is 1,144 square feet, and the total heating surface 40,320 square feet.

There are six safety valves on the double ended and four on the single ended boilers, all of 4 inches diameter.

The installation of boilers is equally divided between two water tight compartments. There are thus three double ended and two single ended boilers in each, and the installation is worked under Howden's system of forced draft, by which the air is heated before being passed into the furnace. The stokehold is open, and is specially well ventilated. It is divided longitudinally in the middle line by a thin plating or screen, which comes to within 6 feet of the heads of the stokers. The down air shaft is on the one side of this screen, and the other side is closed in at the top, excepting the intake for the forced draft fans. Thus the current of air is brought as near the stoking floor as possible—an arrangement which, like several others, is due to the long experience of Mr. Doran, the superintending engineer of the American Company. The eight fans—two for each stokehold—are of the Sturtevant type, driven by two cylinder engines, 8 inches by 6 inches stroke. The fans are 80 inches in diameter, draw the air from the top of the stokehold, and deliver it into the air heating tubes in the uptake, whence it passes to the space inside the furnace door, and thence through small holes to the fire. The system is too well known to require further description. There is bunker capacity for carrying 2,500 tons of coal, which will just equal eight days' consumption. There is a small bunker athwartship, between the engine room and the after boiler compartment, one between the two compartments, and a third at the fore end of the forward compartment. There is 40 feet of the length of the ship between each boiler compartment. There is a donkey boiler for supplying steam to the deck machinery.

There are two funnels, 11 feet 6 inches by 14 feet, the height being 100 feet from the grates.

Among the auxiliary machinery first reference may be made to the electric machinery. It is by the Electro Dynamic Company of Philadelphia. There are four dynamos, each coupled direct to high pressure engines, with two cylinders 12 inches in diameter by 10-inch stroke, and with a piston valve common to both cylinders. They are four-pole machines, with compound wound Gramme ring armatures, each giving 360 amperes and 112 volts at 470 revolutions, and running 700 lights. Any of the machines may be used for any circuit. The ship is wired on the double wire system, and one feature is that the connections are all in water tight cases, while the distribution boxes are all water tight, having three compartments, for fuse, switching and binding, the fuse box only having a glass front. The circuit is subdivided into four sections, any or all of which may be worked separately. The lights are 16-candle power, and for cargo purposes, six are grouped in a bell shaped reflector, the connection to the mains being by a socket pipe in an india rubber covered casing. There are several motors for driving Sturtevant fans for ventilating the passenger decks, including two 9-horse power, two 7-horse power, and four 5-horse power machines. The motors are of the two-pole, Gramme ring type, and in addition there are two 10-horse power and one 5-horse power motors for the refrigerating plant for the ship's stores. They are of the same type as the other motors, but are series wound to admit of greater variation in the speed. The fan motors are shunt wound. There is also a motor for driving the pumps for the organ, placed in the gable of the arched well of the dining saloon. The motor, &c., is placed between the inner casing of the dome and the outer and much stronger casing. Electricity is also used for a "tell-tale" at the navigating bridge and in the chief engineer's room, to indicate the revolving speed of the engines. Acceleration in speed of the shaft increases the current passed to the tell-tale, and thus operates the indicator. The movements of the rudder are similarly recorded. On the rudder head is a pointer which is moved over a contact plate, completing a circuit at each point, and thus indicating the movement of the rudder on the dial at the captain's bridge.

For ventilating the compartments where passenger cabins are situated, there are four stations, each with two fans, one for exhausting and the other for supplying air. These fans are driven by electric motors, as already stated. The exhaust trunks are carried to each state room, while the supply fans discharge into the corridors and passages, to pass thence through the jalousies of the doors. The fans, as a rule, are 5 feet in diameter, and may run to 470 revolutions. The air supplied may, in winter weather, be passed through a casing with a large series of steam pipes supplied direct from the boiler. There is a valve by which the amount of steam may be varied to suit any temperature of air desired. The radiator pipes are in five sections, each controlled by a valve. There is, however, no corresponding means of cooling the air. Possibly were some method adopted, greater success would attend the ventilation, especially in calm summer weather. Such a cooling process has been introduced in other vessels.

The steering of the ship is by gearing which in general arrangement is somewhat similar to that first introduced, if we mistake not, by Brown, of Edinburgh, and now much used in large British mercantile and Navy ships. The gear in the *St. Louis* was constructed by Messrs. Williamson, Philadelphia, and is actuated by Brown's telemotor. There is a right and left-handed screw, 8 inches in diameter and 10 feet long, on which run two nuts, from which are connecting rods to the crosshead on the rudder. The nuts are made in halves, so that should it be required they may be quickly removed. The revolving of the screw thus operates the nuts, and through the nuts the rudder. The engine for this purpose is horizontal, of the high pressure type, with two cylinders 14 inches in diameter by 12 inches stroke. The piston valve is operated direct by Brown's hydraulic telemotor, or by shafting from the deck above, through bellcrank levers. The crankshaft of the engine works gearing which is of brass with V-teeth made in halves, to admit of machine cutting, and thoroughly pinned together. Buffer springs are used to arrest the motion when the rudder is put hard over, and when released aid in bringing it back to amidships. Clutches throw the steam engine out or into gear, and similarly three handwheels may, when required, be geared up to the right and left handed screw. Moreover, there is a tiller on the rudder head, standing out above the right and left handed screw; by this the ship may be steered either by the interposition of the steam engine or hand gear, through wire ropes winding round a series of pulleys, and made fast to the end of the tiller. A friction strap is provided to a horizontal pulley on the rudder head to take up the strain of the rudder while any change in the gearing is being made. The gearing, which is fitted with electric tell-tale as already described, is of massive design, and should stand much wear.

The vessel is fitted with the Hyde windlass in the forecastle, and there are two power and two speed capstans forward, and one power and two speed capstans aft on the poop, all of the same design, and supplied from the Bath Iron Works. The cylinders of the windlass are vertical, each 12 inches diameter by 10 inches stroke, with slide valves. The capstan engines are also vertical and not inverted, and the gearing is so arranged that either engine can drive windlass or capstans. The chain, it may be said, is 2¾ inches, the largest yet made in the States, but ¼ inch smaller than the *Campania's*. There are seven anchors, the weights being 105 hundredweight, 104 hundredweight, 79 hundredweight, 78 hundredweight, 39 hundredweight, 18 hundredweight and 10 hundredweight. They are of the Hall and Trotman construction. The vessel will carry about 1,500 tons of cargo, and there are six hatches, for which five winches have been supplied. These are of the Williamson type, with horizontal engines, the cylinders being 8 inches by 10 inches, with a 24-inch drum. On the boat deck there is a boat hoist with long shafts and double drum on either side. There are 16 ordinary boats, besides a number of collapsible boats and 16 rafts.

There are two refrigerating installations, one amidships in connection with the stores for ship's use, and one in the forecastle for cargo hold. Both are on the Kilbourn system. From the cold store there is an electric elevator. Part of the drum shaft is threaded for carrying a nut, which at the end of its travel releases the switch connection when the elevator has reached top or bottom. The connection is made by the half turning of a wheel on which the switch is mounted, until the switch is brought in contact with the gearing.

Kherson.—A twin screw steamer for the Russian Volunteer Fleet, built by Messrs. Hawthorne, Leslie & Co. She is of the following dimensions:

Length between perpendiculars, feet	455
over all, feet	500
Breadth, extreme, feet	54
Depth, feet	36
Draught, load, feet	24
Deadweight on above draught, tons	4,076
Bunker capacity, tons	1,300

Her engines are of the triple-expansion type, and are of 12,500 I.H.P. Steam will be furnished by twenty-four main and one auxiliary boiler of the Belleville type, each of eight elements, and working under a pressure of 250 pounds, which is reduced to 170 at the engines. The grate surface is 1,132, and the heating surface 36,000 square feet. The main boilers are arranged in three groups. The screws are of manganese bronze.

The contract requires a mean speed of 19.5 knots on a twelve hours' trial, during which the piston speed must not exceed 800 feet per minute.

Ohio.—Formerly the *Egyptian Monarch*, and now belonging to the Wilson Line, has recently been fitted with quadruple expansion engines and Belleville boilers by Earle's Shipbuilding and Engineering Company, Hull. The engines are of 1,640 I.H.P., and have cylinders 22½, 32, 45 and 64 inches diameter by 42 inches stroke, working at a pressure of 200 pounds. The boilers are four in number, and on trial had 185 square feet of grate, and 6,000 square feet of heating surface; but the grate surface has since been reduced to 112 square feet.

Hero.—This steamer was built by Earle's Shipbuilding and Engineering Company, Hull, for the well known Wilson Line. She is of the following dimensions: Length between perpendiculars, 217 feet; breadth, molded, 30 feet; depth of hold, 13 feet 8 inches; and 775 tons gross register. The engines are of 1,300 I.H.P., triple-expansion, the cylinders being 18½, 31 and 53 inches in diameter, and have a stroke of 33 inches. The boilers, two in number, are of Babcock and Wilcox's patent water tube type, and supply steam at a pressure of 200 pounds per square inch. They are 9 feet 6 inches wide, 10 feet long, and about 15 feet in height, having a total heating surface of 4,400 square feet, and a grate surface of 88 square feet. Each boiler has one furnace with two doors and two ashpits. The lower tubes are 4 inches diameter, and the upper ones 2 inches diameter. By the adoption of these boilers it is calculated there is a saving of weight of from fifty to sixty tons. It is noteworthy that the boiler feeding arrangements are merely of the usual character for ordinary boilers, the ordinary feed pump being part of the main engines, and the auxiliary one of Pearn's duplex pumps. The engine room equipment includes a Kirkaldy's Compactum Evaporator, and one of the same maker's compactum filters. The trial trip, on June 7, was of a most successful character, the steam supply was constant and steady, and the mean speed of four runs with and against the tide, with the engines running at 108 revolutions, on the measured mile, at Whithernsea, was nearly 14 knots.

Turret Cape.—Another steamship fitted with two Babcock and Wilcox's water tube boilers, the *Turret Cape*, had a successful trial trip on June 8th. This vessel is a sister ship to the *Turret Crown*, and has a gross tonnage of 1,890 tons. Both vessels have been built to the order of Messrs. Petersen, Tate & Co., Newcastle-on-Tyne, by Messrs. Wm. Doxford & Sons, Limited, Sunderland, who are the inventors of the "Turret" design of steamships. The engines are of 1,100 I.H.P., working at 180 pounds per square inch. A modification in the boilers has been made by reducing the total grate area from 110 square feet to 83 square feet, by erecting fire brick divisions, namely, two on each boiler, so that there are now three furnaces on each boiler instead of one large furnace.

The engines are triple-expansion, with cylinders 21½, 36 and 59 inches diameter and a stroke of 39 inches. The hull is constructed on the Bell-Rockliffe system of joggled plating.

The trial trip was conducted as a progressive one, commencing with an engine speed of 40 revolutions per minute. The highest mean speed allowed on the measured mile at Whitley was 11.5 knots, with 68 revolutions per minute. During the trial the heat of the waste gases at the base of the funnel was carefully observed by means of a high grade nitrogen thermometer, and with readings taken every minute during the highest speed runs, the mean of the readings gave 455 degrees Fah. Unfortunately time did not permit of a consumption trial, but it is confidently anticipated that the reduction of the grate area will be productive of increased economy in the fuel consumption.

The arrangements for feeding the boilers are of an ordinary character, the feed pump being driven off the main engine, while the auxiliary feed is an ordinary Worthington pump. A Yaryan patent evaporator of the latest type is fitted, having the brine pump worked from the main engine lever instead of having an independent pump, and gave every satisfaction, as also did Rankine's patent filter.

Zenith City.—The following description is taken from the "Marine Review:"

"This steel steamer, 400 feet long, is being built by the Chicago Ship Building Company for service in the iron ore, grain and coal trades on the lakes. The *Zenith City* is the first freight carrier in this country of large dimensions to be fitted with water tube boilers. They are of the Babcock & Wilcox Co.'s marine type. The engines to which these boilers are to furnish steam at 200 pounds pressure are of the vertical triple-expansion type with cylinders 23, 38 and 62 inches diameter and of 40 inches stroke.

The boilers each contain 3,000 square feet of heating surface and 72 square feet of grate. They are composed entirely of open hearth steel forgings and straight charcoal iron boiler tubes, not a pound of cast or malleable metal or a bent tube entering into their construction. The boiler consists essentially of two banks of tubes placed at an angle of 15 degrees from the horizontal and separated by a combustion chamber, the lower bank being composed of 4-inch tubes placed four rows high, and the upper bank of 2-inch tubes placed 11 rows high. All tubes are expanded at their ends into sinuous wrought steel front and rear headers, forged into shape by hydraulic pressure. The rear headers are connected at their upper ends by 4-inch tubes to a steam and water drum 42 inches diameter, and at their lower ends to a mud drum or blow-off connection. The front headers are suspended from a cross box supported by two front corner boxes. The cross box is in turn connected to the steam and water drum by 4-inch tubes, completing the cycle for circulation, *i. e.*, from the drum down the rear headers towards the mud drum—where any sediment in the water is deposited—up the inclined tubes to the front headers, up the front headers to the cross box, and from the cross box to the drum. On account of the stagger given to the headers, the tubes are so disposed that the gases are entirely broken up and thoroughly mixed in their passage through the boiler.

Opposite the end of each tube is an opening, through which the tube may be examined and cleaned, or, when necessary, withdrawn and a new tube inserted. The hand hole plate and inside guard closing this opening are made from rolled plate and forged into shape by hydraulic pressure, the headers being flanged out to form the metal to metal seat under each hand hole cap. The inside guard is of such shape that should the 1⅛-inch bolt holding the guard and cap in place break, only a leak would result. This same joint has been in constant use in stationary practice for years, and has given excellent satisfaction.

The boiler is encased on the sides with 4-inch tubes expanded into straight manifolds, the furnace sides being formed of square water boxes constructed of open hearth steel half an inch in thickness, doing away with all fire brick in contact with the fire, with the exception of the regulation bridge wall in the rear of the grate. These water box sides insure a cool casing, even when the combustion is forced to the rate of sixty pounds of coal per square foot of grate, and avoids clinkering and repairs. Against the side tubes is placed asbestos and 2 inches of magnesia block covering, the whole being held into place by sheet iron plates braced with angle irons and bolted to the foundations.

Following are some of the reasons urged in favor of the adoption of this boiler:

First. Reduction in weight for high steam pressure, the weight being 27 pounds per square foot of heating surface for 250 pounds pressure, against 75 pounds per square foot in Scotch boilers for 175 pounds pressure.

Second. Reduction of space occupied, and increased furnace capacity.

Third. Absolutely free circulation, enabling any amount of forcing that the fireman is capable of.

Fourth. Water sides to furnace, preventing serious radiation, obtaining a cooler fireroom, and avoiding clinkering of furnace sides and repair to brickwork.

Fifth. Absence of automatic devices of all kinds that are continually getting out of order and giving trouble, such as feed regulators, reducing valves, steam separators, etc.

Sixth. On account of the body of water carried in the steam and water drum at the water level, and the freedom of circulation, sudden fluctuations in the water level when forcing are eliminated.

Seventh. Steam space sufficient to obtain dry steam without the necessity of expanding from a higher to a lower pressure in order to evaporate the water in the steam.

Eighth. Increased ratio of heating to grate surface, thereby materially improving the economy.

Ninth. Ability to clean, renew or plug a tube through a hand hole of sufficient size opposite the end of same, without removing any other tube or pressure part, or cooling down the boiler other than blowing off the pressure.

Tenth. All joints are metal to metal, no gaskets of any kind being used. All joints exposed to products of combustion are expanded into bored holes, no screwed fittings being used.

Eleventh. Boilers of large units can be employed, thus doing away with an increased number of small boilers, multiplicity of fittings and additional apparatus.

Kingstown and Holyhead Mail Service.—Four new twin screw steamers are about to be constructed for the improved mail service between Holyhead and Kingstown. These vessels will be 371 feet long, 40 feet beam, 29 feet 3 inches in depth from hold to spar deck, and of 2,676 tons. The engines are to be triple-expansion and of 8,250 horse power. These vessels are for the City of Dublin Steam Packet Company. The service is to be twice daily in each direction, and four vessels must be built to meet the views of the Postmaster General, strict conditions and penalties being laid down to insure regularity and speed. The subsidy up to March 31, 1917, is to be £100,000 per annum, but unless a year's notice be given, the contract will continue, but the sum will, after 1917, be £80,000, and the contract will be terminable on either side on twelve months' notice. A percentage of the passenger receipts, which is compounded at £2,000 per annum, must be paid to the Postal Department. Now as to penalties. The four boats must be complete and ready for service by March 1, 1897, or £50 must be paid for each day the vessels are behind time. The vessels must go on the service on April 1, 1897, or £250 must be paid for every day they are behind. Other penalties, for delay in starting and making the trips, are provided.

Cape Ann.—Was built by The Neafie & Levy Company, of Philadelphia, for the Boston & Gloucester Steamboat Company. The new boat is built throughout of steel, 185 feet long, 29 feet beam and 14½ feet depth of hold. She is propelled by a single screw, with compound engines, having cylinders 25 and 50 inches diameter by 30 inches stroke, steam being supplied by three Scotch boilers. The new boat is thoroughly modern and up to date in all her fittings and equipments and has the Williamson steam steering engines and American ship windlasses. A complete electric light plant is installed, and it is the intention of both owners and builders to have a steamboat equal to any afloat. She will run between Boston and Gloucester, Mass., and will be large enough to carry about one thousand passengers, in addition to what might be ordinary freight, and she is guaranteed to develop a speed of 16 knots when in service.

Messrs. Neafie & Levy were awarded the contract (their bid being $101,085) for the boat on account of agreeing to deliver her in five months' time, although they were not the lowest bidders. A penalty was to be exacted for each day over the time specified. The contract was signed the first week in January and the boat delivered in Boston the first week in June. She made the trip from Philadelphia to Boston in 46 hours, although no attempt was made to force her. The new steamer had a very satisfactory trip on the Delaware before she started around to Boston.

Chesapeake.—This steamer, launched on Wednesday, June 26, from the shipbuilding yard of Messrs. David J. Dunlop & Co., Port Glasgow, was built for the Anglo-American Oil Company, London, for carrying petroleum in bulk. She will be the largest oil steamer afloat, her deadweight carrying capacity to Lloyd's freeboard being 6,000 tons, with a gross register of about 4,600 tons. The dimensions of the steamer are 385 feet over all, 370 feet between perpendiculars, 47 feet beam, 29 feet 3 inches in depth molded to upper deck. She is a three-deck vessel, and the hull is divided logitudinally into 18 compartments by transverse water tight bulkheads. There are 10 double tanks for carrying the oil, the longitudinal middle line bulkhead dividing each of the 10 tanks. To preclude the possibility of oil finding its way into the holds or engine and boiler space, a cofferdam, 4 feet long, is placed at each end of the two main oil divisions of the steamer. An important feature in the construction of the bulkheads is that all the caulking can be done in each alternate tank. The whole of the bulkheads dividing the oil tanks were subjected to a pressure of 20 feet head of water above the main deck, and withstood this unusual test in a highly satisfactory manner. The machinery consists of a set of triple-expansion single screw engines, having cylinders 27 inches, 43½ inches and 70 inches in diameter by 51 inches stroke. The oil pump machinery consists of two "Snow" duplex pump engines, 12 inches by 12 inches, one placed in the pump room aft, and one in the pump room forward. A noticeable point in the construction of this steamer is the placing of machinery in midships, necessitating the construction of an absolutely water tight tunnel for the main shafting. This tunnel is entirely cut off from communication with the engine room, the only access to it being obtained from the trunks leading from the poop deck, this precaution being considered necessary (in the event of any damage to the tunnel through the shaft breaking or any other cause) to prevent the access of oil or oil vapor to the engine room.

Georgic.—A twin screw steamer built by Messrs. Harland and Wolff, Belfast, launched on 22d of July. She has been built for the Oceanic Steam Navigation Company, and is intended to run in their cargo and live stock service between Liverpool and

New York, and is the thirty-fourth steamer constructed by Messrs. Harland and Wolff for the White Star Line, and the largest cargo steamer afloat. Her tonnage is about 6,580 net and 10,000 gross. She will be fitted for the accommodation of about 900 head of cattle on the upper and bridge decks, and will, in addition, have permanent stalls of a most perfect kind for a large number of horses in the center of the upper deck. The machinery for the vessel, which has been constructed in the engine works of the builders, consists of two sets of triple-expansion four-cylinder engines of the most modern type. The vessel will be fitted throughout with the electric light. Her length is 557 feet, beam, 60 feet, and depth, 40 feet. The two screws overlap each other slightly in the hole where the deadwood is cut away.

Germanic.—This steamer, of the White Star Line, was built at Belfast, in 1875, by Messrs. Harland and Wolff, and from that time until the end of last year, was regularly at work on the Atlantic, and has made no less than 211 round voyages, 422 passages across the Atlantic, or a distance of more than 1½ million statute miles. The original engines, after nearly twenty years' work, have now been taken out, as well as the boilers, and have been replaced by triple-expansion engines of about 6,000 I.H.P. The ship has besides undergone a thorough overhaul, and many improvements have been introduced, all the work being effected by Messrs. Harland and Wolff, Limited. The *Germanic*, after a satisfactory trial and adjustment of compasses, left Belfast for Liverpool on May 9th. On her first trip to New York, she broke all her previous records to that port. She made the passage in six days twenty-three hours and twenty-seven minutes. Her day's runs were 400, 396, 405, 411, 420 and 326 knots, covering a total distance of 2,779 miles. Her previous record was seven days ten hours and thirty-five minutes.

Sumatra.—This steamer, built by Messrs. Alex. Stephen & Sons for the P. & O. Steam Navigation Co., was launched June 25. She is 400 feet long, 46 feet 6 inches beam, and has a depth of hold of 31 feet. Her gross tonnage is about 4,650 tons, and her deadweight capacity about 5,900 tons. Her construction complies with the Admiralty regulations for transport service. There are seven water tight bulkheads extending to upper deck. She is handsomely fitted for passenger service. The engines are triple-expansion, with cylinders 28, 46 and 77 inches diameter, and a stroke of 54 inches. Howden's forced draft system is used, and the boilers work at a pressure of 180 pounds per square inch. There is a complete system of vertical compound pumping and auxiliary engines. Electric lights are fitted throughout the ship.

YACHTS.

Free Lance.—This steam yacht was constructed at the yard of Lewis Nixon, Elizabethport, N. J., and is 108 feet on water line, 137 feet from point of figurehead to taffrail, 20 feet beam, and 6 feet 9 inches draught. The cross section of the *Free Lance* is different from all other steam yachts. The keel is 2 feet wide, and flat at the bottom, and the form of the section is that of a sailing yacht, a sharp dead rise, and very little bilge, with a flared side. The forefoot is entirely cut away, and the bow is carried out with a long head. The stern has a long overhang and a full load water line. The vessel is built of steel. The plating is lap work, and the lines of plating have received much attention. There will be two houses on deck. The forward one will be used as a pilot house and rooms for officers. Below will be the galley and quarters for the crew. Aft will be the staterooms and dining room, and the after house will also be used as a dining room. There is a triple-expansion engine of about 600 I.H.P., with cylinders 11, 17 and 29 inches in diameter, and a stroke of 20 inches. The boilers will be of the Almy water tube type, with 52 square feet of grate surface.

Veglia.—This large screw steam yacht was built by Messrs. D. and W. Henderson & Co., Partick, and was launched on June 24. The dimensions are: Length over all, 275 feet; breadth, 30 feet 6 inches; depth, 20 feet. The vessel is classed as 100 A1, in Lloyd's yacht registry. The machinery has been constructed by the builders' firm, and consists of a set of triple-expansion engines and a very large boiler fitted with forced draft. The cylinders are 23 inches, 38 inches and 64 inches in diameter, with a stroke of 36 inches, and the working pressure is 160 pounds.

Catania.—Another steam yacht by the builders of the *Veglia*, was launched on June 6th. She is classed in Lloyds, and is of the following dimensions: Length over all, 225 feet; breadth, 26 feet 6 inches; depth, 16 feet 6 inches. Externally the vessel has a very graceful appearance. A novelty in the design of the vessel is a shade deck, extending nearly three-fourths the length and from side to side of the vessel, covering the deck houses and machinery casing. This will furnish a long unbroken promenade not usually obtained in a steam yacht. It is supported at the sides by stanchions above the main rail. The engines are triple-expansion with four cylinders, 18 inches, 28½ inches, and two of 32 inches diameter, with a stroke of 27 inches. There is a large single ended boiler, fitted with forced draft.

Urania.—This steam yacht was launched on Friday, June 7, from the yard of Messrs. James and George Thomson, Clydebank. She is 200 feet long, 26 feet 3 inches broad and 16 feet 6 inches deep, and has a tonnage of 550 tons, and has been built to the highest class of the British Corporation. The vessel is specially intended for long ocean cruises, and has a coal capacity of more than 200 tons, which will enable her to steam for 6,000 knots without coaling, at a speed of 10 knots. A large electric launch, which will be capable of steaming for a distance of 100 knots, and four other boats are supplied.

Monsoon.—The trial trip of this steam yacht took place on the measured mile at Stokes Bay on July 4. She was built by Messrs. Day, Summers & Co., Southampton. Her dimensions are: Length, 138.5 feet; breadth, 19.125 feet; depth, 11.1 feet; tonnage, yacht measurement, 235; tonnage, gross register, 171. Engines of the compound type have been fitted, the diameters of the cylinders being 15½ inches and 30 inches by 23 inches stroke. The boiler is 10 feet in diameter, the length 9 feet, and the working pressure 100 pounds. The total heating surface is 856 square feet, and the total grate area 38 square feet. The propeller has four blades 8 feet in diameter, 12 feet 6 inches pitch, and 18 square feet surface. The draught on trial was, forward, 8 feet 7¾ inches; aft, 10 feet 4⅝ inches; mean, 9 feet 6¼ inches, the displacement being 280 tons. The weights on board included coal, 43 tons; water, 6⅜ tons; ballast, 30 tons. The mean steam pressure was 96 pounds, vacuum, 25 inches, and revolutions, 110.

The mean speed on four runs was 11.014 knots, and the mean indicated horse power, 266.

Oneonta.—This steam yacht was launched by the Delaware River Iron Shipbuilding and Engine Works, Chester, Pa., on July 23d. She is 136 feet over all, 18 feet beam and 6 feet draught, is beautifully modeled, and in appearance resembles a torpedo boat more than a steam yacht. There is a triple-expansion engine of 800 horse power, and a Thornycroft tubulous boiler built in this country, supplying steam of a pressure of 250 pounds to the square inch under forced draft. The speed will be about fifteen knots. The propeller is 5 feet 9 inches in diameter. There is an independent circulating pump. There is only one mast, situated abaft the engine room. Her deck fittings, instead of being of brass, as is usual, are of white metal, so as to be perfectly rust proof. The crew's quarters are below the main deck, forward of the boiler space.

Thespia.—This steel steam yacht was launched from the works of Messrs. Wm. Cramp & Sons, Philadelphia. She is 174 feet 5 inches long on the water line, 195 feet length over all, 23½ feet beam, 13 feet depth of hold and 10 feet draught. The engines are compound, with cylinders 22 and 42 inches diameter by 24 inches stroke. Steam will be supplied by two boilers 10 feet 9 inches long and 11 feet in diameter. All the engine and other auxiliaries will be of the most approved type. The yacht when finished will be an important addition to the New York Yacht Club's already splendid fleet of steam yachts.

Huntress.—This steam yacht was launched at the yards of her builders, Charles L. Seabury & Co., Nyack-on-Hudson, at 20 minutes past midnight, on June 29th. The *Huntress* is 120 feet over all, 97 feet on load water line, 16 feet beam, 9 feet depth, 6 feet 6 inches draught. She has excellent accommodations. The engines are triple-expansion, and there is a Seabury safety water tube boiler of latest type. The guaranteed speed in contract is 16 miles per hour for three consecutive hours. She is schooner rigged, flush deck.

Peregrine.—This steam yacht was built by the Bath Iron Works, of Bath, Me. She is of the following dimensions: Length over all, 158 feet 3 inches; on load water line, 131 feet; beam, extreme, 23 feet; depth of hold, 13 feet; mean draught, 10 feet; extreme draught, 10 feet 9 inches. There is a large mahogany deckhouse 72 feet long, with an average width of about 13 feet. Large circular sliding lights or air ports, 16 inches in diameter, give light and air to the living compartments of this deck house, and these lights have proved a great improvement over the ordinary swinging ones. A donkey boiler will be placed in the boiler room for steam heating and auxiliary purposes. A Williamson steam steerer, a Hyde hand screw steerer and a Hyde patent steam windlass are also fitted. The vessel will be lighted throughout by electricity, the dynamo being in the engine room, and a 12-inch search light and display lights for the rigging will be fitted. There will also be efficient telephone and electric bell communication between various parts of the boat. She will carry three small boats and a 23-foot naphtha launch. She is rigged as a two-masted schooner, the total sail area being about 3,500 square feet. There is a vertical triple-expansion engine, with cylinders 14, 21 and 34½ inches diameter, and a stroke of 22 inches. Piston valves are used throughout; the high pressure cylinder is between the intermediate, which is forward, and the low pressure. The condenser forms part of the framing at the back of the engine, the cylinders being well supported and braced by steel columns. The propeller is of manganese bronze, four-bladed, with a diameter of 8 feet 3 inches and a pitch of about 10 feet. There are two Almy water tube boilers, built for a working pressure of 185 pounds each, occupying a space 83 inches long, 83 inches wide and 104 inches high. The grate surface is 65, and the heating surface about 2,500 square feet. The designed indicated horse power is 800, and the speed over 14 knots.

Calypso.—This steam yacht is schooner rigged, and was designed and built by the Atlantic Works at East Boston, Mass., during the past year. The hull is of wood, and the principal dimensions are: Length on load water line, 102 feet; beam, 17 feet; draught, 7 feet 4 inches, with tanks and bunkers full and all stores on board.

She has one deck house of mahogany, located forward.

Her engines are vertical, inverted, direct acting compound, with cranks set at 90 degrees, and cylinders 12 and 22 inches diameter, and a stroke of 16 inches. The main valves are of the piston type and are actuated by a Stephenson link motion. The cylindrical surface condenser has 400 square feet of cooling surface. There are two independent feed pumps and a combined air and circulating pump, all of the Blake type. There is a Hancock locomotive inspirator and a bilge ejector. There is an auxiliary suction pipe and valve from the circulating pump to the bilge for use in case of emergency. The boiler is of the Almy double water tube type, the working pressure being 130 pounds. The entire machinery is below deck, the smoke stack and whistle and escape pipes only appearing above deck.

The electric plant, located in the engine room, is very compact. It consists of a multipolar dynamo driven direct by a compound engine with cylinders 2¾ inches and 5 inches diameter and 2½ inches stroke, and has a capacity to furnish current for sixty 16-candle power lamps at a pressure of 75 volts. There is a storage battery of sufficient capacity to run thirty lights for nine hours, which can be charged in the day time when steam is up, thus dispensing with the necessity of keeping up steam and running the dynamo at night. There is a Huntington search light of a capacity of 4,000 candle power, which can be run either from the storage battery or direct from the dynamo.

Her maximum speed is about 15 miles per hour, and her actual continuous speed under natural draft, as shown on her cruises from port to port, is about 14 miles. She went into commission the 18th day of May, and since then has made several cruises along the coast, some of them being in very severe weather. She has proved remarkably able and comfortable under all circumstances.

BOOK REVIEW.

AMERICAN STEAM VESSELS, by Samuel Ward Stanton; Smith & Stanton, New York.

The engineers and shipbuilders of the United States owe a debt of gratitude to Mr. Samuel Ward Stanton for his publication with the above title, representing as it does a world of patience, labor and research, and which enables one to note at a glance the gradual evolution of the floating palaces on our lakes, rivers and sounds, like the *Priscilla* and *Northwest;* the ocean greyhounds, like the *St. Louis;* and the battleship and fast cruiser, like the *Indiana* and *Minneapolis,* from Fulton's *Clermont* and *Demologos*.

The book also is of great service in calling to mind the names of the early engineers and constructors who, starting with little or nothing to guide them, by their own energy and ability, in spite of difficulties and discouragements, made a brilliant success of what in less able hands would have been but a dismal failure, and, by their solution of the problem of steam navigation, were no small factors in the progress and development of the country.

We of to-day, accustomed to 100-ton steam hammers and power tools that can take in and handle any part of the largest marine engine, are apt to overlook the difficulties experienced by the earlier Engineers, when shafts had to be forged by tilt hammers that now appear ridiculously small for the work, and valve seats faced off by securing the cylinder alongside of the planer and traversing the tool forward and backward by an angle plate bolted to the platen, the feed being in most cases regulated by hand. The earlier air pumps were in many instances staved, like a barrel, and more perfect work and exact fittting could not be turned out to-day.

In some of the very earliest steamers we see the same beauty of form and grace of outline that have since made the American model famous the world over; we see too how the river boat engine, starting with the "grasshopper" on the *Clermont*, changed into the crosshead or square engine, and then into the overhead beam, which, in the hands of its skillful designers, became a marvel of strength and lightness, combined with perfect working.

The artistic beauties of the book are apparent on the most cursory examination ; its historical value becomes more apparent the more closely it is studied, and it should have a place in the library of every one interested in the development, the progress or the present condition of American shipping.

OBITUARY.

EZRA J. WHITAKER.

Chief Engineer E. J. Whitaker was born in North Adams, Mass., April 12, 1839. He entered the Navy as a Third Assistant Engineer, February 21, 1861, was promoted to Second Assistant, December 17, 1862; to First Assistant, December 1, 1864; and on June 6, 1873, was commissioned a Chief Engineer.

His tour of sea duty comprised seventeen years of cruising on many vessels, including his service during the late war.

His last cruise was on the North Atlantic Station as Chief Engineer of the *Philadelphia*.

Among the more important duties on which he had been engaged while on shore was his service at the Navy Yard, Boston, in 1872–'74, and as member of Board for the Inspection of Merchant Vessels, at New York. He was detached and placed on the Retired List on May 8, 1895, having the relative rank of Commander.

He died at the age of 56, at Sackett's Harbor, N. Y., August 21, 1895.

ROBERT B. HINE.

Chief Engineer Robert B. Hine, U. S. Navy, was born in Durham, England, February 6, 1841. He entered the Navy as a Third Assistant Engineer, August 24, 1861; was promoted to Second Assistant, April 21, 1863; to First Assistant, October 11, 1866; and attained the rank of Chief Engineer on the 14th of December, 1882.

Considerably more than half of his career in the Navy was spent at sea, he having served with efficiency and zeal for eighteen years on vessels which cruised in many parts of the world. His last active service was on the *Concord*.

His shore service comprised duty at the Bureau of Steam Engineering, and as Member of Board of Naval Examiners at Washington, D. C.; his last term of shore duty being at the Quintard Iron Works, where he was engaged in preparing the *Concord* for sea.

Retiring on February 20, 1893, with the relative rank of Lieutenant-Commander, he lived a little over two years, and died at Washington, D. C., on the 27th of June, 1895, at the age of 54.

WM. W. HEATON.

Chief Engineer William W. Heaton was born in New York, N. Y., on May 23, 1839. Entering the Navy, December 2, 1861, as Third Assistant Engineer, he was promoted to Second Assistant, September 8, 1863; to First, October 11, 1866, and to Chief Engineer, January 26, 1886, with the relative rank of Lieutenant Commander.

His duty at sea extended over more than fifteen years, and included service on all stations. His last cruise was on the *Newark*, on the South Atlantic Station.

His shore service included duty at the Navy Yards New York and Norfolk, Member of Board for the Inspection of Foreign Vessels, and as Inspector of Machinery of Government Vessels being built at the Quintard Iron Works 1890–93.

While on the *Newark* he became seriously ill, was detached and sent to the Naval Hospital, New York, and subsequently ordered to appear before a retiring board.

He died at Naval Hospital, New York, on May 31, 1895, at the age of 56, before being transferred to the Retired List.

JOURNAL

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The Society as a body is not responsible for statements made by individual members.

CONTRACT TRIAL OF THE UNITED STATES COAST-LINE BATTLE SHIP *INDIANA*.

BY PASSED ASSISTANT ENGINEER HARRY HALL, U. S. NAVY.

The *Indiana* is a twin-screw armored coast-line battle ship, and was built by the William Cramp & Sons' Ship and Engine Building Company, of Philadelphia, Pa., the designs having been furnished by the Navy Department. The contract was signed on November 19, 1890, the price being $3,063,333, and the time for completion three years. The speed guarantee was fifteen knots per hour, to be maintained successfully for four consecutive hours, during which period the air pressure in the fire rooms was not to exceed one inch of water, the vessel to be weighted to a mean draught of twenty-four feet. It was stipulated that for every quarter knot of speed maintained above fifteen knots the contractors should receive a premium, over and above the contract price of the vessel, of twenty-five thousand dollars, and that for every quarter knot the vessel failed to reach the guaranteed speed there should be deducted from the contract price the sum of twenty-five thousand dollars.

HULL.

The hull is constructed of mild steel of domestic manufacture, with frames spaced 4 feet throughout the length of the double bottom, and 3.5 feet forward and abaft the double bottom. The thickness of the outer keel plate is $\frac{3}{4}$ inch, of the inner $\frac{5}{8}$ inch, and of the vertical keel $\frac{1}{2}$ inch. The outer bottom plating is $\frac{5}{8}$ inch thick, and the inner bottom plating $\frac{3}{8}$ inch.

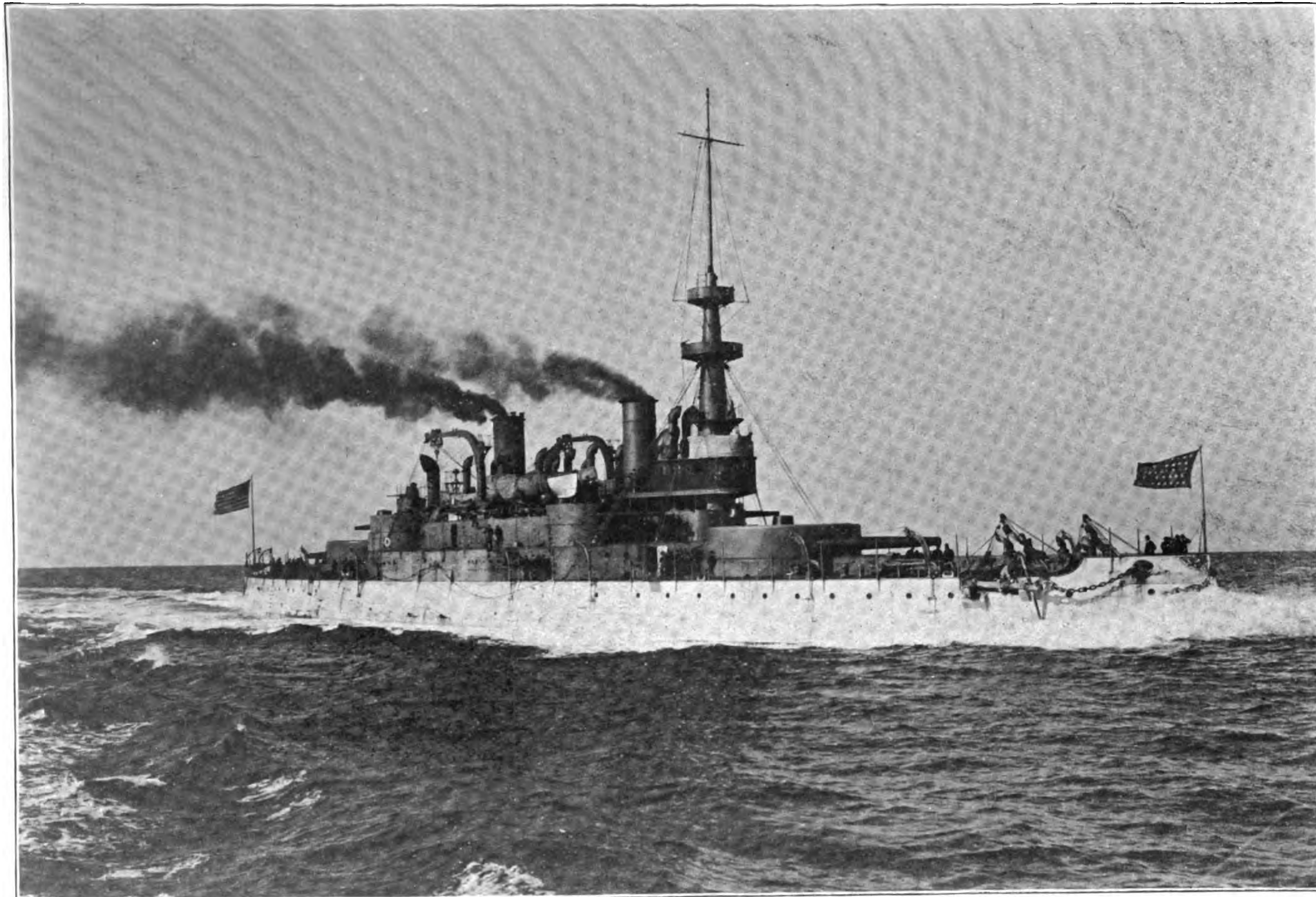
The ship is divided into 269 water tight compartments. The double bottom extends from frame 18 to frame 78, a distance of 240 feet, and runs up to the armor shelf. It is 3 feet 3 inches in depth amidships and is divided into 19 water tight compartments. Coffer dams, 6 feet wide, are on each side of the vessel extending forward and abaft the armor belt, from the orlop deck to the berth deck, and are packed with cellulose. The transverse bulkheads are carried through the coffer dams to divide them into water tight compartments.

Hold.—In the hold abaft the engine compartments and forward of the boiler compartments are: Coal bunkers, 6-inch and 8-inch magazines and shell rooms, fixed ammunition rooms, turning gear for 13-inch turrets, store rooms and trimming tanks.

After platform.—On the after platform are: 13-inch magazines and shell rooms, 13-inch handling room, store rooms, steering engine and gear.

Forward platform.—On the forward platform are: 13-inch magazines and shell rooms, 13-inch handling room, store rooms.

Orlop deck.—On the orlop deck, forward and abaft the athwartship armor, are: Store rooms and fresh water tanks; and within the citadel, coal bunkers, ventilating fans, dynamo room, hydraulic machinery, 8-inch turret turning machinery, air compressors for torpedo tubes, central station for voice pipes and telephones, auxiliary magazines for 8-inch, 6-inch and rapid fire guns. Outboard on each side is an armored passage extending from bulkhead at frame 29 to bulkhead at frame 64. Inboard of the armored passage, and extending the same length, is an ammunition passage.



U. S. S. "INDIANA."

Berth deck.—On the berth deck are the living quarters, the auxiliary boilers, coal bunkers, the refrigerating plant and torpedo rooms.

There are 30 coal bunkers with a total capacity of 1,650 tons at 43 cubic feet to the ton. They are distributed as follows: 16 in the hold with a capacity of 1,340 tons; 6 on the orlop deck with a capacity of 78 tons; 8 on the berth deck with a capacity of 232 tons. They are filled through chutes and trunks fitted between decks. The trunks are fitted with shunt doors at the top where they pass through the coal bunkers on the berth deck, and vertical doors at the bottom, so that the coal can be passed from these bunkers into the trunks, and through the orlop deck into the bunkers below. Armored shutters are fitted in the trunks where they supply coal to the bunkers through the orlop deck.

There are two ash chutes on each side, on the outside of the vessel, semi-oval in shape. The upper ends of the chutes extend above the main deck, where hoppers are formed inside. Trolley-ways for carrying the ash buckets are fitted under the deck beams above, leading from the ash hoists to the chutes.

Drainage system.—For draining the compartments there is a 14-inch main drain pipe on the port side and a 7½-inch secondary drain pipe on the starboard side, extending in the double bottom throughout the engine and boiler compartments. Each pipe has branches leading to a cistern in each compartment and is fitted with screw-down non-return valves. The main drain pipe is connected with the port main circulating pump, and through the manifolds with four engine room auxiliary pumps. The secondary drain pipe is connected through the manifolds with the suctions of eight of the auxiliary pumps. The auxiliary feed pumps are connected with the bilge of the boiler compartments, and the fire and bilge pumps with the bilge of the engine compartments, and also with the bilge of the compartment next abaft the engine rooms. The side compartments empty directly into the midship compartments by means of water-tight sluices on the bulkheads. The compartments at the extremities drain into the compartments at the ends of the main drain pipe by means of gun-metal sluices. Each compartment within the double bottom has its own suction, and these suctions lead to valve boxes placed in the engine rooms. The suctions forward and abaft the limits of the double bottom are led to valve boxes located in the fire rooms and engine rooms respectively. A drain valve is fitted to each compartment above the platform decks, with a strainer box over it, and with a pipe leading to the bilge. For draining above the orlop deck, forward and aft, screw-down valves are fitted in the armor deck, two forward and two aft, with sluice valves in the store room and other bulkheads; from these valves pipes lead the water to the main drain pipe. The waste water from the bath and wash rooms is led by pipes to tanks located in the ammunition passages, and is pumped overboard by a Blake plunger pump, with steam cylinder 4½ inches diameter, plunger 3¾ inches diameter, and stroke 7 inches.

The boats carried are as follows:

1 33-foot steam cutter.
1 30-foot steam cutter.
2 29-foot whale boats.
1 30-foot whale boat gig.
1 32-foot sailing launch.
2 28-foot cutters.
1 26-foot cutter.
1 24-foot cutter.
2 20-foot dinghies.
1 Balsa.
2 Punts.

Length between perpendiculars, feet	348.
on L.W.L., feet	348.
over all (including rudder), feet and inches	350–10¼
Beam, extreme, feet and inches	69– 3
at L.W.L., feet and inches	69– 3
Ratio of length to beam	5.03
Depth in hold from top of main deck beams to top of floor, feet	32
Height of superstructure above main deck beams, feet and inches	7– 4
Draught forward, seagoing trim, feet	23.69
aft, seagoing trim, feet	24.06
mean, seagoing trim, feet	23.88

Displacement, seagoing trim (load draught), tons	10,225.
per inch, at L.W.L., tons	42.76
Area of immersed midship section, square feet	1,540.
L.W.L. plane, square feet	17,980.
Center of gravity of L.W.L. plane, aft of midship section (frame No. 45), ft.	.94
buoyancy above bottom of keel, feet	13.52
aft of midship section, feet	1.86
gravity above bottom of keel, feet	24.
Transverse metacenter above center of buoyancy, feet	15.27
Longitudinal metacenter above center of buoyancy, feet	335.5
Coefficient of fineness on extreme dimensions	.622
of midship section	.931
of L.W.L	.746
Cylindrical coefficient	.668
Number of frames	91.
water tight compartments	269.

ARMOR.

The armor consists of a side belt of Harveyized nickel steel extending through the machinery and boiler spaces and to the bases of the 13-inch gun turrets. It is 3 feet above, and 4 feet 6 inches below the normal load water line amidships, diminishing to 4 feet 2½ inches below the load water line at the ends. The outside surface conforms to the shape of the vessel, with a thickness of 18 inches extending from the top of armor to 12 inches below the load water line, from which point it tapers to 8 inches in thickness at top of armor shelf. At each end of the side, or water line belt, there is an athwartship belt 14 inches thick, thus completing the fort or armored citadel. The citadel is covered with an armored deck of nickel steel 2¾ inches thick, and forward and abaft the citadel there are protective decks of 3-inch nickel steel. Above the 18-inch side belt, extending to the main deck, there is a casemate of 5-inch armor, made up of two ½-inch plates and one 4 inch plate.

The armor of the turrets for the 13-inch guns is of nickel steel 17 inches thick, and the bases of the turrets are protected by barbettes of the same thickness of nickel steel. The armor of the turrets of the 8-inch guns is 6 inches thick, the top plating 2 inches, and the sighting towers 5 and 3 inches thick. The bases of the 8-inch turrets are protected by barbettes with armor 8 inches thick on the outer sides and 6 inches thick on the inboard sides.

The armored protection of the 6-inch guns is 5 inches thick, made up of two inner thicknesses of ½ inch each and an outer thickness of 4 inches. The armored protection for the 6-pounder guns on the main deck is 2 inches thick. The armored protection for the 1-pounders at the ends of the vessel consists in having the plating increased to a total thickness of 2 inches in wake of the ports, so that it will act as a shield.

The conning tower is located above the superstructure deck; it is of steel, forged hollow in one piece, 10 inches thick, and has an internal diameter of 6 feet 11 inches.

An armored tube, 7 inches thick and 12 inches internal diameter, extends from the conning tower to the armored deck and protects the electric wires, voice tubes, connections to engine room telegraphs, steering gear and engine tell-tales.

ARMAMENT.

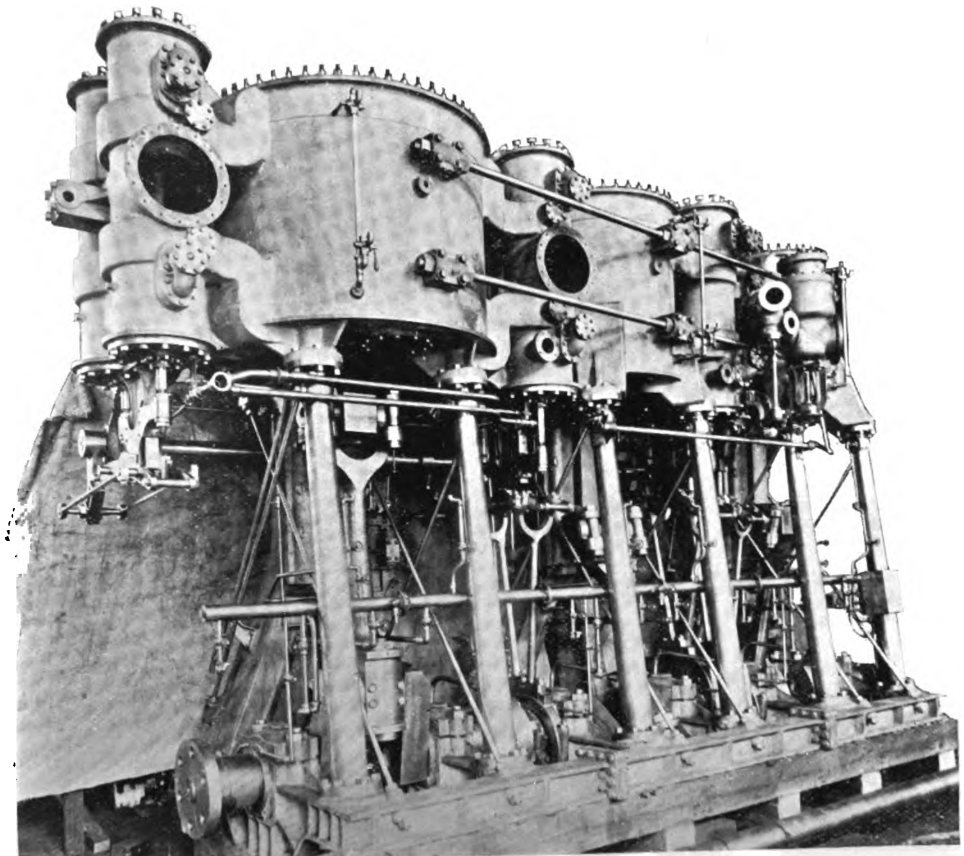
The main battery consists of four 13-inch breech loading rifles, 35 calibers, mounted in pairs in the two main turrets; eight 8-inch breech loading rifles, 35 calibers, mounted in pairs in the four turrets on the superstructure; and four 6-inch breech loading rifles, two on each side, on the main deck within the superstructure.

The secondary battery consists of twenty 6-pounder Hotchkiss rapid fire guns; six 1-pounder Hotchkiss rapid fire guns; and four light machine guns in the military tops.

The 13-inch turrets are worked by steam, and the guns by hydraulic power; the 8-inch turrets by steam power, and the guns by hand. The 6-inch guns are worked by hand on central pivot carriages.

There are six tubes for Whitehead torpedoes, two on each side, one in the bow, and one in the stern, all discharging directly from the berth deck.

The armament is a heavy one, throwing a weight of projectile from the main battery, in boadside at one discharge, of 5,600



TRIPLE-EXPANSION ENGINE U. S. S. "INDIANA."

pounds; and at one complete discharge of the main battery, of 6,800 pounds.

MAIN ENGINES.

There are two vertical inverted, direct acting, triple expansion engines placed abreast of each other in separate water tight compartments, the high pressure cylinders being forward.

Each cylinder is supported by an inverted Y frame on one side, and by two hollow forged steel cylindrical columns on the other. The intermediate and low pressure cylinders are steam jacketed on the sides and bottom, but the high pressure are not, but are fitted with working liners. There are no starting valves on the cylinders, provision being made for starting the engines by admitting live steam to the receivers. The relief valves for the cylinders are placed on the valve chest casings, on connections between the steam and exhaust sides of the main valves. There are two receivers for each engine, consisting of exhaust pipes and valve chests, the safety valves of which are set at 100 pounds for the I.P. and at 60 pounds for the L.P. The main valves are of the single ported piston type, there being for each engine, one for the H.P., two for the I.P. and four for the L.P. cylinder. They are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. The valve gear is of the Stephenson type with double bar links. There are no independent cut-off valves, but provision is made to cut off in each cylinder, varying from .5 to .7 of the stroke, by means of a block to which the suspension links are attached, which block can be moved by hand screw gear in a slot in the end of the arm on the reversing shaft.

The main pistons are steel castings, dished, and are each fitted with two packing rings $\frac{5}{8}$ inch wide and $\frac{3}{4}$ inch thick. The piston rods and connecting rods are of forged steel. The crossheads are of forged steel, and each has a manganese bronze slipper, the sliding faces of which are fitted with white metal. The crosshead guide to take the thrust when going ahead is of cast iron bolted to the inverted Y frame. The back of the guide is recessed and covered with wrought-iron plates to form a passage for circulation of water. Cast-iron lips are bolted on each side of the go-ahead guide to take the thrust when backing. The eccentrics are of cast iron. Each backing eccentric is securely keyed on the shaft, and each go-ahead eccentric is secured to the corresponding backing one by through bolts in slotted holes. The eccentric straps are of composition, faced with white metal, and the eccentric rods of forged steel. The I.P. and L.P. valve stems have manganese bronze crossheads which take hold of the link blocks directly. Each engine bed plate consists of three sections of steel castings. The steam reversing gear consists of a cylinder 14 inches in diameter and 20 inches stroke, secured to an engine Y frame, the piston rod being connected to an arm on the reversing shaft. The valve is moved by a hand lever and is controlled by a floating lever. The hand reversing gear consists of a wheel, worm shaft, pinion and rack, the latter being connected to an arm on the reversing shaft.

There is a double cylinder, simple, inverted, turning engine with cylinders 7 inches in diameter and 7 inches stroke secured to the high pressure Y frame. It drives a worm wheel on the forward end of the high pressure crank shaft by means of worm gearing and a second worm; the latter is made to slide on a feather key, and is held in place by a collar below and a removable key above it. A ratchet is fitted to the shaft of the engine for turning by hand.

Each main engine is fitted with a disc stop valve 13½ inches in diameter, having a screw stem and a balance piston, and a butterfly throttle 15⅛ inches in diameter. The main steam pipes are of copper and strengthened with steel bands 6 inches apart.

In the port engine room there is a distributing oil tank supplied from the main oil tanks by a Blake duplex pump, steam cylinders 2 inches in diameter, oil cylinders 1¼ inches in diameter, stroke 2¾ inches. The tank is fitted with an overflow pipe. Distributing pipes lead to the various manifolds which are fitted with adjusting valves, and from the manifolds tubes lead to the various parts to be lubricated. The suction pipe of the pump is fitted with a strainer.

Cylinders, number for each engine	3
diameter of H.P., inches	$34\frac{7}{16}$
diameter of I.P., inches — Starboard	$48\frac{3}{32}$
diameter of I.P., inches — Port	48
diameter of L.P., inches	75
Stroke of pistons, inches	42
Valves, diameter of H.P. (one for each cylinder), inches	17
diameter of I.P. (two for each cylinder), inches	17
diameter of L.P. (four for each cylinder), inches	17
Balance pistons, diameter of H.P., inches	$5\frac{1}{4}$
diameter of I.P., inches	$5\frac{1}{4}$
diameter of L.P., inches	7
Valve stems, H.P. (1) diameter, inches	$2\frac{5}{8}$
H.P. (1) diameter through valve, inches	$1\frac{3}{4}$
I.P. (2) diameter, inches	$2\frac{5}{8}$
I.P. (2) diameter through valve, inches	$1\frac{3}{4}$
L.P. (4) diameter, inches	$2\frac{5}{8}$
L.P. (4) diameter through valve, inches	$1\frac{3}{4}$
Main steam pipe (13 inches diameter) area of cross section, square inches	132.73
Exhaust pipe to I.P. cylinder ($16\frac{1}{2}$ inches diameter) area of cross section, square inches	213.82
to L.P. cylinder ($20\frac{1}{2}$ inches diameter) area of cross section, square inches	330.06
to condenser (2) ($18\frac{1}{2}$ inches diameter) area of combined cross sections, square inches	537.6
Volume swept by H.P. piston per stroke, cubic feet	22.17
I.P. piston, per stroke — Starboard, cubic feet	43.69
I.P. piston, per stroke — Port, cubic feet	43.51
L.P. piston, per stroke, cubic feet	106.91
Ratio of net area of H.P. to I.P. pistons	1.97
I.P. to L.P. pistons	2.45
H.P. to L.P. pistons	4.82
Clearance of H.P. cylinder, per cent — Starboard — Top	14 76
Clearance of H.P. cylinder, per cent — Starboard — Bottom	24.33
Clearance of H.P. cylinder, per cent — Port — Top	14.76
Clearance of H.P. cylinder, per cent — Port — Bottom	24.33
Clearance of I.P. cylinder, per cent — Starboard — Top	12 03
Clearance of I.P. cylinder, per cent — Starboard — Bottom	22.88
Clearance of I.P. cylinder, per cent — Port — Top	12.10
Clearance of I.P. cylinder, per cent — Port — Bottom	22.05
Clearance of L.P. cylinder, per cent — Starboard — Top	9 09
Clearance of L.P. cylinder, per cent — Starboard — Bottom	19.59
Clearance of L.P. cylinder, per cent — Port — Top	9.09
Clearance of L.P. cylinder, per cent — Port — Bottom	19.28
Piston rods, diameter, inches	7
length from piston to crosshead, feet and inches	$5-5\frac{3}{8}$

Connecting rods, length from center to center, feet	7
diameter of upper end, inches	$6\frac{5}{8}$
diameter of lower end, inches	$8\frac{1}{2}$
thickness (sides as faced), inches	$6\frac{5}{8}$
crosshead bolts (4), diameter, inches	3
crank pin bolts (2), diameter, inches	$4\frac{1}{4}$
Crossheads, surface (ahead), square inches	$446\frac{1}{2}$
surface (backing), square inches	$352\frac{1}{2}$
pins, diameter, inches	$7\frac{1}{2}$
pins, length, inches	$9\frac{1}{8}$
Reversing gear, steam cylinder, diameter, inches	14
stroke, inches	20

Shafting and Bearings.—The crank, line and propeller shafting is hollow and of forged steel. The crank shaft of each engine is in three interchangeable sections, the cranks placed at angles of 120 degrees, and for the ahead motion follow in the order H.P., I.P. and L.P. There are two sections of line shafting to each engine supported on three bearings. The propeller shafts are fitted with a composition casing from inboard the stern tube stuffing box to the propellers; they extend far enough inboard to allow the inboard stern bearings to be withdrawn without moving the shafts. The shaft coupling bolts are tapered and finished to fit the holes snugly. They are put in from the after side of the coupling and are set up on the forward side with a wrought-iron nut and split pin.

Each thrust bearing is of cast iron of the horse shoe pattern. The end and side walls of the pedestal form an oil trough inside of which, both forward and aft the horse shoes, is a composition bearing lined with white metal for taking the weight of the shaft. The cap of this bearing is of cast iron lined with white metal. There is an oil cup in the top of each horse shoe, from which there is an oil hole to each collar, the white metal being channeled for the distribution of the oil. At each end of the bearing there is a divided stuffing box and gland to prevent the escape of oil. The pedestal is bolted to a cast-iron sole plate fitted with wrought-iron wedges at each end of the pedestal for adjusting the bearing fore and aft.

Crank shafts,	diameter, inches	14
	axial hole, inches	6
	coupling discs, diameter, inches	26½
	coupling discs, thickness, inches	3¼
	tapered coupling bolts in one flange (6), diameter, inches	3⅛ to 3 11/16
	journals, diameter, inches	14
	journals, length, inches	17⅜
	length of each section, feet and inches	8–6
Crank pins,	diameter, inches	15
	length, inches	17
	axial hole, inches	6½
Crank webs,	width, inches	15½
	thickness, inches	9¼
Thrust shafts,	diameter, inches	13¾
	diameter of coupling disc, inches	26½
	axial hole, inches	6
	collars, number each shaft	11
	collars, diameter, inches	21
	collars, thickness, inches	2
	collars, distance between, inches	4
	surface, total for both engines, square inches	4.353.18
	length, feet and inches	16–⅞
Line shafts,	diameter, inches	13¾
	axial hole, inches	6
	diameter of coupling discs, inches	26½
	(2) total length, feet	40
Propeller shafts,	diameter, inches	14
	axial hole, inches	6
	diameter of coupling discs, inches	26½
	length, feet and inches	40–8
Stern bracket bearing,	length, inches	49⅛
	diameter, inches	15 27/32
Stern tube bearing, length...	forward, inches	33½
	aft, inches	35½

There are six coupling bolts for each section of shafting. They are taper, from 3⅛ to 3 11/16 inches in diameter.

Main Condensers.—There are two main condensers, one for each engine, of cast composition, in five sections, including the heads, and bolted together. The circulating water passes through the tubes. Baffle plates are fitted to direct the steam over the tubes, and plates are provided for supporting the tubes and also to act as baffle plates.

Diameter of shell (inside), feet and inches	5–9
Thickness of shell, inch	½
Length over heads, feet	12
Tubes, diameter (outside), inch	⅝
length between heads, feet and inches	10–3
thickness, No. 20 B.W G., inch	.035
number in each condenser	3.790
Cooling surface, each condenser, square feet	6,355
total, square feet	12.710
Ratio of total cooling to total heating surface.. Main boilers	1 to 1.356
Ratio of total cooling to total heating surface.. Main and auxiliary boilers.	1 to 1 51

Main Air Pumps.—For each main engine there is a Blake double, vertical, single acting air pump, similar to those on the *Minneapolis.* The steam cylinders are placed directly over the pump cylinders, the pump rods and piston rods forming a continuous length. The pumps are connected by means of a beam, which is pivoted at its center, and from which beam the valve motion is actuated. The beam receives its motion through links swinging from crossheads on the pump and piston rods.

Diameter of steam cylinders (2), inches	12
pump cylinders (2), inches	25
Stroke, inches.	18
Diameter of piston rods, inches	2¼
pump rods, inches	4
Kind and diameter of pump valves (vulcanized rubber), inches.	5½
Ratio of volume swept by L.P. piston, per stroke, to that of the two air pump buckets, per stroke	10 59

Main Circulating Pumps.—For each main condenser there is a centrifugal double inlet circulating pump, which is arranged to draw from the sea, bilge and main drain pipe, and to discharge either into the condenser or directly overboard. It is driven by a horizontal single cylinder engine. Each pump is capable of discharging 9,000 gallons of water per minute from the bilge. The sea and bilge injection valves are fitted with a self-locking arrangement so that both cannot be opened at the same time.

Diameter of steam cylinder, inches	12
Stroke, inches	6
Diameter of pump runner, inches	32

Width of runner, inches...at hub 6¾, at rim	2¾
Diameter of inlet nozzle, inches	15
outlet nozzle, inches	15

Auxiliary Condersers.—There is in each engine room a Wheeler condenser connected with the auxiliary exhaust pipes. Each has a horizontal combined air and circulating pump, the steam cylinder being between the water cylinders, and all the pistons being on one rod. The tubes are arranged and packed as in the main condensers.

Cooling surface, one condenser, square feet	400
Diameter of steam cylinder, inches	8
water cylinder (circulating), inches	9
air pump cylinder, inches	9
Stroke, common, inches	10

Screw Propellers.—The propellers are of manganese bronze, each with three adjustable blades bent back 15½ degrees. They are true screws, with the pitch variable from 14 feet 3 inches to 16 feet 3 inches. Each boss is secured to the shaft by a feather key and a wrought steel nut screwed on and locked in place. The end of the hub is covered with a composition cap.

Number of blades	3
Diameter, feet and inches	15–6
of hub, feet and inches	3–11½
Length of hub, feet and inches	3–1
Pitch as set, feet	16
Greatest width of blade (4 feet from axis), inches	45$\frac{5}{16}$
Helicoidal area of each screw, square feet	53.859
Projected area, square feet	45.24
Disc area, square feet	188.69
Pitch ÷ diameter	1.03
Helicoidal area ÷ disc area	.285
Projected area ÷ disc area	.24
Disc area of both screws ÷ I.M.S	.245
Immersion of center at mean draught (23.88 feet), feet	15.88
Center above lowest point of keel, feet	8
from center line of vessel, feet and inches	11–10

BOILERS.

There are four double ended main and two single ended auxiliary steel boilers of the horizontal fire tube type. Each main boiler has eight, and each auxiliary boiler two corrugated furnaces. The shell of each main boiler is made up of three courses of three plates each. The longitudinal joints of the shells of the main boilers are treble riveted with double butt straps, and the circumferential joints are lapped and treble riveted. The shell of each auxiliary boiler is in one course of two plates, double butt strapped and treble riveted, the joints with the heads lapped and double riveted. The joints in furnaces and combustion chambers are single riveted. The heads of the main boilers are flat; those of the auxiliaries are curved at the top to a radius of 2 feet $2\frac{1}{2}$ inches for the front head, and 2 feet $1\frac{39}{64}$ inches for the back head. The furnaces are fitted with "Cone's" patent shaking grate bars. Each main boiler has one quadruple $3\frac{1}{2}$-inch safety valve in one case, and each auxiliary boiler one 3-inch double safety valve in one case. Weir's hydrokineters are fitted to each main boiler for circulating the water while raising steam if there is steam in one boiler. The auxiliary feed pumps can be used to circulate the water, pumping from the bottom blow and delivering through the auxiliary feed checks, the main and auxiliary internal feed pipes being connected and arranged to give a good distribution of the water. The tubes in all boilers are of steel.

The main boilers are located fore and aft in four water-tight compartments. There is a passage way amidships extending from the athwartship engine room bulkhead to the athwartship bulkhead of the forward fire rooms, and in this passage way there are water tight doors to each fire room. By this arrangement there are two athwartship fire rooms in each main boiler compartment, and eight main fire rooms in all. The auxiliary boilers are located on the berth deck in separate boiler rooms. There are two main and two auxiliary smoke pipes, the latter running up inside the former.

MAIN BOILERS.

Steam pressure, pounds	160
Number of boilers	4

Length, feet	18
Diameter, outside, feet	15
Thickness of shell, inches	$1\frac{19}{64}$
heads, top, inch	1
bottom, inch	$\frac{3}{4}$
tube sheets, inch	$\frac{5}{8}$
furnaces, inch	$\frac{1}{2}$
Combustion chambers, number in each boiler	4
thickness of plates, inch	$\frac{9}{16}$
width at top, feet and inches	$2-5\frac{5}{8}$
depth, feet and inches	$7-5\frac{1}{2}$
Furnaces, greatest internal diameter, feet and inches	3-4
least internal diameter, feet	3
length of grate, feet and inches	5-9
number in each boiler (corrugated)	8
Tubes, outside diameter, inches	$2\frac{1}{2}$
length between tube sheets, feet and inches	$6-\ \frac{5}{8}$
number of ordinary	676
number of stay	248
spaced vertically, inches	$3\frac{1}{2}$
horizontally, inches	$3\frac{3}{4}$
thickness of ordinary, B.W.G. No. 12, inch	.109
stay, B.W.G. No. 6, inches	.203
Diameter of rivets in shell sheets, inches	$1\frac{1}{4}$
screw stays, inches	$1\frac{17}{64}$
Number and diameter of through upper braces, inches	24 of $2\frac{1}{4}$, 3 of $2\frac{1}{2}$
lower braces, inches	3 of $1\frac{3}{4}$
braces around lower manholes, inches	12 of $1\frac{3}{4}$
from head to back tube sheets, inches,	20 of 2
Heating surface, tube, square feet	3,647.5
furnace, square feet	245
combustion chambers, square feet	418
total, square feet	4,310.5
Grate surface, square feet	138
Area through tubes, square feet	25.13
over bridge walls, square feet	15.56
Volume of furnaces and combustion chambers above grates, cubic feet,	559.93
Steam room, water six inches above tubes, cubic feet	737.41
Water surface, water six inches above tubes, square feet	239.22
Smoke pipes (2), diameter, feet	7
area of both, square feet	68.42
height above lowest grates, feet	70
Number and diameter of safety valves (four on one base), inches	4 of $3\frac{1}{2}$
Diameter of boiler main stop valves, inches	9
auxiliary stop valves, inches	5

Totals for four boilers:

Heating surface, tube, square feet	14 590
furnaces, square feet	980
combustion chambers, square feet	1,672
total, square feet	17,242
Grate surface, square feet	552
Area through tubes, square feet	100.52
over bridge walls, square feet	62.24
Volume of furnaces and combustion chambers above grates, cu. ft.	2,239.72
steam room, cubic feet	2,949.64
Area of water surface, square feet	956 88

Ratios:

Tube H.S. to G.S	26.43 to 1
Furnace H.S. to G.S.	1.78 to 1
Combustion chamber H.S. to G.S	3.01 to 1
Total H.S. to G.S	31.24 to 1
Area through tubes to G.S	.18 to 1
Steam room per square foot of G.S.	5.34 to 1
Volume of furnaces and combustion chambers above grates to G.S.	4 06 to 1

AUXILIARY BOILERS.

Steam pressure, pounds	160
Number of boilers	2
Length, feet and inches	8-6
Diameter, outside, feet and inches	10-1 25/32
Thickness of shell, inch	47/64
Thickness of heads, top, inch	47/64
bottom, inch	3/4
Thickness of tube sheets, inch	3/4
Thickness of furnaces, inch	15/32
Combustion chambers, number in each boiler	2
thickness of plates, inch	1/2
width at top, inches	23 1/4
depth, feet	4
Furnaces, greatest internal diameter, feet and inches	3- 1/16
least internal diameter, feet and inches	2-9
length of grate, feet	6
number in each boiler, corrugated	2
Tubes, outside diameter, inches	2 1/2
length between tube sheets, feet and inches	5-8 1/8
number of ordinary	158
number of stay	58
spaced vertically, inches	3 1/2
spaced horizontally, inches	3 3/4
thickness of ordinary, B.W.G. No. 12, inches	.109
thickness of stay, B.W.G. No. 6, inches	.203

Diameter of rivets in shell sheets, inch	1
Diameter of screw stays, inches	$1\frac{9}{64}$
Pitch of screw stays, inches	$6\frac{1}{2}$
Number and diameter of through upper braces, inches	8 of 2
lower braces, inches	2 of $1\frac{9}{16}$, 1 of $1\frac{3}{4}$
braces from head to back tube sheets, ins	2 of $2\frac{1}{2}$, 2 of $1\frac{9}{16}$
Heating surface, tube, square feet	824.67
furnaces, square feet	55.4
combustion chambers, square feet	96.25
total, square feet	976.32
Grate surface, square feet	32.
Area through tubes, square feet	5.43
over bridge walls, square feet	2.62
Volume of furnaces and combustion chambers above grates, cubic feet	104.58
Steam room, water six inches above tubes, cubic feet	114.
Water surface, water six inches above tubes, square feet	72.94
Smoke pipes (2), diameter, feet and inches	2–$3\frac{3}{4}$
area of both, square feet	8.4
height above lowest grates, feet and inches	46–7
Number and diameter of safety valves (2 on one base), inches	2 of 3
Diameter of boiler stop valves, inches	5.
Totals for two boilers:	
Heating surface, tube, square feet	1,649.34
furnaces, square feet	110.8
combustion chambers, square feet	192.5
total, square feet	1,952.64
Grate surface, square feet	64.
Area through tubes, square feet	10.86
over bridge walls, square feet	5.24
Volume of furnaces and combustion chambers above grates, cubic feet,	209.16
steam room, cubic feet	228.
Area of water surface, square feet	145.88
Ratios:	
Tube H.S. to G.S.	25.77 to 1
Furnace H.S. to G.S.	1.73 to 1
Combustion chamber H.S. to G.S.	3 to 1
Total H.S. to G.S.	30.51 to 1
Area through tubes to G.S.	.169 to 1
Steam room per square foot of G.S	3.56 to 1
Volume of furnaces and combustion chambers above grates to G.S.	3.27 to 1
Totals for all boilers:	
Heating surface, tube, square feet	16,239.34
furnaces, square feet	1,090.8
combustion chambers, square feet	1,864.5
total, square feet	19,194.64
Grate surface, square feet	616.

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Area through tubes, square feet	111.38
over bridge walls, square feet	67.48
Volume of furnaces and combustion chambers above grates, cubic feet.	2,448.88
steam room, cubic feet	3,177.64
Area of water surface, square feet	1,102.76
Ratios of all boilers:	
Tube H.S. to G.S.	26.36 to 1
Furnace H.S. to G.S.	1.77 to 1
Combustion chamber H.S. to G.S.	3.03 to 1
Total H.S. to G.S.	31.16 to 1
Area through tubes to G.S.	.181 to 1
Steam room per square foot of G.S.	5.16 to 1
Volume of furnaces and combustion chambers above grates to G.S.	3.97 to 1

Forced Draft.—The closed fire room system of forced draft is used. The air is supplied by ten Sturtevant blowers, one in each main and in each auxiliary fire room. The fans are driven by two-cylinder, vertical, simple, enclosed engines with cranks at 180 degrees.

BLOWERS IN MAIN FIRE ROOMS.

Diameter of steam cylinders, inches	5
Stroke, inches	4
Diameter of fan, inches	60
Width of fan at rim, inches	14
Area of induction nozzle, square inches	1,060.7
eduction nozzle, square inches	2,241

BLOWERS IN AUXILIARY FIRE ROOMS.

Diameter of steam cylinders, inches	3.5
Stroke, inches	2.5
Diameter of fan, inches	36
Width of fan at rim, inches	12
Area of induction nozzle, square inches	520.7
eduction nozzle, square inches	1,056

Feed Pumps.—In each feeding fire room of the main boilers, and in each fire room of the auxiliary boilers, there are two vertical, duplex, double acting Blake pumps, one for the main and one for the auxiliary feed. The main and auxiliary feed systems are not connected, but any pump can be used to feed any boiler. The main feed pumps draw from the feed tanks and deliver only to the boilers. The auxiliary feed pumps draw from the feed tanks, sea, bilge, secondary drain pipe and boilers, and deliver into the boilers, fire main and overboard. The dimensions of the pumps in the main fire rooms are: Steam cylinders, 8 inches diameter; water cylinders, 5 inches diameter; stroke, 12 inches. The capacity of each pump is 200 gallons per minute. Those in the auxiliary fire rooms are: Steam cylinders, 6 inches diameter; water cylinders, 4⅛ inches diameter; stroke, 7 inches. The capacity of each pump is 100 gallons per minute.

Feed, Fire and Bilge Pumps.—In each engine room there is a vertical, duplex, double acting Blake pump which draws from the sea, the bilge, the secondary drain pipe, the drainage cistern, the feed tanks and the air pump suctions, and delivers into the main and auxiliary feed pipes, the fire main and overboard. Their dimensions are: Steam cylinders, 12 inches diameter; water cylinders, 7 inches diameter; stroke, 12 inches. The capacity of each pump is 400 gallons per minute.

Fire and Bilge Pumps.—In each engine room there is a vertical, duplex, double-acting Blake pump which draws from the sea, the bilge, the secondary drain pipe and the drainage cistern, and delivers into the fire-main and overboard. Their dimensions are: Steam cylinders, 12 inches diameter; water cylinders, 7 inches diameter; stroke, 12 inches. The capacity of each pump is 400 gallons per minute.

Water Service Pumps.—In each engine room there is a vertical, duplex, double acting Blake pump which draws from the sea, and delivers into the water service pipes and fire-main. Their dimensions are: Steam cylinders, 8 inches diameter; water cylinders, 5 inches diameter; stroke, 12 inches. The capacity of each pump is 200 gallons per minute.

Ash Hoists.—In each main fire room hatch there is a Williamson double, reversible ash hoist, by means of which one bucket of ashes of 300 pounds (with a steam pressure of 60 pounds) can be hoisted in 5 seconds. The steam cylinders are 4½ inches in diameter, with a piston stroke of 4½ inches.

Grease Extractors.—There is a grease extractor in each feeding fire room. It is similar to a Macomb strainer; the basket is perforated and covered with burlap through which the water filters.

By-pass pipes and valves are fitted to feed the boilers while overhauling the extractor.

Feed Tanks.—There is a feed tank, of 1,000 gallons capacity, in each engine room. A part of the tank is fitted as a filter into which the water from the air pumps is delivered. The filter is provided with sponges, which are readily accessible. Each tank has a man-hole, glass water gauge, shut-off cocks, and drain cocks. An overflow pipe is fitted and so arranged that any water passing down it may be seen. Each feed pump suction is provided with a balanced valve operated by a copper float in the feed tank and so arranged that no air will enter the feed pipes.

Steam Traps.—The separators, the jackets, the main and auxiliary steam pipes, the radiators, and all places where condensed steam can accumulate are fitted with drain pipes and cocks, or valves, and with automatic traps which discharge into the feed tanks. The traps are provided with by-pass pipes and valves for convenience of overhauling.

Workshop.—The workshop is situated on a platform in the after part of the engine rooms. It is fitted with a vertical engine, 6 inches by 6 inches, a lathe, a shaping machine, a double-geared drilling machine, a grind stone and an emery wheel.

Distilling Apparatus.—There are two Baird distillers and two Baird evaporators with a maximum distilling capacity of 5,500 gallons of potable water in twenty-four hours; the ordinary capacity is 4,000 gallons. A Davidson pump (steam cylinder 4½ inches diameter; water cylinder 5 inches diameter; stroke 8 inches) is used to circulate the water through the distillers. After leaving the distillers the circulating water passes through the flushing pipes, and by-pass valves and pipes are fitted so that the water can enter the flushing pipes without passing through the distillers. A horizontal combined pump is used to feed the evaporators and to deliver the water from the filters to the ship's tanks; it has a steam cylinder 2½ inches diameter, water cylinders 1½ inches diameter, and a stroke of 3 inches. There is a pump to deliver the drain water from the evaporators into the feed tank; it has a steam cylinder 2½ inches diameter, a water cylinder 1½ inches diameter, and a stroke of 3 inches.

Ventilating Fans.—There is in each engine room a ventilating fan, which is used only for engine room service. For ventilating the ship generally, there are four fans situated on the orlop deck, and they are so arranged, by means of reversible valves, as to exhaust from, or force air to the various parts of the ship. The fans are driven by engines similar to those of the forced draft blowers.

Diameter of steam cylinders (2), inches	4
Stroke, inches	3
Diameter of fan, inches	48
Width of fan, inches	19

Steam Cutters.—There are two steam cutters, one 33 feet, and the other 30 feet long. They have Towne boilers, compound engines and keel condensers. The cylinders for the 33-foot cutter are 4 inches and 7 inches diameter by 7 inches stroke, and those for the 30-foot cutter, 3½ inches and 7 inches diameter by 6 inches stroke.

Telegraphs and Revolution Indicators.—There is a Cory mechanical telegraph in each engine room connected to transmitters in conning tower, pilot house and bridge, and a mechanical gong in each engine room with bell pulls at the steering wheels at after part of the superstructure deck. Mechanical tell-tales are fitted on the bridge and in the conning tower to show the direction of revolution of the main engines. In each engine room there are two mechanical indicators to show the speed and direction of revolution of each propeller. The two indicators are connected and each has two hands, a red one which turns with the port engine, and a green one which turns with the starboard engine. The hands can be turned on their shafts like the hands of a clock, so that by setting them together the relative speeds of the propellers can be seen as the hands separate or remain together in their revolutions over the dial of the indicator.

Telephones and Voice Pipes—For communication between the various parts of the ship there is a complete system of telephones, and voice pipes with call bells. The most important stations are connected direct with voice pipes, but for general purposes, in order to lessen the number of pipes, a central station is used.

Steering Engine.—On the after platform deck there is a Williamson combined hand and steam steering engine; cylinders, 13 inches diameter; stroke, 10 inches. The engine is connected to a horizontal fore-and-aft shaft, on the after end of which is a right-and-left-hand screw. The screw works in two crossheads, one on the starboard and one on the port side, and the rudder yoke is connected by rods to these crossheads. With the steam gear, the rudder can be put hard over from amidships in 10 seconds when the ship is going full speed.

Steam Windlass.—On the main deck forward there is a steam windlass, built by the American Ship Windlass Company, Providence, Rhode Island. The engine is reversible, double cylinder, vertical, direct acting, with cylinders 15 inches in diameter, and a stroke of 14 inches. The windlass is fitted with four wild cats to take the chains, also two drums or gypsies to take hawsers.

Steam Winches.—There are four double cylinder Williamson reversible winches or hoisting engines situated on the main deck, two forward and two aft. Each has one drum for wire rope and two gypsies for hawsers. Steam cylinders 8 inches diameter, stroke 8 inches. There are also two winches, of the same size as the above, situated on the superstructure deck, for hoisting boats.

Thirteen-inch Turret Turning Machinery.—Each 13-inch turret is turned by a double, horizontal engine, with cylinders 11½ inches diameter and 10 inches stroke. One engine is located in the compartment forward of the boilers, the other in the compartment abaft the engines. The turrets are turned by means of shafting and gearing, pinions on the top of the vertical shafting engaging a rack on the bottom of the turret. Each engine has a controlling valve, which is worked by means of shafting and gearing, from the sighting hood of the turret. Each turret can be turned through an angle of 270 degrees, and in order to prevent it from turning beyond its limits, automatic stop gear is provided which acts on the controlling valve. Provision is also made for turning by hand.

Eight-inch Turret Turning Machinery.—Each 8-inch turret is turned by a double, vertical engine, with cylinders 8 inches diameter and 7 inches stroke, located in the ammunition passages on the orlop deck. A worm on the crank shaft of the engine engages a worm wheel on the lower end of the ammunition tube. Each engine is provided with a controlling valve, which can be operated at the engine, and also from the sighting hoods of the turrets by means of shafting and gearing. Automatic stop gear is provided to prevent the turrets from turning too far. In case the engine becomes disabled, provision is made for turning by hand.

Air Compressors.—There are two Rand air compressors for torpedo tubes situated on the orlop deck within the citadel, one forward and one aft. Each compressor has two steam cylinders, diameter 9 inches, stroke 4 inches. The air cylinders are above the steam cylinders and are enclosed in a chamber through which water circulates. The compressors are capable of making 200 revolutions per minute with 50 pounds steam pressure, the air pressure in the accumulator being 1,700 pounds to the inch.

Hydraulic Plant.—There is an hydraulic plant situated forward on the orlop deck within the citadel. It is used to elevate and depress the 13-inch guns, to load the guns, and also to hoist the ammunition for them. It consists of two horizontal, double acting duplex Blake pumps, an accumulator water tank, and the necessary piping. The combined capacity of the pumps is 1,000 gallons per minute, the working pressure being 600 pounds per square inch. This duty is done with 100 pounds steam pressure at the pump throttles. There is an accumulator consisting of a steam cylinder, a steam piston, and a water plunger. The steam piston is connected by means of shafting and levers to the throttle valves of the pumps.

The water tank has a capacity of 200 gallons, and fresh water only is used.

The delivery pipes are 4 inches in diameter and of wrought steel; the return pipes are 6 inches in diameter and of wrought iron. The flanges of the pipes are turned male and female and the joints made with leather gaskets. The delivery and return pipes lead to a double composition pipe casting around which a composition chamber revolves. The revolving chamber turns with the turret; it is divided into pressure and exhaust passages, and the joints are made with cup-leather packing. The delivery and return pipes from the cylinders, for working the guns and hoisting the ammunition, are connected to the revolving chamber. All parts of the hydraulic system, except the suction, was tested to 1,200 pounds water pressure.

Steam cylinders,	number	4
	diameter, inches	24
	stroke, inches	12
Water plungers,	number	4
	diameter, inches	8
	stroke, inches	12
Accumulator	steam cylinder, diameter, inches	28
	water plunger, diameter, inches	10
	stroke, inches	30

Electric Plant.—The installation consists in general of three generating sets, 500 incandescent lights, 4 search lights, 1 set of signalling apparatus, 2 stationary ventilating fans driven by electric motors, 4 portable ventilating fans driven by electric motors, 4 electric motors for 8-inch ammunition hoists, 1 main switch board, together with the necessary wire, wiring accessories, molding and fixtures.

The generating sets were made by the General Electric Company at Schenectady, N. Y. In each set there is a 24-kilo-watt dynamo of the multipolar type, having a capacity of 300 amperes at 80 volts, compound wound on 144 armature sections cross connected at 180 degrees. The engines driving the dynamos are two-cylinder vertical, inverted; diameter of cylinder, 10½ inches; stroke, 5 inches. The crank shaft and armature shaft are connected by a rigid coupling. The engines are designed to run, with full load, at 400 revolutions per minute with 80 pounds steam pressure. The bed plate is common to both engine and dynamo and measures 7 feet 3 inches by 3 feet 10 inches. The weight of each generating set (engine, dynamo and bed plate) is about 8,500 pounds. The incandescent lights are 10, 16 and 32-candle power designed for 80 volts.

There are four search lights, made by the General Electric Company; two mounted on the top of the pilot house, and two mounted in hammock berthing near the after end of the fore-and-aft bridge. The projectors are 60 centimeters in diameter and electrically controlled. All lamps are horizontal combination, hand or automatic, and designed for a current of 80 amperes at about 50 volts. The carbon holders are adjustable, and the life of the carbon is six hours. Each search light has a power of about 25,000 candles.

The signal apparatus consists of four double signal lanterns, cable connection and key board. Each half of each double lantern is fitted with a fresnel lens, the upper lens being red. The key board is arranged to admit of thirty combinations of lights being made, each combination requiring but one motion to close the circuit.

There are two stationary ventilating fans, one arranged to force air into, and the other to exhaust the air from the dynamo room. Each fan is capable of delivering 2,200 cubic feet of air per minute at a speed of 1,570 revolutions, and is connected directly to a 2-horse power electric shunt motor.

There are four portable fans, to be used to exhaust the air from the double bottoms and various compartments. Each fan is capable of delivering 400 cubic feet of air per minute at a speed of 1863 revolutions, and is directly connected to a ¼-horse power electric series motor.

There is a standard Navy switchboard complete, containing the necessary connections, switches, cut-outs, &c., for 9 incandescent, 4 search light, and 3 motor circuits. It is provided with a pressure board, ground detector and measuring instruments. The pressure board has points connecting the volt meter with the terminals of each of the dynamos, and with each of the search light circuits. The ground detector is arranged to be thrown on either arc or incandescent circuit when operated separately.

Electric speed indicators and transmitters are fitted on the bridge, pilot house and in conning tower; also electric helm indicators.

There are water alarms in each bilge compartment, and thermostats in each coal bunker and paint room, with annunciators on bulkhead forward of cabin.

There are four 5-horse power electric motors for hoisting the ammunition for the 8-inch guns.

3	300-ampere generators, . . .			72,000 watts.
522	lights, 10, 16, 32-candle power,	25,775	watts.	
4	search lights, . . .	16,000	"	
	signalling apparatus, . .	96	"	
2	2-H.P. motors, . . .	2,984	"	
4	¼-H.P. motors, . . .	746	"	
4	5-H.P. motors, . . .	14,920	"	
		60,521	"	60,521 "
		Reserve power =		11,479 "

Ice Machine.—There is an Allen dense air machine capable of making one ton of ice per day, or 200 pounds of ice and at the same time keeping the refrigerating rooms near the freezing point, and cooling 300 gallons of water to 40 degrees Fahrenheit. Steam cylinder, 7 inches diameter; air compressor cylinder, 5¾ inches diameter; air expansion cylinder, 4¾ inches diameter; stroke, 10 inches. The circulating water and primer pumps are single acting, each 1⅝ inches diameter and 10 inches stroke.

NUMBER OF ENGINES ON *INDIANA*.

Engines.	*Steam cylinders.*
2 main propelling engines,	6
2 main air pumps,	4
2 main circulating pumps,	2
2 auxiliary air and circulating pumps,	2
2 main reversing engines,	2
2 main turning engines,	4
1 workshop engine,	1
6 evaporator and distiller pumps,	6
1 oil pump,	2
2 feed, fire and bilge pumps,	4
2 fire and bilge pumps,	4
2 water service pumps,	4
4 main feed pumps for main boilers,	8
4 auxiliary feed pumps for main boilers,	8

Engines.	Steam Cylinders.
2 main feed pumps for auxiliary boilers,	4
2 auxiliary feed pumps for auxiliary boilers,	4
10 forced draft blowers,	20
2 ventilating blowers in engine room,	4
4 ventilating blowers for ship,	8
4 ash hoisting engines,	8
3 dynamo engines,	6
1 steering engine,	2
2 13-inch turret turning engines,	4
4 8-inch turret turning engines,	8
1 ice machine,	1
1 windlass and capstan engine,	2
6 winches,	12
2 hydraulic pumps,	4
1 accumulator,	1
2 air compressors for torpedo tubes,	4
1 pump for waste water tank,	1
2 steam cutter propelling engines,	4
2 steam cutter feed pumps,	4
86 Total	158

As the battery of the *Indiana* is placed well above the water line, it was expected that the ship would prove to be a heavy roller in a sea-way, and extensive preparations were made to record the degrees of roll. The first opportunity to test her sea qualities was off the capes of the Delaware. The sea was moderate, and while swinging ship to adjust compasses, it got abeam. Instead of rolling, the ship remained perfectly steady, and the seas spent their force against her side. On the return from the official speed trial, a stiff breeze and rough sea were encountered, and still she remained steady, except a slight pitching, which, however, was not deep. The greatest roll recorded was 1½ degrees, so that the ship will prove an excellent gun platform.

In comparing the *Indiana* with the battle-ships of foreign navies it is found that the former is inferior in only one respect, that of speed. This important feature was slightly sacrificed in order to obtain a heavy armament. As she is intended to defend the coast line, she would be nearer her base in time of war, and hence would, in all probability, have a cleaner bottom than foreign vessels, so that her speed would be very little, if any, less. And, furthermore, her boiler power is as large as that of larger foreign battle-ships, which are credited with greater speed; so that it is fair to infer that, even in this particular, she is little, if at all, inferior to them.

OFFICIAL SPEED TRIAL.

The official speed trial took place off the New England coast on October 18, 1895. It consisted of two runs over a measured course of 31 nautical miles. The average speed of the two runs was 15.547 knots per hour. The sea was moderate, the wind was abeam and blew with a force of 4 to 5 on the Beaufort scale. All boilers were in use under forced draft. All the steam generated was used by the main engines and auxiliaries, except that used in the steering engine and in the engine for the dynamo to light the engine and boiler compartments. The coal used was selected Pocahontas. The boilers steamed freely and steadily, and showed no evidence of priming. The main engines worked well and without vibration. No water was used on the engines, except what circulated through the crank shaft brasses and caps and crosshead guides. The air and circulating pumps worked well and required no special attention, except that of oiling.

After the trial the boilers, main engines and auxiliaries were examined and found in good condition.

DATA OF OFFICIAL TRIAL.

Draught, mean for trial, forward, feet	23.69
aft, feet	24.06
Displacement at mean draught on trial, tons	10,225
Area of immersed midship section, square feet	1,540
Wetted surface, square feet	30,500
I.H.P. (total) per 100 square feet of wetted surface	31.93
at 10 knots, reduced in ratio of 3.5 power	6.814
Average speed in knots	15.547
Slip (mean of both screws), per cent	24.85
Speed $^3 \times$ area of immersed midship section $\div$ I.H.P	606 28
displacement$^{2/3}$ $\div$ I.H.P	185.47

SYNOPOSIS OF STEAM LOG.

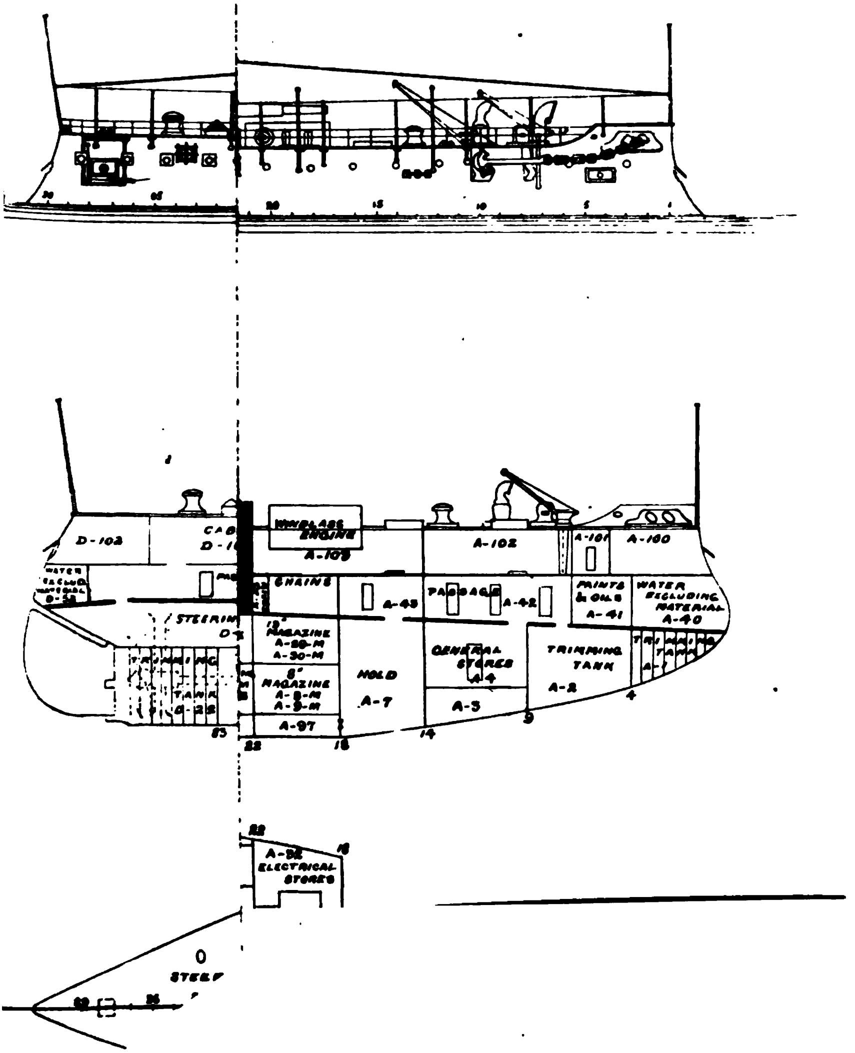
	Starboard.	*Port.*
Revolutions of main engines per minute, mean	130.79	131.25
Piston speed in feet, per minute	915.53	918.75
Steam pressure at boilers, per gauge	166.53	
engines, per gauge	163.6	165.
1st receiver, absolute	70.39	75.61
2d receiver, absolute	25.55	25.83
Vacuum in condensers, inches of mercury	24.68	24.68
Opening of throttle	wide.	
Steam cut-off in fractions of stroke from beginning, H.P	.634	.640
I.P	.699	.667
L.P	.718	.708
Double strokes of air pump, per minute	31.65	29.75
Revolutions of circulating pumps per minute	247.4	170.2
Temperatures in degrees, Fahrenheit, engine room	77	79
injection	50	50
discharge	102	119
hot well	108	85
feed	107	109
fire rooms	101	
Air pressure, in inches, of water in fire rooms	.955	
Revolutions of blowers per minute, fire rooms	398.4	
engine rooms	236.23	
Mean pressures in cylinders, H.P	65.031	57.315
I.P	31.598	33.55
L.P	13.1854	12.623
equivalent reduced to L.P	39.37	37.98
I.H.P.:		
H.P. cylinder	1,644.64	1,454.06
I.P. cylinder	1,575.57	1,672.25
L.P. cylinder	1,605.68	1,545.80
Collective, each main engine	4,825.89	4,672.11
both main engines	9,498	
Air pumps	11.048	9.367
Circulating pumps	19.51	7.234
Feed pumps	74.607	
Blowers, forced draft	52.808	
Other auxiliaries	65.917	
Collective I.H.P. of all auxiliaries	240.491	
main engines, air and circulating pumps,	9,545.159	
all machinery in operation	9,738.491	
Indicated thrust (main engines only), pounds	76,102.13	73,418.87
per square foot of developed area of propellers, pounds	1,412.99	1,363.16
Indicated thrust per square inch of thrust bearing, pounds	34.96	33.73

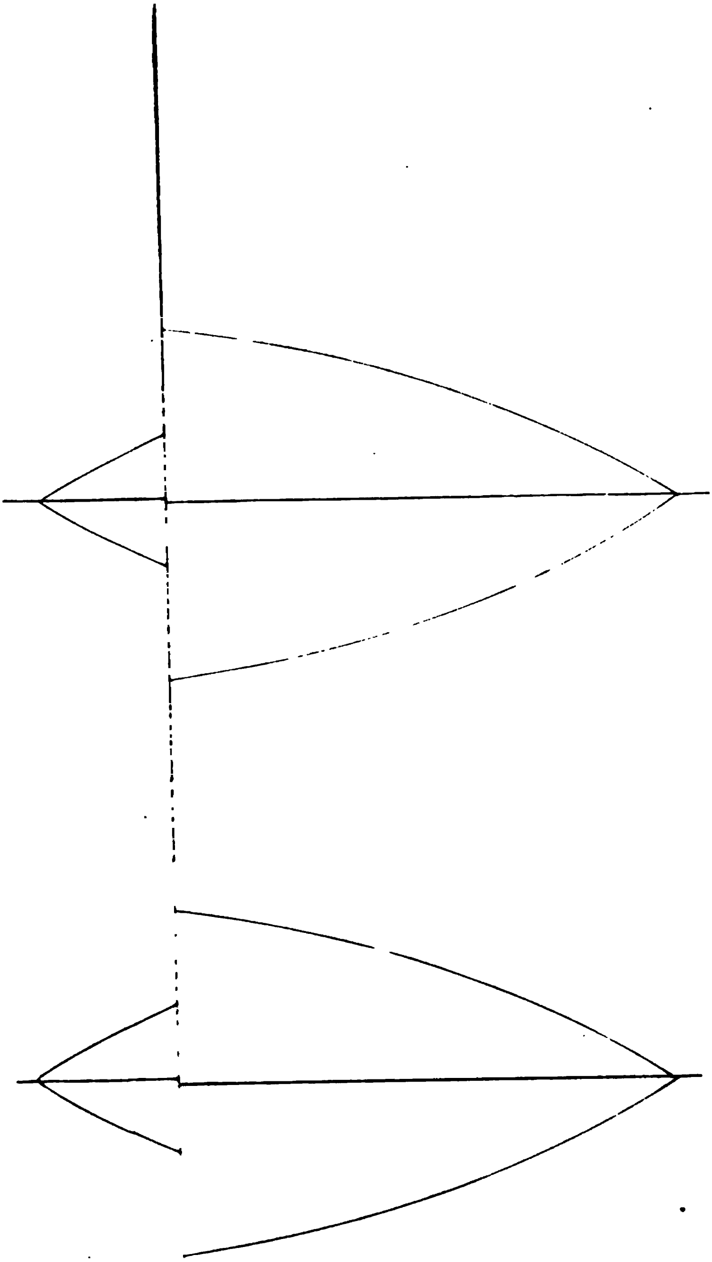
	Starboard.	Port.
Cubic feet swept per minute by L.P. piston per I.H.P.	5.82	6.03
Square feet of cooling surface per I.H.P	1 387	
total heating surface per I.H.P	1.971	
I.H.P. per square foot of G.S. (all machinery in operation)	15.8	

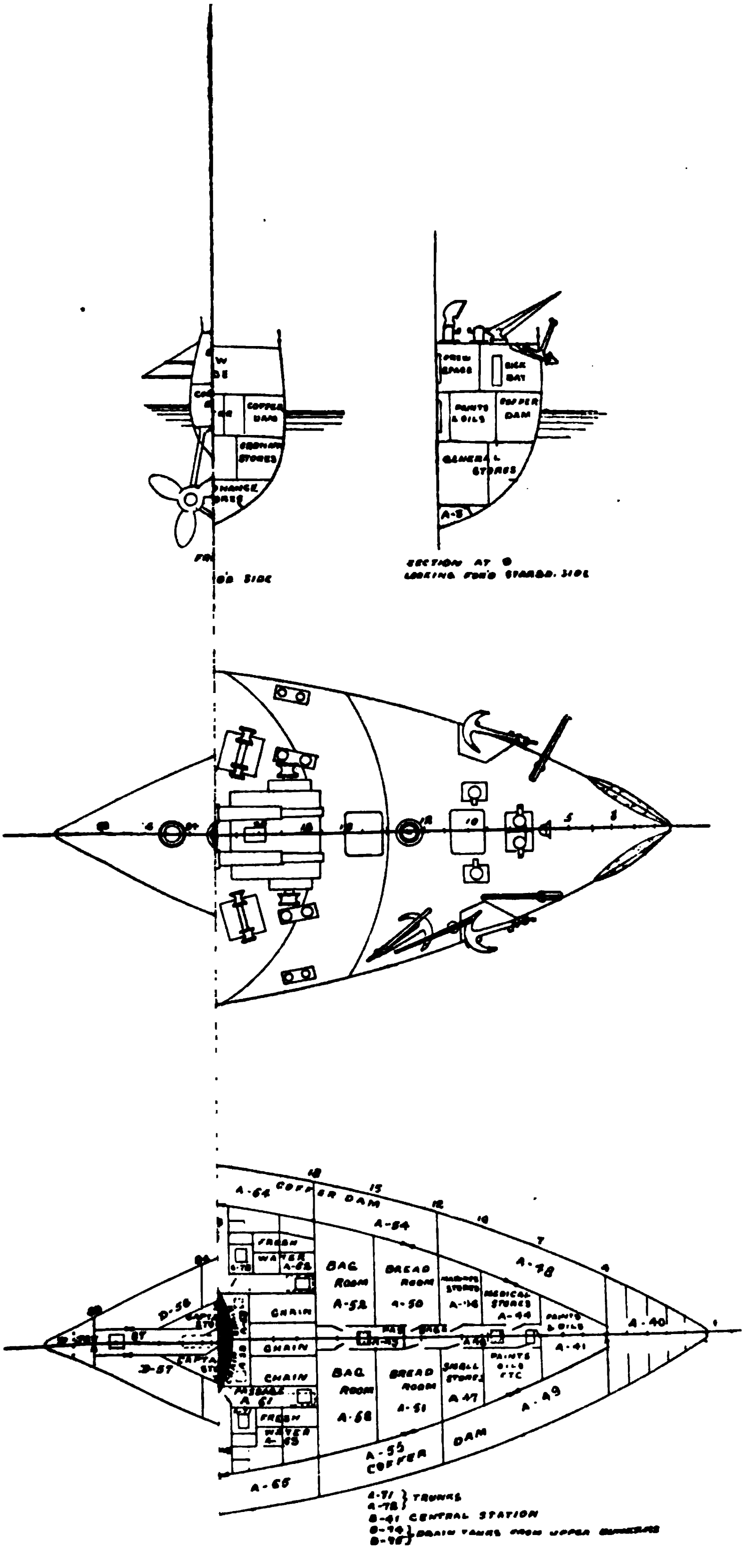
COAL CONSUMPTION TRIAL.

The coal consumption trial was for six hours, with the two after main boilers under forced draft.

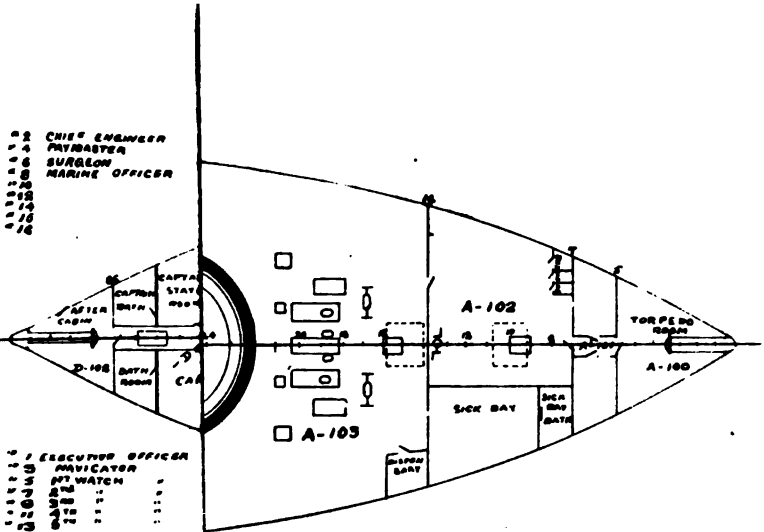
	Starboard.	Port.
Revolutions of main engines per minute	95 97	95.4
Piston speed, in feet, per minute	671.79	667.8
Steam pressure at boilers, per gauge	152.37	
engines, per gauge	150 5	150.21
1st receivers, absolute	34.3	36.28
2d receivers, absolute	16.57	17.43
Vacuum in condensers, inches of mercury	24 19	24.57
Opening of throttle, holes	1	.8
Steam cut-off in fractions of stroke from beginning: H.P	.474	.428
I.P	.699	.667
L.P	.718	.708
Double strokes of air pumps per minute	21 66	22.14
Revolutions of circulating pumps per minute	194 66	158.14
Temperatures, in degrees, Fahrenheit: engine rooms	89	89
injection	55	55
discharge	123	128
feed	124	130
fire rooms	120	
Air pressure, in inches, of water in fire rooms	1.04	
Revolutions of blowers per minute: fire rooms	406	
engine rooms	175	
Mean pressures in cylinders:		
H.P	38.049	37.383
I.P	11.314	12.357
L.P	7.034	6.779
Equivalent reduced to L.P	19.499	19.563
I.H.P.:		
H.P. cylinder	705.78	689.48
I.P. cylinder	410.51	444.425
L.P. cylinder	629.74	603.42
Collective, each main engine	1,746.03	1,740.325
both main engines	3,486.355	
Air pumps	3.541	3.961
Circulating pumps	9.755	5.788
Feed pumps	57.224	

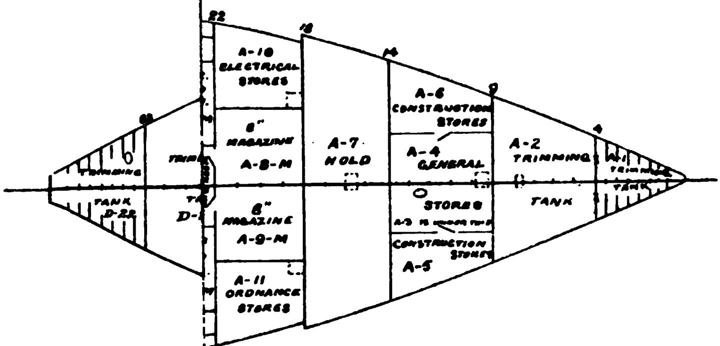

D-102
WINDLASS ENGINE
A-103
A-102
A-101
A-100
CHAINS
A-43
PASSAGE
A-42
PAINTS & OILS
A-41
WATER EXCLUDING MATERIAL
A-40
13" MAGAZINE
A-29-M
A-30-M
8" MAGAZINE
A-8-M
A-9-M
A-97
HOLD
A-7
GENERAL STORES
A-4
A-3
TRIMMING TANK
A-2
ELECTRICAL STORES

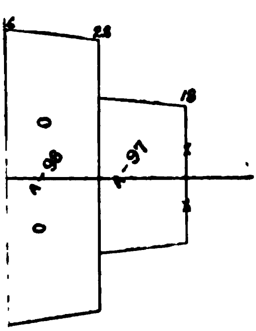




CREW SPACE
SICK BAY
PAINTS & OILS
COFFER DAM
GENERAL STORES
A-3
COFFER DAM
SECTION AT 9
LOOKING FOR'D STARBD. SIDE
A-64 COFFER DAM
A-54
A-48
FRESH WATER A-62
BAG ROOM A-52
BREAD ROOM A-50
MEDICAL STORES A-44
PAINTS & OILS
A-40
A-41
CHAIN
CHAIN
CHAIN
D-56
D-57
BAG ROOM
BREAD ROOM A-51
SMALL STORES A-47
PAINTS OILS ETC
A-49
FRESH WATER A-63
A-55 COFFER DAM
A-65
A-71
A-78 } TRUNKS
B-41 CENTRAL STATION

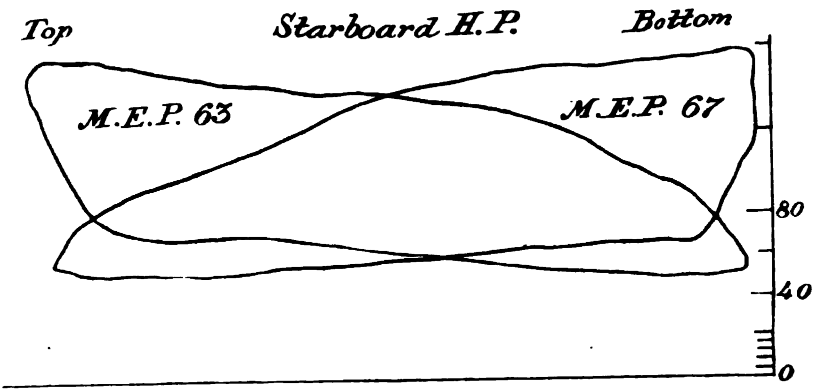

#2 CHIEF ENGINEER
#4 PAYMASTER
#6 SURGEON
#8 MARINE OFFICER
AFTER CABIN
CAPTAIN BATH
BATH ROOM
D-102
A-102
A-103
TORPEDO ROOM
A-100
SICK BAY
SICK BAY BATH
#1 EXECUTIVE OFFICER
#3 NAVIGATOR
#5 1ST WATCH
#7 2ND
#9 3RD
#11 4TH
#13 5TH

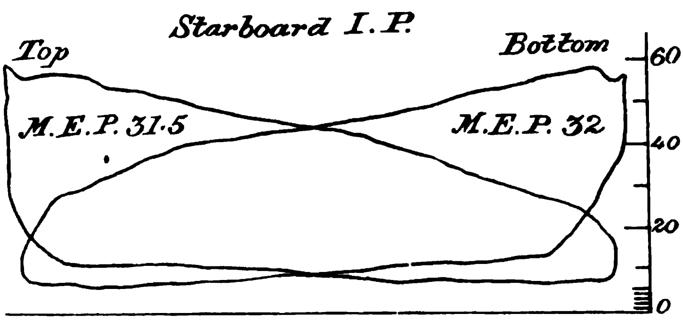

A-10 ELECTRICAL STORES
6" MAGAZINE A-8-M
6" MAGAZINE A-9-M
A-11 ORDNANCE STORES
A-7 HOLD
A-6 CONSTRUCTION STORES
A-4 GENERAL STORES
CONSTRUCTION STORES
A-5
A-2 TRIMMING TANK
TRIMMING TANK
TANK D-22

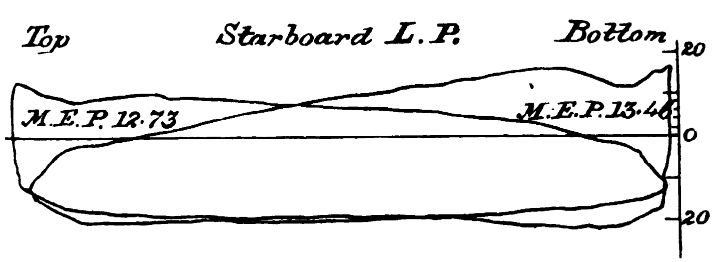

A-98
A-97

U. S. S. Indiana.

Vacuum	24.68
Revolutions	130.79

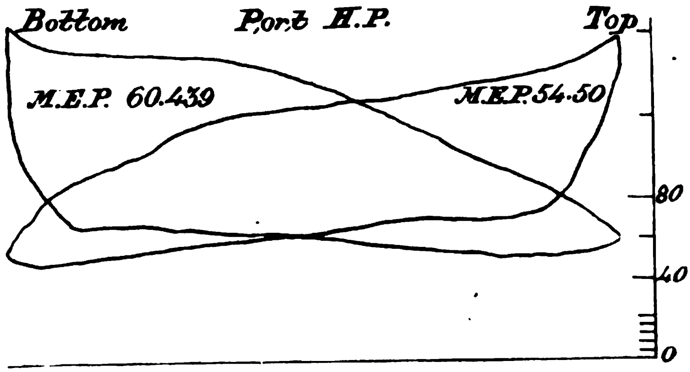


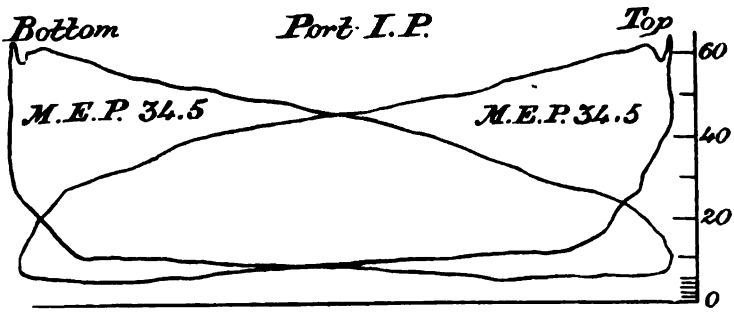


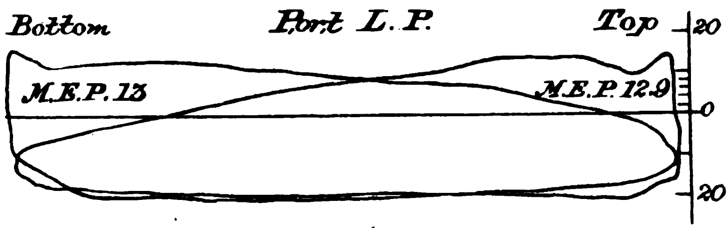


U.S.S. Indiana.

Vacuum 24.79
Revolutions 131.25



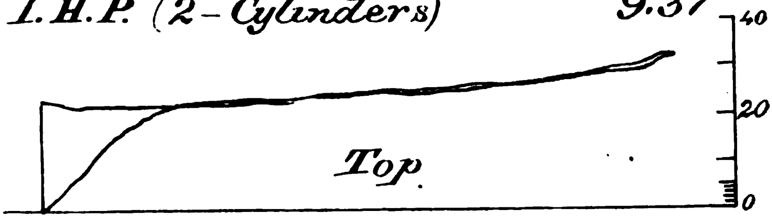


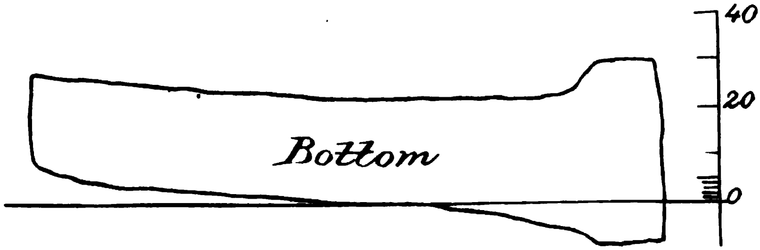


U. S. S. Indiana

Port Air Pump Cards.

Double Strokes	29.75
Vacuum	24.75 ins.
Steam Pressure	161 lbs.
Scale	40 lbs.
I.H.P. (2-Cylinders)	9.37





I.H.P.:	Starboard.	Port.
Blowers, forced draft	24.768	
Other auxiliaries	40.96	
Collective I.H.P. of all auxiliaries	145.997	
main engines, air and circulating pumps	3,509.4	
all machinery in operation	3,632.352	
Square feet of heating surface in use	8,621	
grate surface in use	276	
Quality and kind of coal	selected Pocahontas.	
Coal burned per hour, actual weight, pounds	7,347.57	
per square foot of grate surface	26.62	
per square foot of heating surface	.852	
per I.H.P. of all machinery	2.022	
per I.H.P. of main engines, air and circulating pumps	2.093	

THE STEAM-YACHT *YOSEMITE*.

By Chief Engineer Isherwood, U. S. Navy.

The *Yosemite* was a large and very elegant iron steam-yacht, the hull and appointments of which were designed by the late Mr. Edward Faron, formerly a United States Naval Engineer, and at that time the Superintendent of the Delaware River Iron Ship Building and Engine Works, at Chester, Delaware county, Pennsylvania, where the yacht was built by John Roach & Son, the proprietors of those works at that time.

The machinery was designed by the late Mr. Henri Leverat, at that time the engineer and superintendent of the Morgan Iron Works, in the city of New York, where it was constructed by John Roach & Son, the proprietors of the works.

The *Yosemite* in hull, machinery and appointments, was in all respects of design, execution, accommodations and speed, a first-class sea-going yacht, containing all the latest improvements. She was perfectly safe and comfortable for the most extended sea voyages and in the worst weather. The hull was not sheathed, and had a very light schooner rig. About 200 tons of coal were carried in the bunkers when the latter were filled.

During July and August of 1884, Mr. Roach placed the *Yosemite* at the command of the Secretary of the Navy for his personal use and to show the high speed and general efficiency that could be given to a sea-going vessel of her relatively small dimensions. She made under these circumstances a voyage from New York City to Portsmouth, New Hampshire, *via* Newport, Rhode Island; and thence back to New York, a distance of about 650 geographical miles in Long Island Sound and at sea, having been experimented with during this time by a Board of Naval Officers embracing among others the Chief of the Bureau of Steam Engineering in the Navy Department, who caused the notes and indicator diagrams to be taken during a trial of four consecutive runs, with maximum speed, over the measured geographical mile in Narragansett Bay, near Newport, and during an extended run at sea with medium speed between Wood's Holl, Massachusetts, and Portsmouth, New Hampshire, from which the calculations have been made that will be found in the table hereinafter given under the head of "Performance." Previous to this table are given the dimensions of the hull and machinery of the vessel, as follows:

HULL.

The hull was of iron and had the following dimensions:

Extreme length, feet and inches	197–6
Length on load water line from forward edge of stem to after edge of stern-post, feet and inches	176–8½
Extreme breadth on load water line, feet	24
Depth of keel below plating, inches	11
Depth from load water line to bottom of plating, feet and inch	10–1
Load draught of water from bottom of keel, forward, feet	10
Load draught of water from bottom of keel, mean, feet	11
Load draught of water from bottom of keel, aft, feet	12
Area of the greatest immersed transverse section, square feet	160.62
Area of the load water section, square feet	2,932.00
Area of the immersed or wetted surface of the hull, exclusive of keel and rudder, square feet	4,522.52
Area of the wetted surface of the keel, square feet	271.36
Area of the wetted surface of the rudder, square feet	66.80
Aggregate area of the wetted surface of hull, keel and rudder, square feet	4,860.68
Displacement to load water section, cubic feet	16,023.00
Displacement to load water section, tons	458.69
Displacement at load water section per inch of draught of water, tons	6.99
Angle of dead rise amidship, degrees	16½
Angle of entrance of load water section at end of bow, degress and min.,	3–39
Greatest obliquity of load water section at entrance, degrees and minutes,	12–41
Ratio of the length on the load water line from forward edge of stem to after edge of stern post, to the extreme breadth on load water line	7.363
Ratio of the greatest immersed transverse section to its circumscribing parallelogram	0.664
Ratio of the load water section to its circumscribing parallelogram	0.691
Ratio of the load displacement to its circumscribing parallelopipedon	0.375
Ratio of the displacement to a solid having the greatest immersed transverse section for base, and the length on the load water line from forward edge of stem to after edge of stern post for height	0.564

ENGINE.

There was one compound engine, consisting of one small cylinder and two large cylinders, the latter being duplicates; and all three cylinders had the same stroke of piston, and the same diameter of piston rod, which rod was on the lower side of the pistons only.

The engine had one surface condenser and one air pump; the axes of the three cylinders were vertical and in the same plane with the axis of the crankshaft. The air pump was vertical and single acting, as were also the feed pump and the bilge pump. All three pumps were worked from a reducing beam or lever which received its motion from a main crosshead, their strokes of piston being one inch longer than half the stroke of the steam pistons. The steam cylinders were *not* steam jacketed, and each was fitted with a variable Meyer cut off valve working on the back of the steam valves. All the cylinder valves were slides worked by eccentrics; the steam valves were fitted with the Stephenson Link as a reversing gear.

The injection or condensing water was supplied to the condenser by a centrifugal or fan pump (Gerick's patent) which drives the water through the tubes, the latter being surrounded by the exhaust steam from the two large cylinders. This pump was driven by a small independent steam cylinder, which exhausted into the condenser.

The following are the dimensions of the principal details of the engine:

Number of small cylinders	1
Number of large cylinders	2
Diameter of the small cylinder, inches	28½
Diameter of the piston rod of the small cylinder, inches	5
Net area of the small cylinder, exclusive of area of piston rod, square ins.,	630.122
Stroke of the piston of the small cylinder, inches	33
Space displacement of the piston of the small cylinder per stroke, cubic ft.,	12.034
Space in the clearance and steam passage at one end of the small cylinder, cubic feet	0.904
Number of steam ports at each end of the small cylinder	2
Breadth of each steam port at each end of the small cylinder, inches	2
Length of each steam port at each end of the small cylinder, inches	16

Aggregate area of the two steam ports at each end of the small cylinder, square inches	64
Diameter of the large cylinders, inches	40
Diameter of the piston rod of the large cylinders, inches	5
Aggregate net area of the two large cylinders, exclusive of the area of their piston rods, square inches	2,493.639
Stroke of the pistons of the two large cylinders, inches	33
Aggregate space displacement of the pistons of the two large cylinders, per stroke, cubic feet	47.622
Aggregate space in the clearances and steam passages at one end of the two large cylinders, cubic feet	3.663
Number of steam ports at each end of each large cylinder	2
Breadth of each steam port at each end of each large cylinder, inches	2
Length of each steam port at each end of each large cylinder, inches	28¾
Aggregate area of the two steam ports at each end of the two large cylinders, square inches	115
Clearance of the small and of the large cylinders at their top, inch	½
Clearance of the small and of the large cylinders at their bottom, inch	¾
Fraction of the space displacement of the piston of the small cylinder per stroke in the clearance and steam passage at one end	0.075
Fraction of the aggregate displacements of the pistons of the two large cylinders per stroke, in the aggregate clearances and steam passages at one end	0.077
Ratio of the aggregate net areas of the two large cylinders to the net area of the small cylinder	3.957
Ratio of the aggregate displacements per stroke of the pistons of the two large clyinders plus the aggregate spaces in the clearances and steam passages at one end of these cylinders, to the space displacement per stroke of the piston of the small cylinder plus the space in the clearance and steam passage at one end of this cylinder	3.964
Diameter of crosshead journal, inches	6
Length of crosshead journal, inches	8
Length of crosshead guide-gib (slipper guide), inches	21
Breadth of crosshead guide gib, inches	14½
Area of crosshead guide gib, square inches	304½
Length of connecting rod between centers, feet	6
Diameter of connecting rod neck, at crosshead end, inches	5
Diameter of connecting rod neck, at crankpin end, inches	5½
Number of main or crankshaft journals	6
Diameter of crankshaft journals, inches	10
Length of the two crankshaft journals that are outside of frame, inches	15
Length of the four crankshaft journals that are inside of frame, inches	11
Diameter of crankpin journal, inches	9
Length of crankpin journal, inches	12
Diameter of line shaft journals, inches	9½
Length of line shaft journals, inches	14

Breadth of eccentric strap for small cylinder, inches	$3\frac{1}{2}$
Breadth of eccentric strap for the two large cylinders, inches	$4\frac{3}{4}$
Diameter of feed pump plunger, inches	$3\frac{1}{2}$
Stroke of feed pump plunger, inches	17
Displacement of the feed pump plunger per stroke, cubic foot	0.087
Diameter of air pump (one and single acting), inches	20
Diameter of air pump piston rod, inches	3
Stroke of air pump piston, inches	17
Space displacement of the air pump piston per stroke, cubic feet	3.021
Number of tubes (brass) in the surface condenser	1,526
Length, between plates, of the tubes in the surface condenser, inches	80
Outside diameter of the tubes in the surface condenser, inch	$\frac{5}{8}$
Aggregate condensing surface of the tubes in the surface condenser, sq. ft.	1,664.612
Diameter of the steam cylinder driving the centrifugal pump which supplied the condensing or injection water, inches	8
Stroke of the piston of the steam cylinder driving the centrifugal pump which supplied the condensing or injection water, inches	9
Diameter of the centrifugal pump supplying the injection water, inches	30

BOILERS.

The boilers were two in number, placed side by side, with the fireroom in the athwartship direction. The uptakes of both boilers discharge into the same chimney, the lower portion of which is surrounded by an annular steam drum or "steam chimney" whose interior surface is thereby made steam superheating surface. The natural draft of the boilers was sufficient, with anthracite, for supplying steam for all ordinary speeds—say, up to 13 geographical miles per hour; but for speeds higher than that, and for the maximum performance, the combustion of the anthracite was forced by a fan blower delivering its air into closed ashpits. There was only one blower, and it was driven by one independent steam cylinder directly attached, that is, driving the fan without belt or other gearing. The exhaust steam from this cylinder was delivered into the surface condenser.

The boilers were of steel, cylindrical, with shells $\frac{11}{16}$-inch thick. Each boiler contained three cylindrical furnaces.

The tubes were of iron, and were returned above the furnaces in the usual manner.

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

Number of boilers	2
Diameter of boilers, feet and inches	12–2
Length of boilers (exclusive of uptake), feet	11
Total number of furnaces	6
Diameter of each furnace, feet and inches	3–4
Length of grate bars, feet and inches	7–4½
Total area of grate surface, square feet	149
Number of tubes (iron) in each boiler	188
Outside diameter of boiler tubes, inches	3¼
Inside diameter of boiler tubes, inches	3.012
Length of boiler tubes, feet and inches	7.9
Total area of heating surface in boiler tubes calculated for their outside diameter, square feet	2,479.4
Total area of heating surface in boiler tubes calculated for their inside diameter, square feet	2,297.8
Total cross area of boiler tubes for draught, square feet	18.605
Height of chimney above the level of the grates, feet	50
Diameter of the chimney, elsewhere than in the steam drum, feet and inches,	5.5
Cross area of the chimney in the steam drum, square feet	18.665
Outside diameter of the steam drum, feet	8
Inside diameter of the steam drum, feet and inches	4–10½
Height of the steam drum above the shell, feet	7
Steam superheating surface in the steam drum, square feet	107.207
Steam superheating surface in the two uptakes, square feet	19.793
Total steam superheating surface, square feet	127.000
Total water heating surface in the boilers, calculated for the outside diameter of the tubes, square feet	3,220.0
Total water heating surface in the boilers, calculated for the inside diameter of the tubes, square feet	3,038.4
Square feet of water heating surface, calculated for the outside diameter of the tubes per square foot of grate surface	21.611
Square feet of water heating surface, calculated for the inside diameter of the tubes per square foot of grate surface	20.392
Square feet of steam superheating surface per square foot of grate surface	0.852
Square feet of grate surface per square foot of cross area of tubes for draft	8.009
Square feet of grate surface per square foot of the cross area of the chimney in the steam drum	7.982
Number of fan blowers	1
Number of steam cylinders driving the fan blower	1
Diameter of steam cylinder driving the fan blower, inches	7
Stroke of the piston of the steam cylinder driving the fan blower, inches	7

SCREW.

There was one cast-iron screw of the Hirsch form with the pitch expanding uniformly from the front edges to the back edges of the blades.

Diameter of the screw, feet	11
Diameter of the hub, feet	1.75
Pitch at the front edge of the blades, feet	15.50
Pitch at the back edge of the blades, feet	18.50
Mean pitch of the screw, feet	17.00
Number of blades	4
Length of the blades at the hub in the direction of the axis, feet	2.125
Length of the blades at the periphery in the direction of the axis, foot	0.500
Aggregate helicoidal surface of the blades, square feet	38.346
Aggregate projected surface of the blades on a plane at right angles to the axis, square feet	26.827
Fraction used of the pitch (17 feet)	0.300
Thickness of the blades at the fillet of the hub, inches	6⅛
Thickness of the blades at the periphery, inch	¾

EXPLANATION OF THE TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS.

The following table contains the data and results of the two experiments made with the *Yosemite.* The first experiment was made to ascertain the maximum speed that could be given to the vessel during four consecutive runs over a measured base of one geographical mile, by forcing the combustion of anthracite in the furnaces by means of a Sturtevant blower driven at its maximum and delivering air into the closed ash pits. Two sets of indicator diagrams, from top and bottom of cylinders, were taken on each mile, making eight sets in all, from which the quantities in the table are obtained.

The second experiment consisted of a run at sea of 12 hours and 27 minutes consecutively, in smooth water and nearly calm air between lighthouses, burning anthracite with the natural draught of the boilers and at the lowest practicable rate of combustion that would keep the grates covered with ignited coal. During this experiment the weight of anthracite consumed was carefully ascertained. The indicator diagrams were taken every twenty minutes. The fires were not cleaned during the run, and all the conditions were such as to produce the power with the greatest possible economy of fuel.

The bottom of the vessel was perfectly smooth and clean, having been scraped and painted only a few days before the experiments were made.

In the following table, the different quantities are grouped as they stand in natural relation, and the lines containing them are numbered for facility of reference.

Vessel.—Lines 1 to 6, both inclusive, contain respectively, the vessel's draught of water during the experiments, and the greatest immersed transverse section, the displacement, and the external immersed surface corresponding thereto.

Engine.—Line 7 contains the mean steam pressure in the boilers in pounds per square inch above the atmosphere; and line 8 contains the mean steam pressure in the receiver between the small cylinder and the two large cylinders, in pounds per square inch above the atmosphere.

Lines 9 and 10 contain respectively the fractions of the stroke of the steam pistons, measured from the commencement of the stroke, on the indicator diagrams at the point where the throttled curve changes into the reversed expansion curve, at which the steam is cut off in the small cylinder and in the large cylinders. The cut off valve was so set on all the cylinders that the cutting off of the steam took place at the same point of the stroke of all the steam pistons.

Line 11 gives the number of times the steam was expanded by volumes. The expansion in the small cylinder was first ascertained by dividing the space displacement of its piston per stroke plus the space in the clearance and steam passage, by the space displacement of its piston per stroke up to the point of cutting off plus the space in the clearance and steam passage, and multiplying the quotient by the ratio which the space displacement of the pistons of the two large cylinders per stroke plus the space in their clearances and steam passages at one end, is to the space displacement of the piston of the small cylinder per stroke plus the space in the clearance and steam passage.

Line 12 gives the vacuum in the surface condenser in inches of mercury; that is to say, the difference between the atmospheric pressure and the pressure in the condenser.

Line 13 gives the pressure in the condenser in pounds per square inch above zero, assuming zero to be 14.688 pounds per square inch below the atmospheric pressure.

Line 14 gives the number of double strokes made by the pistons of the engine, or of revolutions made by the screw, per minute.

Speed.—Lines 15 and 16 show the speed of the vessel, respectively, in statute miles, of 5,280 feet per hour, and in geographical miles of 6,086 feet. The speed in both experiments is absolutely accurate, being obtained from fixed landmarks.

Line 17 shows the slip of the screw in per centum of the axial speed of its form, calculated for the final pitch of 18.50 feet, and *not* from its *mean* pitch. The true slip is the speed imparted to the water by the screw. All the water that passes over the screw leaves it with a velocity equal to the difference between the axial speed of the final pitch and the speed of the vessel. The previous pitches—down to the initial pitch—gradually increase the horizontal speed of the water acted on by the screw from the front edge to the back edge of its blades, and thus assist in the propulsion of the vessel; but the speed ultimately obtained is that which is due to the final pitch, and with this speed the whole mass of water acted on by the screw leaves it.

Steam Pressures in the Small Cylinder per Indicator.—Lines 18 to 27, both inclusive, contain the various steam pressures in the small cylinder, as given by the means obtained from all the indicator diagrams.

Lines 18, 19 and 20 contain, respectively, the steam pressures on the piston of the small cylinder at the commencement of its stroke, at the point of cutting off the steam, and at the end of its stroke, in pounds per square inch above zero.

Line 21 contains the mean back pressure, including cushioning, against the piston of the small cylinder during its stroke, in pounds per square inch above zero.

Line 22 contains the back pressure in pounds per square inch above zero against the piston of the small cylinder at the point (line 23) where the cushioning commenced on the return or exhaust stroke of the piston. The back pressure at this point is at the minimum. From this point to the end of the stroke of the piston the back pressure steam contained in the cylinder between the piston and the same at the end of its stroke, and in the clearance and steam passage, is compressed into the space of the clearance and steam passage, thus forming the cushioning. Of course, the weight of steam drawn from the boilers per stroke of piston is just so much the less by the weight of steam thus "cushioned."

Line 23 shows the fraction completed of the exhaust or return stroke of the piston of the small cylinder when the exhaust port is closed and the "cushioning" of the back pressure commences.

Line 24 contains the mean indicated pressure on the piston of the small cylinder; and line 25 contains the mean net pressure on the same, in pounds per square inch. The net pressure is the indicated pressure less the pressure required to work the unloaded engine. This latter pressure is taken at 3.60 pounds per square inch of the piston of the small cylinder.

Line 26 contains the mean total pressure on the piston of the small cylinder, exclusive of the cushioning, in pounds per square inch above zero, obtained in the following manner: The mean back pressure against the piston, exclusive of cushioning, in pounds per square inch above zero, is reduced in the proportion of 1 or unity to the fraction on line 23, and the quantity thus obtained is added to the indicated pressure on line 24. The quantity on line 26 is the entire resistance per square inch of the piston of the small cylinder that is overcome by the steam drawn from the boiler.

Line 27 contains the mean pressure of the expanding steam alone in the small cylinder, in pounds per square inch above zero; that is to say, the mean pressure of the steam after the closing of the cut off valve of the small cylinder.

Steam Pressures in the Two Large Cylinders per Indicator.— Lines 28 to 37, both inclusive, contain the various steam pressures in the two large cylinders, as given by the means taken from all the indicator diagrams. It will be understood that the large cylinders, though mechanically two, are in effect only one, and should be considered in all respects as one cylinder of double capacity of each.

Lines 28, 29 and 30 contain respectively the steam pressures on the pistons of the large cylinders at the commencement of their stroke, at the point of cutting off the steam, and at the end of their stroke, in pounds per square inch above zero.

Line 31 contains the mean back pressure, including cushioning, against the pistons of the large cylinders during their stroke, in pounds per square inch above zero.

Line 32 contains the back pressure in pounds per square inch above zero against the pistons of the large cylinders at the point (line 33) where the cushioning commenced on the return or exhaust strokes of the pistons. The back pressure at this point is at the minimum. From this point to the end of the stroke of the pistons the back pressure steam contained in the large cylinders between their pistons and the same at the end of their stroke, and in the clearances and steam passages at one end of the cylinders, is compressed into the space of these clearances and steam passages, thus forming the "cushioning." Of course, the weight of steam drawn from the receiver per stroke of pistons is just so much the less by the weight of steam thus "cushioned."

Line 33 shows the fraction completed of the exhaust or return stroke of the pistons of the large cylinders when their exhaust ports are closed and the "cushioning" of the back pressure commences.

Line 34 contains the mean indicated pressure on the pistons of the large cylinders; and line 35 contains the mean net pressure on the same, in pounds per square inch. The net pressure is the indicated pressure less the pressure required to work the engine, *per se*, or unloaded. The latter pressure is taken at 0.90 pound per square inch of the pistons of the two large cylinders.

Line 36 contains the mean total pressure in pounds, per square inch above zero, exclusive of the cushioning, on the area that remains of the aggregate area of the pistons of the two large cylinders after deducting the area of the piston of the small cylinder. This pressure is the entire resistance, per square inch of the above annular area of the pistons of the large cylinders that is overcome by the steam drawn from the receiver, and is obtained as follows: The mean back pressure against the pistons, exclusive of cushioning, in pounds per square inch above zero, is reduced in the proportion of 1 or unity to the fraction on line 33, and the quantity thus obtained is added to the indicated pressure on line 34.

Line 37 contains the mean pressure of the expanding steam in the large cylinders in pounds per square inch above zero. All the steam used in the large cylinders is expanding steam from the beginning to the end of the stroke of their pistons. The cut off valve placed on the large cylinders does not increase or influence the ratio of the expansion of the steam for the entire compound engine, in which respect the point in the stroke of the pistons of the large cylinders at which the cut off valve is arranged to close is immaterial. The use of that valve is to increase or decrease, according as it closes earlier or later, the back pressure against the piston of the small cylinder, and to work the steam expansively which is evaporated in the small cylinder during the exhaust stroke of the piston from the water of liquefaction deposited therein during the steam stroke. This re-evaporated steam is used in the large cylinders with whatever measure of expansion is due to the point at which their cut off valves close.

Horses-Power.—Lines 38 and 39 contain respectively the indicated horses-power developed in the small cylinder and in the two large cylinders of the engine. They are calculated for the areas of the pistons of the respective cylinders, for the speed of piston due to the quantities on line 14, and for the pressures on lines 24 and 34. Line 40 contains the sum of the quantities on lines 38 and 39, and gives the aggregate indicated horses-power developed by the engine.

Lines 41 and 42 contain, respectively, the net horses-power developed in the small cylinder and in the two large cylinders of the engines. They are calculated for the areas of the pistons of the respective cylinders, for the speed of piston due to the quantities on line 14, and for the pressures on lines 25 and 35.

Line 43 contains the sum of the quantities on lines 41 and 42, and gives the aggregate net horses-power developed by the engine.

Line 44 contains the total horses-power developed in the small cylinder, calculated for the area of its piston, for the speed of its piston due to the quantities on line 14, and for the pressure on line 26, which pressure it will be observed is above zero.

Line 45 contains the total horses-power developed in the two large cylinders, calculated for the speed of their pistons due to the quantities on line 14, for the pressures on line 36, and for what remains of the aggregate areas of the pistons of the two large cylinders after the area of the piston of the small cylinder has been deducted. The deduction of the area of the piston of the small cylinder is rendered necessary by the fact that the total pressures upon it (line 26) has been taken above zero and consequently includes the total pressure upon the pistons of the large cylinders for an area equal to that of the piston of the small cylinder; therefore, the total power developed in the two large cylinders will be only what is due to what remains of their aggregate area after deduction of the area of the piston of the small cylinder.

Line 46 contains the sum of the quantities on lines 44 and 45, and gives the aggregate total horses-power developed by the engine.

Line 47 contains the total horses-power developed by the expanding steam alone in the small cylinder, calculated for the area of its piston, for the speed of its piston due to the quantities on line 14, and for the pressure on line 27 reduced in the proportion of 1 or unity to the fraction on line 9.

Line 48 contains the total horses-power developed by the expanding steam alone in the two large cylinders calculated for the speed of their pistons due to the quantities on line 14 for the pressures on line 37 and for what remains of the aggregate areas of the pistons of the two large cylinders after the area of the piston of the small cylinder has been deducted.

Line 49 contains the aggregate total horses-power developed by the expanding steam alone in all the cylinders, and gives the sum of the quantities on lines 47 and 48.

Weight of Steam Accounted for per Hour by the Indicator.—Line 50 gives the number of pounds of steam present per hour in that state in the small cylinder at the point of cutting off the steam (line 9), calculated from the pressure (line 19) there. The calculation is made for the number of cubic feet of space displacement of the piston per hour up to the point of cutting off plus the corresponding spaces in the clearance and steam passage and for the weight of steam per cubic foot due to the pressure on line 19. From the quantity thus obtained is deducted the product of the number of cubic feet in the space displacement of the piston per hour from the point (line 23) at which the cushioning commenced to the end of the stroke, plus the corresponding spaces in the clearance and steam passage multiplied by the weight of the back pressure steam per cubic foot due to the pressure on line 22.

Line 51 gives the number of pounds of steam present per hour in that state in the small cylinder at the end of the stroke of its piston calculated from the pressure (line 20) there. The calculation is made in precisely the same manner as described for the quantities on line 50, substituting the space displacement of the piston per stroke for its space displacement to the point of cutting off.

Line 52 contains the number of pounds of steam liquefied per hour in the small cylinder to furnish the heat transmuted into the total horses-power developed in that cylinder by the expanded steam alone after the closing of the cut off valve. In making this calculation 789¼ foot-pounds of work are taken as the equivalent of one Fahrenheit unit of heat, and one horse power is taken as 33,000 foot-pounds of work done per minute, or as equivalent to $\frac{33{,}000}{789\frac{1}{4}} = 41.812$ Fahrenheit units of heat; consequently this latter number multiplied by 60 minutes and by the number of horses-power (line 47) developed by the expanding steam alone, gives the number of Fahrenheit units of heat transmuted per hour into that power, and this number divided by the latent heat of the mean pressure of the expanding steam alone (line 27) gives the quantity on line 52.

Line 53 contains the sum of the quantities on the two immediately preceding lines. This sum is the number of pounds of steam accounted for per hour by the indicator in the small cylinder at the end of the stroke of its piston.

Line 54 gives the number of pounds of steam present per hour in that state in the two large cylinders at the end of the stroke of their pistons, calculated from the pressure (line 30) there. The calculation is made in precisely the same manner as described for the quantities on line 51.

Line 55 contains the number of pounds of steam liquefied per hour in the small and large cylinders and in the receiver between them, to furnish the heat transmuted into the total horses-power developed in the small and large cylinders by the expanded steam alone after the closing of the cut off valve. The calculation is made for the two large cylinders in precisely the same manner as described for the small cylinder (line 52), the horses-power being those on line 48, and the mean pressures of the expanding steam being those on line 37. These results being added to the quantities on line 52, make those on line 55.

Line 56 contains the sum of the quantities on the two immediately preceding lines (54 and 55). The sum is the number of pounds of steam accounted for per hour by the indicator in the two large cylinders at the end of the stroke of their pistons. This quantity furnishes the *minimum* limit of pounds weight of steam consumed per hour. The consumption might be more but could not be less. An addition of one-eighth of this quantity to the quantity itself, would in the case of the maximum power trial, probably give a very close approximation to the true consumption of steam per hour.

Ratios of the Powers.—Lines 57, 58 and 59 contain, respectively, the per centum which the quantities on lines 40, 43 and 49 are of the quantities on line 46. They show the fraction of the total horses-power (line 46) developed by the engine, calculated for the mean pressure upon the pistons down to the zero line, which is utilized as indicated horses-power (line 40), as net horses-power (line 43), and as power developed by the expansion of the steam (line 49).

Cylinder Pressures Reduced to the Two Large Cylinders Alone.—For purposes of comparison, and for future use, it is necessary to have a single expression for the different *mean* pressures on the piston of the small cylinder and on the pistons of the two large cylinders considered as one of double area. This is obtained by reducing the mean indicated and net pressures on the piston of the small cylinder, in the ratio of the area of that piston to the aggregate area of the pistons of the two large cylinders, and adding the result to the corresponding mean pressures on the pistons of those cylinders. For the mean total pressure on the pistons of the large cylinders, the total horses-power (line 46) developed by the engine is multiplied by 33,000 and the product divided by the product of the aggregate areas in square inches of the pistons of the large cylinders into their speed per minute deduced from the quantities on line 14. In this manner there have been found the quantities on lines 60, 61 and 62, which are, respectively, the indicated, net and total pressures in pounds per square inch which would, if exerted upon the areas of the pistons of the large cylinders alone, when moving at the speed due to the quantities on line 14, have produced the indicated, net and total horses-power on lines 40, 43 and 47, respectively.

The quantities on line 63 are obtained by subtracting the quantities on line 60 from those on line 62, and are the back pressures against the pistons of the large cylinders due not only to the imperfect condensation of the exhaust steam in the condenser, but additionally to the difference between the back pressure exclusive of cushioning in pounds per square inch above zero against the piston of the small cylinder, and the mean pressure on the pistons of the large cylinders in pounds per square inch above zero, from the initial pressure (line 28) to the pressure at the point of cutting off (line 29).

Rate of Combustion.—Line 64 contains the number of pounds of commercial anthracite consumed per hour during the experiment at sea of 12 hours and 27 minutes duration. The refuse was not obtained, but probably did not exceed one-eighth, as the anthracite was burned at an excessively slow rate, and without cleaning of fires.

Line 65 gives the rate of combustion in pounds of anthracite consumed per hour per square foot of grate surface, obtained by dividing the quantity on line 64 by 149.

Line 66 gives the rate of combustion in pounds of anthracite consumed per hour per square foot of water heating surface calculated for the inside diameter of the boiler tubes, obtained by dividing the quantity on line 64 by 3,038.4.

Line 67 gives the rate of combustion in pounds of anthracite consumed per hour per square foot of water heating surface calculated for the outside diameter of the boiler tubes, obtained by dividing the quantity on line 64 by 3,220.

Cost of the Powers.—The quantities on lines 68, 69 and 70, are respectively the quotients of the division of the quantity on line 64 by those on lines 40, 43 and 46, and give the cost of the indicated, net and total horses-power developed by the engine, in pounds of anthracite consumed per hour. The anthracite was burned as slowly as possible, and keep an ignited bed over the entire grate surface.

Note.—The "cushioned" steam in all the preceding calculations has been treated as simply a foreign body in the cylinders, the results of power being calculated entirely for the expenditure of steam drawn from the boilers and exhausted into the condenser.

REMARKS.

The foregoing exact data, and the calculations based on them, add that much to our experimental knowledge in steam engineering, and assist in furnishing the indisputable facts necessary to its successful practice. Especially do the experiments show the power which can be obtained from the machinery employed and from the kind of fuel consumed, the economy as regards the propulsion of the vessel with which that power was applied by the screw, and the speed which such machinery could give to such a vessel as the *Yosemite* under the experimental conditions.

The data and results of these trials allow an analysis to be made of the power exerted, showing what proportion of it was expended in overcoming the various resistances incidental to the propulsion of the hull; and in what proportion the ratio of the power to speed of vessel increased for an increase of speed from the low to the high experimental speed.

Only a portion of the indicated horses-power developed by the engine, and that, too, a very variable portion, according to circumstances and conditions, is applied to the propulsion of the hull.

There is first to be deducted the power required to work the engine, *per se*, or unloaded, at the experimental speed, which is obtainable by disconnecting the screw and taking indicator diagrams from the cylinders when their pistons make the experimental number of double strokes per minute. The *pressure* shown upon the indicator diagrams thus taken, will be found to be practically the same for all speeds of piston from the lowest to the highest, consequently, the *power* required to work the engine, *per se*, will be directly proportional to the number of double strokes made in a given time by its pistons. In the case of a compound engine working unloaded, the pressure upon the piston of the small cylinder will be found by the indicator to be exactly as many times greater than the pressure upon the piston of the large cylinder, as the area of the piston of the large cylinder is greater than the area of the piston of the small cylinder, the pistons of both cylinders having equal length of stroke. This proportion necessarily results from the fact that exactly the weight of steam used in the large cylinder has first to be used in the small one, so that the pressures in the two cylinders must be in the inverse ratio of the space displacements of their pistons per stroke. The aggregate power thus obtained, however, distributed between the small and large cylinders, is the power required to work the engine, *per se*, and it is of little consequence how the distribution is taken provided the aggregate remains the same.

The small and large cylinders of a compound engine do not compose two simple engines with cylinders of unequal capacity and with independent functions. The small and the large cylinder of the compound engine have interacting functions and are indivisible, the two constituting one engine, whereas each cylinder in the case of a simple engine is a complete engine.

After deduction is made of the power required to work the engine, *per se*, from the indicated horses-power (for until the resistance of the unloaded moving organs of the engine are overcome there can be no development of power) the remainder is the net horses-power and is the power applied to the crank pins. This is the external or commercial power developed by the engine additional to the internal power expended in working the engine, *per se.*

Now, there is a friction on the journals and bearing surfaces exterior to the cylinders of all the organs of the engine in motion, due solely to the resistance of the load, and consequently proportional to the net horses-power which represent the load. The greater the resistance of the load the greater is the pressure under which these journals and bearing surfaces move. This friction of the load is taken at 7½ per centum of it—an experimental determination for well lubricated journals. This friction of the load must be deducted from the net horses-power.

The helicoidal surfaces of the screw propeller moving in their helical paths, experience a resistance from the water of the same kind which the wetted surface of the hull experiences, and capable of calculation in the same manner. This resistance is taken to be 0.45 pound avoirdupois per square foot of helicoidal surface moving in its helical path with a velocity of 10 feet per second, and for other velocities this 0.45 pound is modified in the ratio of their squares to the square of 10. When the dimensions of the screw are known, and the number of revolutions it makes per minute, the horses-power expended in overcoming the surface resistance of its blades can be calculated by means of the above data. These horses-power must be deducted from what remains of the net horses-power after subtraction of the horses-power absorbed by the friction of the load, and the remainder are the horses-power expended in the slip of the screw and in the propulsion of the vessel, and are divided in the ratio of the speeds of the two, the pressure exercised by the screw forward in propelling the vessel and backward upon the receding mass of water constituting the slip of the screw being the same. Hence, if the aforesaid remainder of power be multiplied by the speed of the slip expressed in fractions of the axial speed of the screw, the product will be the horses-power expended in the slip, which, being subtracted from the above remainder, leaves the residue as the horses-power expended in the propulsion of the vessel.

The necessary calculations having been made in accordance with the foregoing assumptions, give the following for the distribution of the indicated horses-power developed by the engine when the vessel was at the speed of 10.125 geographical miles per hour:

	Horses-power	Per centum of the net horses-power.
Indicated horses-power developed by the engine........	291.658	
Horses power expended in working the engine, *per se*...	48.888	
Net horses-power applied to the crank pins................	242.770	100 00
Horses power absorbed by the friction of the load.........	18.208	7.50
Horses power expended in overcoming the resistance of the water to the screw surface........................	16 565	6.82
Horses-power expended in the slip of the screw..........	28.274	11.65
Horses-power expended in the propulsion of the vessel	179.723	74.03
Totals..	242.770	100.00

The thrust of the screw, as it would have been measured by a dynamometer directly applied to the shaft during the above performance, calculated from the data given therein and in the distribution of the power, is as follows:

The horses-power expended in the propulsion of the vessel according to the distribution of the power, being 179.723 is equal to ($179.723 \times 33,000 =$) 5,930,864.346 foot-pounds of work per minute, and the speed of the vessel being 10.125 geographical miles per hour, is equal to $\left(\frac{10.125 \times 6,086}{60} =\right)$ 1,027.0125 feet per minute; hence the resistance of the vessel at that speed, or its equivalent, the thrust of the screw, is $\left(\frac{5,930,864.346}{1,027.0125} =\right)$ 5,774.871 pounds.

The distribution of the power given immediately below, is for the maximum speed of 15.6 geographical miles per hour; and the quantities are calculated in exactly the same manner as previously described for the speed of 10.125 geographical miles per hour.

	Horses-power.	Per centum of the net horses-power.
Indicated horses-power developed by the engine..........	1,403.744	
Horses-power expended in working the engine, *per se*...	80.755	
Net horses-power applied to the crank pins.................	1,322.989	100.00
Horses-power absorbed by the friction of the load.......	99 224	7.50
Horses-power expended in overcoming the resistance of the water to the screw surface................................	74.130	5.60
Horses-power expended in the slip of the screw..........	233.814	17.67
Horses-power expended in the propulsion of the vessel..	915.821	69.23
Totals..	1,322.989	100.00

The thrust of the screw, as it would have been measured by a dynamometer directly applied to the shaft during the above performance, calculated from the data given therein and in the distribution of the power, is as follows:

The horses-power expended in the propulsion of the vessel according to the distribution of the power, being 915.821, is equal to (915.821 × 33,000 =) 30,222,095.97 foot-pounds of work per minute; and the speed of the vessel being 15.6 geographical miles per hour, is equal to $\left(\frac{15.6 \times 6.086}{60} =\right)$ 1,582.36 feet per minute; hence the resistance of the vessel at that speed, or its equivalent, the thrust of the screw, is $\left(\frac{30,222,095.97}{1,582.36}\right) = 19,099.381$ pounds.

If the resistance of the hull had increased in the ratio of the square of its speed from the speed of 10.125 to that of 15.6 geographical miles per hour, its resistance at the latter speed would have been ($5,774.871 \times 1.540741^2 =$) 13,714.636 pounds; its actual resistance being 19,099.381 pounds, was $\left(\frac{19,099.381 - 13,714.636 \times 100}{13,714.636} =\right)$ 39.263 per centum greater than was due to this ratio.

The resistance of the hull in function of speed to power, in passing from the speed 10.125 knots to the speed 15.6 knots, increased in the 2.654 power of the speed.

The resistance of a hull of given dimensions is due to the form of its immersed solid, and to the water friction of its wetted surface. Within certain limits of speed, the hull will retain its *trim* and its mean draught of water; its resistance consequently varying sensibly as the square of its speed; but when that limit is passed, the hull will *squat*, that is, its bow will rise and its stern will fall relatively to their previous positions; the vessel's mean draught of water will increase with corresponding increase of greatest immersed transverse section, displacement and wetted surface; the form of the immersed solid will also change relatively to the water level, and its resistance will increase in a higher ratio than the square of speed; in fact, abstractly, for each speed above the squatting limit, there will be a differently shaped immersed solid relatively to the water level, each succeeding solid having a greater resistance than the preceding one, supposing them all to be tried at the same speed, which, though not possible experimentally, can be conceived. Above the squatting limit of speed, so many different speeds, so many different models, each worse than any of its predecessors. As the speed of the vessel increases above that of the squatting limit, the correspondingly increasing mass of water at the bow raised above the normal level, lifts the bow, and the correspondingly decreasing mass of water supporting the stern allows the stern to fall, both causes operating to change the vessel's trim and to increase its resistance above the ratio of the square of the speed. The amount of this increase can only be ascertained by the process herein adopted for the particular cases of *Yosemite*, of analyzing the indicated horses-power developed by the engine for the different speeds, and calculating the exact portion of it applied to the propulsion of the vessel. The usual method of comparing the speeds of the vessel with the entire indicated horses-power developed by the engine will give very erroneous results, misleading and of no value in any particular.

Taking, for illustration, the cases of the *Yosemite*: the indicated horses-power for the speeds of 10.125 and 15.6 knots, compare as 1 to 4.813, while the horses-power actually applied to propelling the vessel compare as 1 to 5.096. The cubes of the speeds compare as 1 to 3.659. And $\frac{4.813}{3.659} = 1.31536$, while $\frac{5.096}{3.659} = 1.39263$, showing that, if the indicated horses-power were taken for the comparison, the increased resistance at the higher speed above the normal ratio would be 31.536 per centum, and if the horses-power actually applied to the propulsion were taken the increased resistance would be 39.263 per centum.

During the maximum speed trial of 15.6 geographical miles per hour, the speed of the screw was 19.583 geographical miles per hour, the slip of the screw being, consequently, 3.983 geographical miles per hour, or 20.338 per centum. Now, the slip of the screw during the 10.125 geographical miles per hour trial was 14.593 per centum, and had its per centage remained the same during the 15.6 geographical miles per hour trial, the speed slip of the screw would have been ($19.582764 \times 0.14593562 =$) 2.857823 geographical miles per hour. Under these conditions, the increased resistance of the hull above what was due to the ratio of the square of the speed, should compare as the speed slips of the screw in the two cases, namely, as 3.982764 to 2.857823; the former quantity is $\left(\frac{3.982764 - 2.857823 \times 100}{2.857823} =\right) 39.364$ per centum greater than the latter. The previous determination of the increased resistance made from the distributions of the power, gave this percentage, 39.263, which is just the same.

The only weights on board the *Yosemite* during these experiments were those of the personnel embarked, their effects, furniture, galley, provisions and water for a few days, anchors and chains, and sufficient coal to make the trials. Of course, if the vessel had to be used for any naval or mercantile purpose, the necessary weights to be added would very largely increase the draught of water and decrease the speed. These facts, however, do not lessen the value of the experimental engineering results, which were obtained with the greatest accuracy.

TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE WITH THE *YOSEMITE* AT MAXIMUM SPEED DURING FOUR CONSECUTIVE RUNS OVER A MEASURED GEOGRAPHICAL MILE IN NARRAGANSETT BAY, RHODE ISLAND, BURNING ANTHRACITE WITH BLOWER DELIVERING AIR INTO CLOSED ASHPITS: AND DURING 12 HOURS AND 27 MINUTES CONSECUTIVELY AT SEA BETWEEN NEWPORT AND PORTSMOUTH, NEW HAMPSHIRE, BURNING ANTHRACITE AT THE SLOWEST PRACTICABLE RATE WITH NATURAL DRAFT. IN BOTH CASES THE WATER WAS PERFECTLY SMOOTH AND THE AIR NEARLY CALM.

No. of line		Mean of four runs over a measured knot at maximum speed, burning anthracite with blower.	Mean of a trial of 12 hours 27 minutes, burning anthracite with natural draft at slowest possible rate.
	Vessel		
	Date of the experiments	July, 1884.	July 23–24, 1884.
1	Vessel's draught of water forward, in feet and inches from bottom of keel	9–10	9– 8
2	Vessel's draught of water aft, in feet and inches from bottom of keel	11–10	11–10
3	Vessel's draught of water amidship, in feet and inches from bottom of keel	10–10	10– 9
4	Vessel's greatest immersed transverse section, in square feet	156.62	154.62
5	Vessel's displacement, in tons of 2,240 pounds	444.702	437.708
6	Vessel's external immersed or wetted surface, in square feet, including keel and rudder	4,800.35	4,770.18
	Engine.		
7	Steam pressure in boilers in pounds per square inch above the atmosphere	108.00	80.87
8	Steam pressure in receiver in pounds per square inch above the atmosphere	....	8.18
9	Fraction completed of the stroke of the piston of the small cylinder when the steam was cut off	0.632	0.111
10	Fraction completed of the stroke of the pistons of the large cylinders when the steam was cut off	0.632	0.111
11	Number of times the steam was expanded	6.027	25,352
12	Vacuum in the condenser in inches of mercury	....	25.75
13	Pressure in the condenser in pounds per square inch above zero	....	2.05
14	Number of double strokes made per minute by the pistons of the engine	107.37	65.00
	Speed.		
15	Speed of the vessel per hour in statute miles of 5,280 feet	17.981	11.671
16	Speed of the vessel per hour in geographical miles of 6,086 feet	15.600	10.125
17	Slip of the screw in per centum of its speed (18.50 feet pitch)	20.338	14.594
	Steam Pressure in the Small Cylinder per Indicator.		
18	Pressure on the piston of the small cylinder at commencement of its stroke in pounds per square inch above zero	111.54	86.73
19	Pressure on the piston of the small cylinder at point of cutting off the steam in pounds per square inch above zero	93.20	82.89
20	Pressure on the piston of the small cylinder at the end of its stroke in pounds per square inch above zero	64.94	21.39

No. of line		Mean of four runs over a measured knot at maximum speed, burning anthracite with blower.	Mean of a trial of 12 hours 27 minutes, burning anthracite with natural draft at slowest possible rate.
	Steam Pressure in the Small Cylinder per Indicator.		
21	Mean back pressure against piston of small cylinder during its stroke (including cushioning) in pounds per sq. in. above zero	28.69	21.27
22	Back pressure against piston of small cylinder at the point where the cushioning of the steam commences in pounds per square inch above zero	27 59	20.17
23	Fraction completed of the return stroke of the piston of the small cylinder when the back pressure steam was cushioned	0.896	0.774
24	Indicated pressure on the piston of the small cylinder in pounds per square inch	64.97	21.87
25	Net pressure on the piston of the small cylinder in pounds per square inch	61.37	18.27
26	Total pressure on the piston of the small cylinder (exclusive of the cushioning) in pounds per square inch above zero	90.06	37.75
27	Mean pressure of the expanding steam alone, in the small cylinder, in pounds per square inch above zero	75.00	33.50
	Steam Pressures in the Large Cylinders per Indicator.		
28	Pressure on the pistons of the large cylinders at commencement of their stroke in pounds per square inch above zero	27.25	20.15
29	Pressure on the pistons of the large cylinders at point of cutting off the steam in pounds per square inch above zero	21 68	17.50
30	Pressure on the pistons of the large cylinders at the end of their stroke in pounds per square inch above zero	14 37	4.81
31	Mean back pressure against the pistons of the large cylinders during their stroke (including cushioning) in pounds per square inch above zero	7.00	4.17
32	Back pressure against the pistons of the large cylinders at the point where the cushioning of the steam commences, in pounds per square inch above zero	6.06	3.82
33	Fraction completed of the return stroke of the pistons of the large cylinders when the back pressure steam was cushioned	0.896	0 774
34	Indicated pressure on the pistons of the large cylinders in pounds per square inch	15.04	5.27
35	Net pressure on the pistons of the large cylinders in pounds per square inch	14 14	4.37
36	Total pressure in pounds per square inch above zero, exclusive of the cushioning, on the area that remains of the aggregate pistons of the large cylinders after deducting the area of the piston of the small cylinder	20.86	8.75
37	Mean pressure of the expanding steam alone, in the large cylinders, in pounds per square inch above zero	22.04	9.44
	Horses-power.		
38	Indicated horses-power developed in the small cylinder	732.604	149 292
39	Indicated horses-power developed in the large cylinders	671.140	142.366
40	Aggregate indicated horses-power developed by the engine	1,403.744	291.658
41	Net horses-power developed in the small cylinder	692.010	124 717
42	Net horses-power developed in the large cylinders	610 979	118.053
43	Aggregate net horses-power developed by the engine	1,322.989	242.770
44	Total horses-power developed in the small cylinder	1,015 520	257.694
45	Total horses-power developed in the large cylinders, by the area that remains of their pistons afrer deducting from them the area of the piston of the small cylinder	695 632	176.646
46	Aggregate total horses-power developed by the engine	1,711.152	434.340
47	Total horses-power developed by the expanded steam alone in the small cylinder	311.219	186.147
48	Total horses power developed by the expanded steam alone in the large cylinders	695 632	176 646
49	Aggregate total horses-power developed by the expanded steam in all the cylinders	1,006 850	362 793

	Weight of Steam Accounted for per Hour by the Indicator.		
50	Pounds of steam present per hour in the small cylinder at point of cutting off the steam, calculated from the pressure there	22,030.112	1,974.192
51	Pounds of steam present per hour in the small cylinder at end of the stroke of its piston, calculated from the pressure there	24,376.753	4,048.657
52	Pounds of steam liquefied per hour in the small cylinder to furnish the heat transmuted into the total horses-power developed in that cylinder by the expanded steam alone after the closing of the cut off valve	869.854	500.018
53	Sum of the two immediately preceding quantities	25,246.607	4,548.675
54	Pounds of steam present per hour in the large cylinders at the end of the stroke of their pistons, calculated from the pressure there	22,776.738	4,073.301
55	Pounds of steam liquefied per hour in the small and large cylinders and in the receiver to furnish the heat transmuted into the total horses-power developed in the small and large cylinders by the expanded steam alone after the closing of the cut off valve in the small cylinder	2,705.757	951.796
56	Sum of the two immediately preceding quantities	25,482.495	5,025.097
	Ratio of the Powers.		
57	Per centum which the aggregate indicated horses-power are of the aggregate total horses-power developed by the engine	82.035	60.243
58	Per centum which the aggregate net horses-power are of the aggregate total horses power developed by the engine	77.316	55.894
59	Per centum which the aggregate total horses-power developed by the expanding steam alone are of the total horses-power developed by the engine	58.841	82.527
	Cylinder Pressures Reduced to the Two Large Cylinders alone.		
60	Indicated pressure in pounds per square inch that would be on the pistons of the large cylinders were the indicated pressure on the piston of the small cylinder divided by the ratio of the area of the small to the aggregate areas of the large cylinders, and the quotient added to the experimental indicated pressure on the pistons of the large cylinders	31.457	10.796
61	Net pressure in pounds per square inch that would be on the pistons of the large cylinders, similarly calculated to the immediately above	29.648	8.987
62	Total pressure in pounds per square inch above zero that would be on the pistons of the large cylinders corresponding to the total horses-power developed by the engine	38.346	16.078
63	Back pressure in pounds per square inch above zero that would be against the pistons of the large cylinders, similarly calculated to the above	6.889	5.282
	Rate of Combustion.		
64	Pounds of anthracite consumed per hour (mean for 12 hours and 27 minutes consecutively)	....	563.000
65	Pounds of anthracite consumed per hour per square foot of grate surface	....	3.779
66	Pounds of anthracite consumed per hour per square foot of water heating surface, calculated for inside diameter of tubes	....	0.185
67	Pounds of anthracite consumed per hour per square foot of water heating surface, calculated for outside diameter of tubes	....	0.175
	Cost of the Powers.		
68	Pounds of anthracite consumed per hour per indicated horse-power	....	1.930
69	Pounds of anthracite consumed per hour per net horse-power	....	2.319
70	Pounds of anthracite consumed per hour per total horse-power	....	1.296

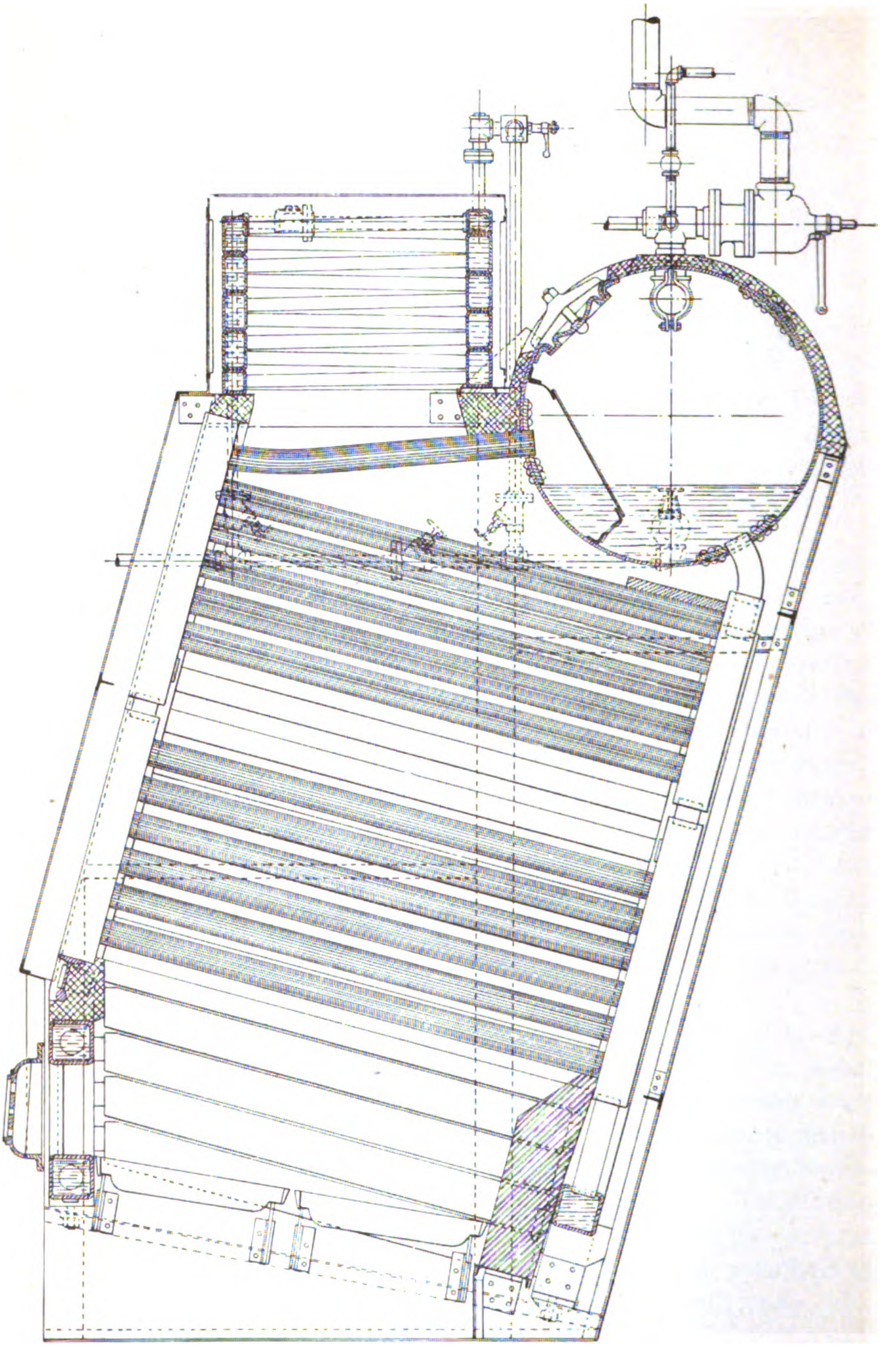
TEST OF A BABCOCK AND WILCOX BOILER TO DETERMINE ITS EVAPORATIVE EFFICIENCY.

The test herein recorded was made on a shop boiler at the works of the Babcock and Wilcox Company, at Elizabethport, New Jersey, and was conducted under instructions from the Bureau of Steam Engineering of the Navy Department by a Board of naval engineers composed of Chief Engineers H. S. Ross and George Cowie, Jr., and Passed Assistant Engineer F. H. Bailey, U. S. Navy, from whose report the data have been taken.

The object of the test being to determine the evaporative efficiency of the boiler at a high rate of combustion, and to ascertain whether such a rate as is sometimes reached on the trial trips of naval vessels could be maintained for a considerable length of time without injury to the boiler, it was arranged between the Board and the firm submitting the boiler for test that the rate of combustion should be maintained at 50 pounds per square foot of grate surface per hour, and that the test should continue for twenty-four consecutive hours. Incidentally, it was desired to obtain figures which might be used in making a comparison with tests of other water tube boilers which had been tested by the Bureau of Steam Engineering, and for this reason the safety valves were set to blow off at 160 pounds per square inch above the atmosphere.

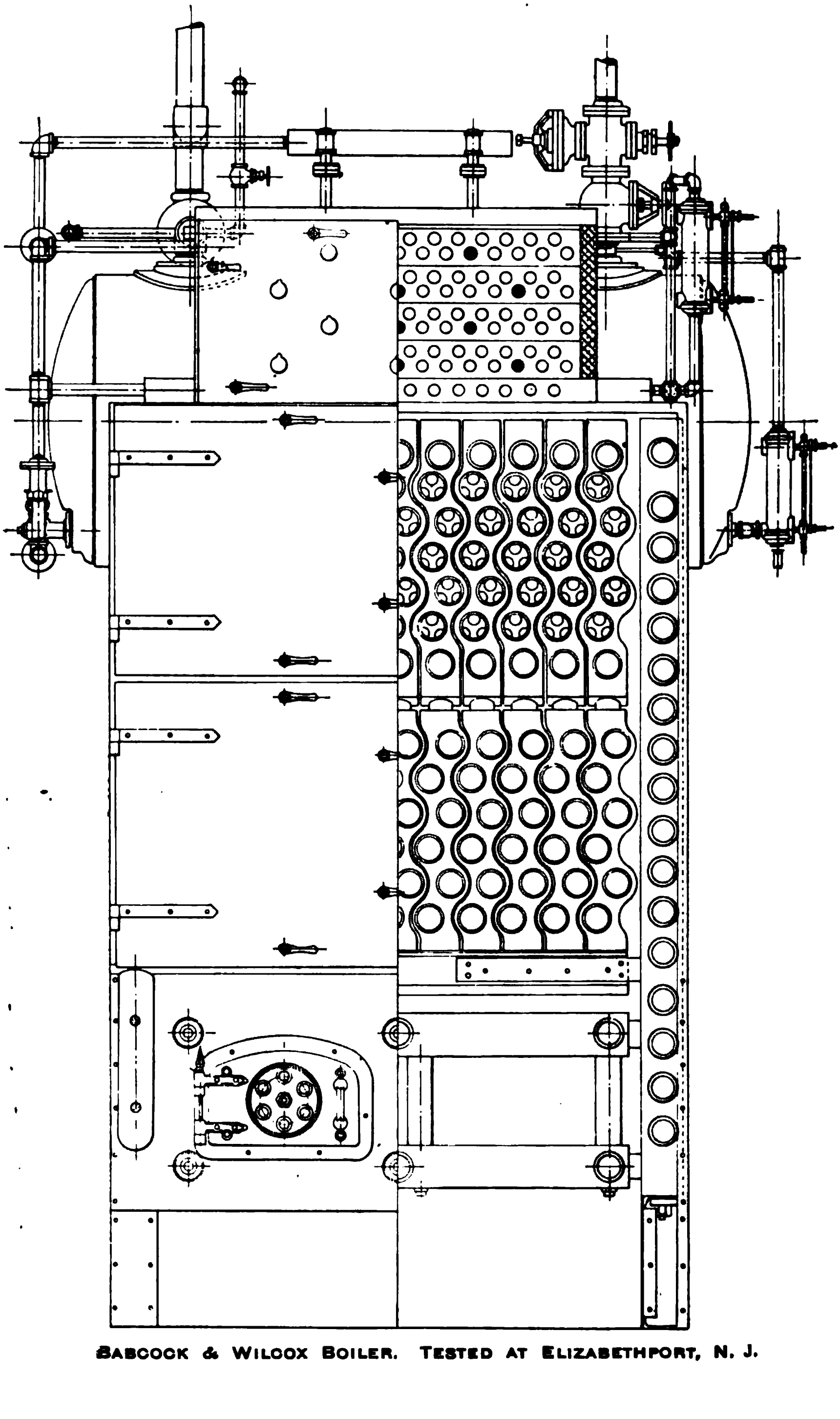
The test commenced at 12·06 P. M. on the 22d of April, 1895, and ended at the same time on the following day. The usual appliances for accurately measuring coal and feed water were used, and also a Barrus throttling and an ordinary barrel calorimeter for testing the dryness of the steam. All the instruments used were carefully tested and found to be correct. They comprised two pressure gauges, one of which was a test gauge from the New York navy yard, and both of which were attached to the top of the steam drum; a barrel calorimeter with a propeller

FIG. I.



BABCOCK & WILCOX BOILER. TESTED AT ELIZABETHPORT, N. J.

FIG. 1.



BABCOCK & WILCOX BOILER. TESTED AT ELIZABETHPORT, N. J.

agitator and a thermometer reading to $\frac{1}{10}$ of a degree Fahrenheit, the steam pipe being heavily coated with non-conducting material, and the attached rubber hose provided with a rosette having $\frac{1}{8}$-inch holes; a Barrus throttling calorimeter, located on top of the steam drum, and taking steam through a $\frac{3}{8}$-inch pipe from the center of the main steam pipe at its discharge from the boiler; three air pressure gauges to measure the pressure of air in inches of water, one connected to the base of the smoke pipe, one to the furnace, and the third to the ash pit, each provided with a vernier reading to $\frac{1}{100}$ of an inch; a Shaeffer and Budenberg metallic expansion pyrometer which was inserted across the base of the smoke pipe; and an Aneroid barometer with attached thermometer. In the base of the smoke pipe, and 8 inches from the side of it, were also two pieces each of lead, zinc and antimony. The platform scales for weighing the coal were new, but were difficult to graduate nearer than one-quarter of a pound, on account of the vibration of the blower engine, near which they were placed, interfering with accurate balancing. The quantity of coal weighed each time was 200 pounds. A portion of the steam generated was reduced to a pressure of 100 pounds and used for running the shop engine, the remainder being blown into the atmosphere by means of a pipe passing from the safety valves up through the roof of the building.

The boiler, which is shown in the accompanying Figure 1, consists essentially of two nests of tubes, one above the other, inclined at an angle of 15 degrees to the horizontal, the ends of the tubes being expanded in sinuous headers at the front and back of the boiler, the front headers connecting with the steam space of a drum placed across the tubes and at the back of the boiler, and the back headers with the water space of this drum. The tubes of the lower nest are 4 inches in diameter, and those of the upper, 2 inches, the latter in groups of three whose ends are accessible through a single opening in the headers; the ends of all tubes are expanded. The headers are forged of wrought iron with ends welded in, and the two tiers of headers at front and back connected by short expanded nipples. The front headers are connected to the steam drum by 4-inch tubes, and the back ones by short bent nipples, which are expanded in drum and header, there being no screwed joints in the boiler.

On each side of the furnace there are four water boxes 6 inches square forming the sides of the furnace, and above these, twelve 4-inch tubes on each side forming the sides of the boiler. These tubes are covered with a non-conducting cement and cased with sheet iron.

Access to the ends of the tubes is had through openings in the headers. These openings are closed by plates making a ground joint on the outside of the header, the dog being inside and of such form that it quite fills the opening, so that if a stud breaks the leakage will be slight.

Above the upper nest of tubes, and in the base of the smoke pipe, there is a feed water heater consisting of ten horizontally placed water manifolds, five at the front and five at the back end, one above the other, connected by short lengths of pipe, and so arranged that the feed water entering at the bottom passes in a zig-zag course through the manifolds and tubes to the outlet at the top to the water drum. From this outlet, return pipes on each side with check valves in them lead to the lower water manifold, so that in the event of the feed being shut off, circulation will be maintained in the heater and danger of burning it out be obviated.

The method of feeding is as follows: The feed enters the lower front manifold of the heater, passes through a series of tubes to the lower manifold at the back and back again to the next higher front manifold; and so on back and forth until it enters the heater drum outside of the boiler casing, from which it passes to the main steam and water drum of the boiler. The top heater manifold at the back is also connected with the first front manifold by two return pipes, one on each side of the heater, each connection containing a check valve opening towards the front. The former manifold is also connected with the heater drum, into which is inserted a small relief valve insuring the heater against the closing of all valves between it and the main steam drum. When the feed is constant, all the aforementioned tubes and manifolds are completely filled with water; but should the feed be stopped at a time when the boiler is steaming rapidly, steam would be generated in the heater tubes and blow the water before it into the main drum leaving the heater tubes dry, were it not for the return connection from the top to the bottom manifold, which establishes a circulation within the heater. By this arrangement, a large body of water is not forced into the main steam and water drum, but only steam due to water that is actually evaporated in the heater. The makers state that in a test made by them, a glass water gauge was placed on the heater and one on the main water drum, the water being allowed to evaporate in the heater until its height could be seen in the glass; the height of water in both glasses was then noted, the feed pump being stopped. The boiler was steaming rapidly, and 9 inches of water was evaporated from the main water drum while only 1½ inches was evaporated in the heater. At this rate of evaporation, the heater would never burn out, as a supply of water would be needed for the boiler before that within the heater could be evaporated. During the time that the feed pump was stopped, the rush of water could be heard passing the check valve in the return connection between the manifolds.

The glass water gauge was at the front of the boiler, on one side, and was connected to the steam space of the drum at the top by a ¾-inch pipe, and to the water space at the bottom, by a 1¼-inch pipe in the head of the drum and 6 inches from the bottom thereof. Another glass gauge was on the heater to indicate the water line when the feed is shut off.

The feed water was supplied through a 1½-inch pipe by a Blake duplex pump with cylinders $6 \times 3 \times 7$ inches stroke. A thermometer in an oil cup was placed in the pipe just before its connection with the heater, and a second one in the pipe after leaving the heater. Another thermometer was placed in the feed tank.

The feed water measuring tank, which was of iron, was located immediately above the feed tank and on accurate platform scales.

The draft was forced by a steam jet at the base of the smoke pipe and by a Sturtevant fan. The following are the particulars of the fan and engine:

Diameter of cylinders (2), inches	3
Stroke, inches	4½
Diameter of fan, inches	36
Width of blades, inches	16
Diameter of fan inlet, inches	27
outlet, inches	22

The following are the particulars of the boilers :

Width of opening to ash pit, inches	8
Length of opening to ash pit, feet	4
Length on floor, feet and inches	10-6
Width on floor, feet and inches	8-½
Height of boiler proper, feet and inches	12-10⅝
Height of boiler and heater, feet and inches	15-7
Tubes, lower nest, diameter, inches	4
length, feet	7
number	66
upper nest, diameter, inches	2
length, feet	7
number	165
side, diameter, inches	4
length, feet	7
number on each side	12
Water boxes, square, inches	6
number on each side of furnace	4
Steam drum, diameter, inches	48
length, feet and inches	9-9
steam pipe, diameter, inches	3
Feed water heater:	
tubes, number	125
diameter, inches	2
length, feet	3
length, feet and inches	5-7
width, feet and inches	3-8
Smoke pipe, diameter, inches	38
top above grate, feet	55
Safety valves, number	2
diameter, inches	2½ and 4
Length of grate, feet and inches	5-6
Grate surface, square feet	38.5
Heating surface, lower nest of tubes, square feet	462
upper nest of tubes, square feet	604.6
header (tube) surface, upper, square feet	36.66
lower, square feet	37.40
side tubes and boxes (½), square feet	115

Heating surface, tubes from headers to drum, square feet	52
drum, square feet	24
front cross-box and tubes, square feet	5 58
total in boilers, square feet	1,337.24
feed water heater, square feet	215
total boiler and heater, square feet	1,552.24
Weight of boiler, feed water heater, casing, grate bars, foundation, etc., pounds	39,818
water at 60° Fahr. in heater and in boiler at steaming level, 5 inches in glass, pounds	9,439
boiler complete with water, pounds	49.257
total, per square foot of heating surface, pounds	31.7
Same per square foot of grate surface, pounds	1,279.4

Steam having been raised to a pressure of 160 pounds, with water at a height of 5 inches in the gauge glass, the fires were hauled and lighted with wood at 12·06 P. M., at which time the test was held to commence, the water level having been noted and the first set of observations made. The blower was started at 12·11, and the steam jet at 1·30.

The coal burned was a fair quality of Pocahontas semi-bituminous, and contained about 73 per cent. of fine coal; it was rather damp. Samples from each barrow were thrown into two iron boxes and placed near the steam drum of the boiler to dry; after drying for twelve hours, the weight in each case was found to have fallen from 25 to 22 pounds, or 12 per cent. The coal burned with a white flame, and smoke showed at the top of the smoke pipe during the charging of the furnace; this soon afterwards lessened to a light thin smoke.

The method of firing was to charge the furnace heavily at the doors, and to push and spread the coal back as soon as it was moderately caked.

The following is an analysis of the coal as made by Professor Stillman, of the Stevens Institute of Technology, Hoboken, N. J.:

Volatile and combustible matter, per cent	18.14
Fixed carbon, per cent	75.92
Sulphur, per cent	.75
Ash, per cent	5.19
	100.00

The pyrometer showed rapid fluctuations during firing which were probably greater than the actual changes in temperature, and possibly due to the sudden change affecting the outer casing of the pyrometer before reaching the inner expanding metal. The lead and zinc suspended in the base of the pipe were entirely melted, and the antimony melted off at the corners, the body remaining intact, indicating a temperature at times above the melting point of antimony (806° Fahr.), but not lasting long enough to effect fusion. At night, some red flame showed at the top of the smoke pipe at intervals, but none was visible during daylight.

It was found from the half-hourly observations of the thermometers in the feed pipes, before and after leaving the heater, that the feed water was raised in temperature 98.85 degrees, going into the drum at an average temperature of 157.42 degrees.

Tables I and II give the log of the barrel calorimeter tests, and the average quality of the steam calculated therefrom is $Q = .94308$.

Tables III and IV give the corresponding evaporative results.

Tables V and VI give the evaporative results corresponding to the dryness of steam as determined from the Carpenter formula.

Tables VII and VIII give the complete log of the test. The temperature of the steam at boiler (in main steam pipe) was taken from the upper thermometer of the throttling calorimeter, and that "at calorimeter," after passing through the $\frac{1}{16}$-inch orifice of the calorimeter to atmospheric pressure. The average of the latter temperatures is 277.4 degrees, and by Carpenter's formula,

$$Q = \frac{y - q + 0.48\,(t' - t)}{v},$$

in which

$y =$ total heat of steam at atmospheric pressure,

$q =$ heat of water at boiler pressure,

$t' =$ calorimeter temperature,

$t = 212$,

$v =$ latent heat at boiler pressure,

the value of Q is .980781, or the moisture is 1.9219 per cent., and the results in Tables V and VI have been calculated for this value of Q.

A calibration of the Barrus calorimeter was made on the day following the test with the fires in the boiler nearly dead and the furnace doors open, no steam leaving the boiler except through the calorimeter. The steam pressure was 175.2 pounds absolute, its temperature 366 degrees, and the temperature by the calorimeter thermometer, 284.5 degrees. As the steam flowing through must have been dry saturated, a temperature of say 285 degrees must be a standard for dry saturated steam under the above pressure; and as the lowest recorded temperature of this calorimeter during the test was 268 degrees, the greatest fall in temperature was 17 degrees. As the latent heat of steam at 366 degrees is 855.5, and the specific heat of superheated steam is 0.48, there would be required for 1 per cent. of moisture a fall of $\frac{8.555}{0.48} = 17.8$ degrees. As the fall was 17 degrees, the percentage of moisture is $\frac{17}{17.8} = 0.9555$, which would give $Q = .990445$.

But as the average difference of temperature for the whole test was only $285 - 277.4 = 7.6$ degrees, the average moisture in the steam was only 0.427 per cent. In other words, it was less than one-half of one per cent., and the quality of the steam was $Q = .99573$.

As the Carpenter and Barrus formulæ agree very closely, it seems quite certain that the steam delivered by the boiler during the test contained an average of less than one per cent. of moisture. During the whole test the water level was very steady, and when the safety valve opened suddenly, the water rose slowly an inch or two, and when it closed, which it did suddenly, the level dropped from two to three inches. The stop valve was opened and shut during eight to ten minutes, and the water rose and fell about the same as when the safety valve opened and shut. No serious disturbance was shown in the glass and no difficulty was experienced in manipulating the boiler at any time during the test; the feed gave no trouble, the water level remaining steady and easily regulated.

The force of the steam jet, blower and feed pump was varied from time to time as was deemed necessary by the attendants, but everything ran evenly except at the time of charging the furnace, and then very little change was necessary.

The sides of the boiler as high as the furnace water boxes were cool, about 100 degrees, while above that, the temperature was much higher, about 150 degrees; and the spaces about the boiler, except in front, were about 90 degrees. The fire room thermometer was hung about 4 feet from the inner front corner of the boiler, out of drafts, but was at once affected when the furnace doors were opened.

After the test was completed the fires were hauled and the water blown out. Two workmen with two helpers then split both ends of a lower tube, drew it out, put in a new one, expanded it, and replaced the caps ready for water in 22½ minutes. The internal surface of the tube was quite clean, but there was considerable soot baked on the outside, more of it near the ends than the center.

There was considerable soot on the tubes, as no cleaning or sweeping had been done during the test, and the fire was cleaned only once during the 24 hours. After the test, 236 pounds of soot were removed by a steam jet.

No leaks were discovered in the tubes or other parts of the boiler, nor any signs of wear except the furnace door linings, which were considerably warped from the intense heat, some flame at times escaping around the edges of the door.

The feed heater gave no trouble and operated very satisfactorily.

An examination of the air pressure columns in the tables shows that, at times, the pipe connected with the furnace gauge must have been choked, so that the reading of the gauge is not to be relied upon.

The boiler which has been described is one of the first of the marine type designed by the Babcock and Wilcox Company, and since it was built, important modifications have been made in the general type, which modifications will be apparent from an examination of Fig. 2, which shows the boiler which has been constructed for the Plant steamer, building by the Newport News Shipbuilding and Dry Dock Company.

A marked reduction in the height of the boiler has been

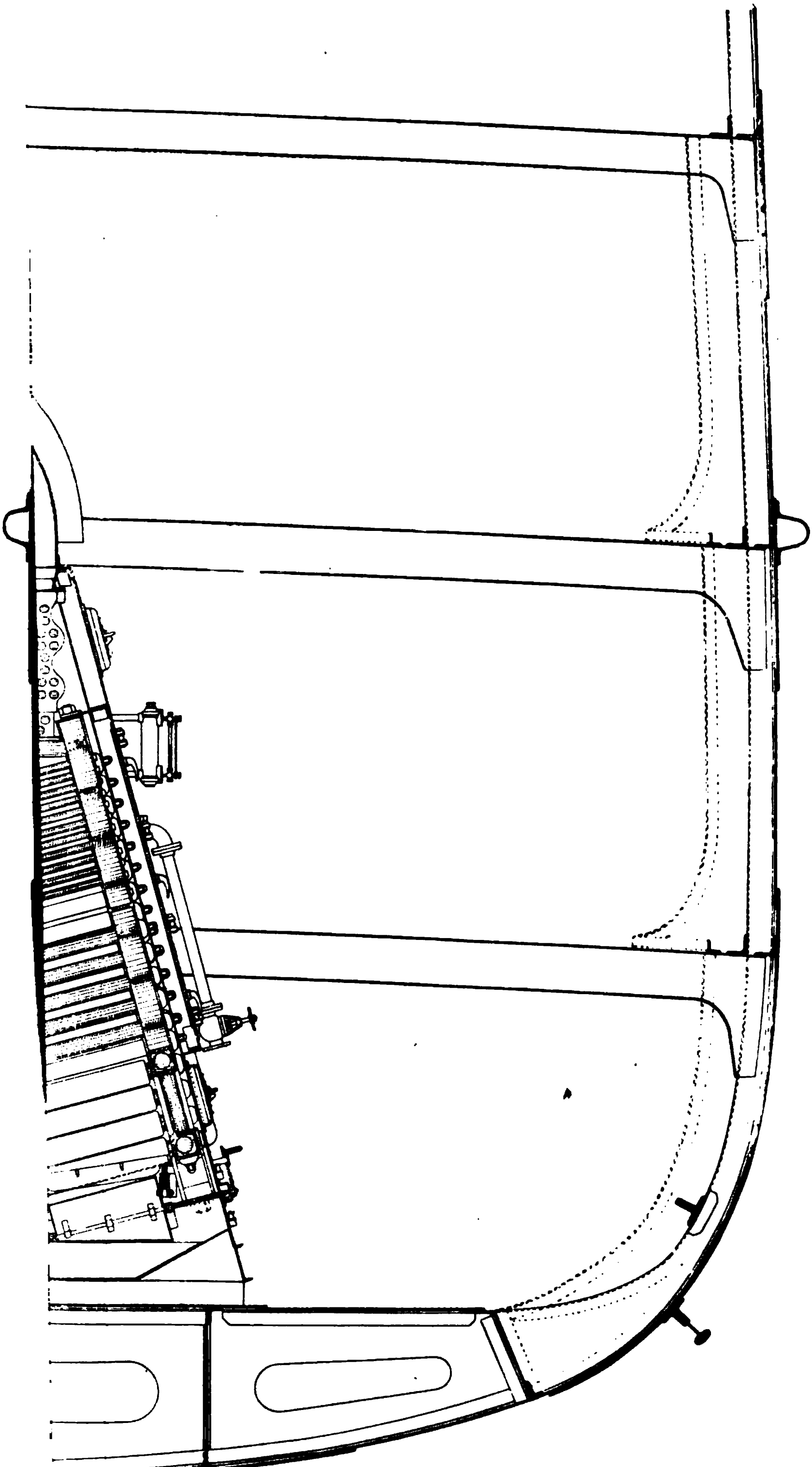
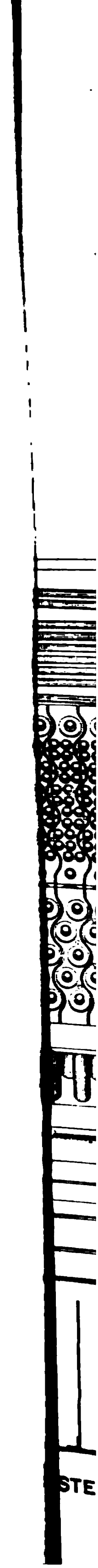


FIG. 2.



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affected by arranging the tubes in clusters of four instead of three in the upper headers. A change in the method of supporting the front sections has also been made. In the boiler tested, the weight was taken by an I-beam just over the furnace door, which not only required protection from the fire, but tended to make the boiler too rigid; this has been changed in the new design, where the sections are supported by nipples expanded into the cross box, as shown, which gives greater flexibility.

The tubes forming the water sides of the boiler and the headers at each end of these tubes are extended clear down to the bottom and fastened to the keelson, making four corner columns as a solid support. On the top of the two front columns is placed a forged steel cross box connected with all the headers, this cross box being in turn connected to the drum by circulating tubes at the top. From the cross box forming the beam, thus supported on its ends, are suspended all the sections by means of expanded nipples, one end being expanded into the cross box and the other into the top of the header.

In the boiler tested, there was no provision for cleaning off the outside surface of the tubes while running. In the new boiler, however, thimbles are screwed into the headers so that a steam jet may be used.

The hand hole bolts have a ball head, so that undue strain may not be brought on one corner of the plate, as is sometimes the case with square headed bolts. The body of each bolt is necked down below the diameter of the thread to insure that the strain put upon the bolt is distributed over a greater length of metal than in the ordinary bolt, where the thread is simply cut down into the metal.

One of the most important modifications is the forged butt strap, into which the connecting nipples between the back headers and the drum are secured. By the use of this form of strap, the bent nipples of the former design are avoided. The straps are forged with a series of pockets, each of sufficient area to take the seating of a single tube connected to a single section. The metal between the pockets is depressed in such shape as to take the bursting strain of the shell on the metal, making a very stiff joint.

TABLE I.

LOG OF CALORIMETRIC TESTS, APRIL 22, 1896.

No. of test.	Time.		Average pressure of steam in lbs. absol.	Weights.					Temperatures.		Q.	Temp. of steam by thermometer.
	At beginning.	At end.	P.	Calorimeter. b.	W + b.	W.	W + b + w.	w.	t'.	t.		
1	12·45	12·50	149.6	87	398	311	409	11	100.2	59.1	1.04975	353.
2	1·10	1·18	162.6	87	451	364	468.375	17.75	111.5	59	.96225	363.
3	1·25	1·29	175.6	87	450.5	363.5	468	18.5	111	59	.86733	355.
4	2·30	2·35	178.6	87	456.75	369.75	473	17.25	108	59.5	.91203	360.
5	3·15	3·19	178.6	87	450.5	363.5	467.5	17	111	59	.97072	362.
6	4·10	4·13	176.6	87	455	368	473	18	109.5	58.3	.89431	361.
7	5·08	5·11	176.6	87	450	363	467.5	17.5	109.5	57.6	.93690	357.
8	6·12	6·14	176.6	87	450.5	363.5	469.5	19	113.7	57.8	.92557	347.
9	7·50	7·54	167.6	87	452	365	470	18	110.3	58	.94069	358.
10	9·59	10·03	173.6	87	452.5	365.5	471.25	18.75	112.1	56.7	.96472	364.
11	10·43	10·47	172.6	87	454.5	367.5	474	19.5	111.5	57.2	.89790	355.
12	11·04	11·09	172.6	87	452	365	470.5	18.5	110.9	56.6	.95349	357.
	Mean values of Q and temperature										.93963	357.7

Percentage of moisture in the steam, 100 (1—Q), 6.037.

Fires were started with wood (388 pounds = 155 pounds of coal) and coal at 12·06, and the blower engine started at 12·11, the water in the glass gauge standing at a height of 5 inches. At 1·30 the steam jet was started in smoke pipe, and at 4·53 the force of the jet and fan blast were increased.

At commencement of the test the sky was overcast, with wind from the southeast. Rain fell at 1·30 and continued until 8·30, when it cleared with wind from the west.

Coal.—Pocahontas, damp and containing a large percentage of fine coal. Smoke showed from smoke pipe on firing.

TABLE II.

LOG OF CALORIMETRIC TESTS, APRIL 23, 1896.

No. of test.	Time.		Average pressure of steam in lbs. absol.	Weights.					Temperatures.		Q.	Temp. of steam by thermometer.
	At beginning.	At end.	P.	Calorimeter. b.	W + b.	W.	W + b + w.	w.	t'	t.		
1	12·46	12·51	175.6	87	450.5	363.5	469	18.5	112.2	56.8	.94570	364
2	2·22	2·25	171.6	87	457	370	475.25	18.25	111.9	56.3	1.01997	362
3	3·23	3·27	172.6	87	452.5	365.5	471.5	19	110.5	56.7	.90838	363
4	4·20	4·24	171.6	87	453	366	471.25	18.25	111.6	57	.98186	363
5	5·22	5·25	172.6	87	455	368	474	19	110.3	56.9	.90927	348
6	6·05	6·08	164.6	87	450	363	468.75	18.75	110.9	56.6	.93787	363
7	7·05	7·08	169.6	87	451.5	364.5	469.75	18.25	110.3	56.6	.91856	361
8	8·09	8·12	171.6	87	457	370	476	19	111.4	56.4	.95353	356
9	10·04	10·07	173.6	87	452.75	365.75	471.25	18.5	110.3	55.7	.95732	364
10	11·35	11·38	172.6	87	452.75	365.75	472.25	19.5	111.2	55.5	.92221	363
11	11·44	11·48	175.6	87	457	370	475	18.25	111.1	57	.97128	363
12	12·02	12·05	168.6	87	450.25	363.25	470	19.75	112	54.8	.93255	363
	Mean values of Q and temperature										.94654	361

Percentage of moisture in the steam, 100 (1—Q), 5.346.

Mean of 24 tests : Q .... .94308
Percentage of moisture 5.692
Observed temperatures of steam.... 359.4

The total refuse from the fuel consisted of 236 pounds of soot, 457 of clinker and 2,163 of ashes, making a total of 2,856 pounds.

Fires were cleaned at 5·10 A. M.

At 10·06, the stop valves were opened wide to observe the effect on the water level.

TABLE III.

RECAPITULATION OF THE RESULTS OF THE EVAPORATIVE AND CALORIMETRIC TESTS, APRIL 22 AND 23, 1896.

NOTE.—All weights are given in pounds and all temperatures in degrees Fahrenheit.

Total Quantities.

$Q = .94308$.

Duration of test, in hours	24
Fuel consumed, Pocahontas, dry, (moisture 12 per cent)	40,811
Refuse from fuel, in dry ashes, dust and clinkers	2,856
Combustible consumed	37,955
Water fed to boiler, by tank measurement, W_1	285,936
Per cent. of the fuel in dry refuse, etc	6.998

Average Quantities.

Temperature of feed water, t_1	58.5
Temperature of steam, by thermometer	362.04
Temperature of uptake	833.33
Temperature of atmosphere	58.08
Temperature of fire room	99.23
Barometer, in inches of mercury	29.939
Pressure of steam at boiler, in pounds per square inch above a perfect vacuum, 14.7 + pressure by gauge in pounds, p	171.01
Air pressure, in inches of water, at ash pit	.8893
Air pressure, in inches of water, at base of smoke pipe	.5410
Air pressure, in inches of water, in furnace	.1688
Revolutions of blowing engines, per minute	452.93

Rates of Combustion.

	Pounds of fuel.	*Pounds of combustible.*
Amount consumed per hour	1,700 4	1,581.45
Amount consumed per hour per square foot of grate surface	44.166	41.077
Amount consumed per hour per square foot of heating surface (exterior)	1.096	1.019

Vaporization in Pounds of Water.

	Per pound of fuel.	*Per pound of combustible.*
Apparent evaporation, by tank measurement, from a temperature t_1 and under a pressure p	7.006	7.533
Equivalent apparent evaporation from and at 212 degrees and under atmospheric pressure	8.472	9.109
Actual evaporation, into steam of quality Q, from a temperature t_1 and under a pressure p	6 607	7.105
Equivalent actual evaporation from and at 212 degrees and under atmospheric pressure	7 985	8.590

	Per pound of fuel.	*Per pound of combustible.*
Potential evaporation, or evaporation had all the heat obtained from fuel been utilized in converting the water in boiler into dry saturated steam from a temperature t_1 and under a pressure p.	6.716	7.121
Equivalent potential evaporation from and at 212 degrees and under atmospheric pressure.	8.120	8.731

TABLE IV.

From the foregoing tables the following data are obtained, from which the computations for the potential evaporation are made:

Q	.94308
Average steam pressure, absolute, p	171.01
Average temperature of the feed water, t_1	58.5
(a) Number of pounds of water vaporized, $W_1 \times Q$	269,661.11
(b) Number of pounds of water carried over with the steam, W_1 $(1-Q)$	16,274.89
Total heat of steam at pressure p	1,194.4
Total heat of water at temperature t_1	26 62
(c) Units of heat required to vaporize one pound of water from a temperature t_1 and under a pressure p	1,167.78
(c^1) Units of heat required to raise the temperature of one pound of water from t_1 to the temperature due to the pressure p	314.38
(d) Units of heat required to vaporize one pound of water from and at a temperature of 212° and under atmospheric pressure.	965.8
Total heat required to vaporize the water, $a \times c$	314,904,726
Total heat required to raise the temperature of the water, $b \times c^1$	5,164,995
(e) Total heat obtained from the fuel, as measured by the steam discharged	320,069,721
(f) Units of heat obtained per pound of fuel	7,842.72
(g) Units of heat obtained per pound of combustible	8.432.87
$\frac{f}{c}$ Potential evaporation per pound of fuel, from a temperature t_1 and under a pressure p	6.716
$\frac{g}{c}$ Potential evaporation per pound of combustible, from a temperature t_1 and under a pressure p	7.221
$\frac{f}{d}$ Equivalent potential evaporation per pound of fuel from and at a temperature of 212° and under atmospheric pressure.	8.120
$\frac{g}{d}$ Equivalent potential evaporation per pound of combustible from and at a temperature of 212° and under atmospheric pressure	8.731

TABLE V.

RECAPITULATION OF THE RESULTS OF THE EVAPORATIVE AND CALORIMETRIC TESTS APRIL 22 AND 23, 1895.

NOTE.—All weights are given in pounds and all temperatures in degrees Fahrenheit.

TOTAL QUANTITIES.

$Q = .980781$.

Duration of test, in hours	24
Fuel consumed, Pocahontas, dry, (moisture 12 per cent)	40,811
Refuse from fuel, in dry ashes, dust and clinkers	2,856
Combustible consumed	37,955
Water fed to boiler, by tank measurement, W_1	285,936
Per cent. of the fuel in dry refuse, etc	6.998

AVERAGE QUANTITIES.

Temperature of feed water, t_1	58.5
Temperature of steam, by thermometer	362.04
Temperature of uptake	833.33
Temperature of atmosphere	58.08
Temperature of fire-room	99.23
Barometer, in inches of mercury	29.939
Pressure of steam at boiler, in pounds, per square inch above a perfect vacuum, 14.7 + pressure by gauge in pounds, p	171.01
Air pressure, in inches of water, at ash pit	.8893
Air pressure, in inches of water, at base of smoke pipe	.5410
Air pressure, in inches of water, in furnace	.1688
Revolutions of blowing engines, per minute	452.93

RATES OF COMBUSTION.

	Pounds of fuel.	*Pounds of combustible.*
Amount consumed per hour	1,700.4	1,581.45
Amount consumed per hour per square foot of grate surface	44.166	41.077
Amount consumed per hour per square foot of heating surface (exterior)	1.096	1.019

VAPORIZATION IN POUNDS OF WATER.

	Per pound of fuel.	*Per pound of combustible.*
Apparent evaporation, by tank measurement, from a temperature t_1 and under a pressure p	7.006	7.533
Equivalent apparent evaporation from and at 212 degrees and under atmospheric pressure	8.472	9.109
Actual evaporation, into steam of quality Q, from a temperature t_1 and under a pressure p	6.872	7.389
Equivalent actual evaporation from and at 212 degrees and under atmospheric pressure	8.309	8.934

	Per pound of fuel.	Per pound of combustible.
Potential evaporation, or evaporation had all the heat obtained from fuel been utilized in converting the water in boiler into dry saturated steam from a temperature t_1 and under a pressure p	6.908	7 428
Equivalent potential evaporation from and at 212 degrees and under atmospheric pressure	8.353	8.981

TABLE VI.

From the foregoing tables the following data are obtained, from which the computations for the potential evaporation are made:

$Q = .980781$.

Average steam pressure, absolute, p	171.01
Average temperature of the feed water, t_1	58.5
(a) Number of pounds of water vaporized, $W_1 \times Q$	280,441.36
(b) Number of pounds of water carried over with the steam, $W_1 (1 - Q)$	5,494.64
Total heat of steam at pressure p	1,194.4
Total heat of water at temperature t_1	26.62
(c) Units of heat required to vaporize one pound of water from a temperature t_1 and under a pressure p	1,167.78
(c^1) Units of heat required to raise the temperature of one pound of water from t_1 to the temperature due to the pressure p	314.38
(d) Units of heat required to vaporize one pound of water from and at a temperatue of 212 degrees and under atmospheric pressure	965.8
Total heat required to vaporize the water, $a \times c$	327,493,834
Total heat required to raise the temperature of the water, $b \times c^1$	1,727,405
(e) Total heat obtained from the fuel, as measured by the steam discharged	329,221,239
(f) Units of heat obtained per pound of fuel	8,067
(g) Units of heat obtained per pound of combustible	8,674
$\frac{f}{c}$ Potential evaporation per pound of fuel, from a temperature t_1 and under a pressure p	6.908
$\frac{g}{c}$ Potential evaporation per pound of combustible, from a temperature t_1 and under a pressure p	7.428
$\frac{f}{d}$ Equivalent potential evaporation per pound of fuel, from and at a temperature of 212 degrees and under atmospheric pressure	8.353
$\frac{g}{d}$ Equivalent potential evaporation per pound of combustible from and at a temperature of 212 degrees and under atmospheric pressure	8.981

TABLE VII.

LOG OF EVAPORATIVE TEST, APRIL 22, 1895.

Reference number.	Time.	Steam pressure by gauge at boilers.	Barometer, in inches of mercury.	Pounds of fuel consumed.	Pounds of water fed to boilers.	Temperatures. Feed water, t_1.	Temperatures. Steam by thermometer. At boiler.	Temperatures. Steam by thermometer. At calorimeter.*	Temperatures. In uptake.	Temperatures. Atmosphere.	Temperatures. Fire room.
1	12·36	135.4	29.97	1,400	....	62	359	279	640	66	100
2	1·06	133.4	.96	1,200	9,612	62	363	281	500	67	100
3	1·36	159.4	.96	1,000	....	63	360	284	500	68	106
4	2·06	160.4	.95	800	12,144	63	363	284	500	65	103
5	2·36	162.4	.95	800	....	62	359	286	650	64	103
6	3·06	162.4	.95	800	12,442	63	358	286	700	63	103
7	3·36	161.4	.95	800	....	63	360	285	780	62	103
8	4·06	160.4	.94	800	12,786	63	363	285	650	61	98
9	4·36	149.4	.94	800	....	62.5	362	284	840	61	96
10	5·06	160.4	.94	800	12,132	62.5	363	286	1,020	59	94
11	5·36	160.4	.94	1,000	....	61.5	362	284	800	60	97
12	6·06	160.4	.94	1,000	13,296	60.5	363	285	1,200	60	100
13	6·36	155.4	.94	1,200	....	61	363	283	1,100	61	103
14	7·06	157.4	.94	1,200	13,906	60	363	285	1,020	60	101
15	7·36	148.4	.94	1,200	....	59.5	347	284	1,200	59	100
16	8·06	161.4	.94	1,000	13,740	59	365	280	700	58	98
17	8·36	161.4	.94	800	....	59	381	289	960	58	95
18	9·06	155.4	.96	1,000	12,420	58	360	276	800	56	89
19	9·36	160.4	.96	1,200	....	57.5	361	273	760	56	95
20	10·06	155.4	.95	1,200	13.314	57	363	274	720	54	100
21	10·36	160.4	.95	1,200	....	57	363	274	900	54	96
22	11·06	157.4	.95	1,000	12,572	57	362	272	800	55	93
23	11·36	153.4	.97	1,000	....	57	359	274	1,150	53	93
24	12·06	157.4	.96	1,000	12,224	56	363	276	1,100	53	96

Reference number.	Air pressure in inches of water. Ash-pit.	Air pressure in inches of water. Furnace.	Air pressure in inches of water. Base of smoke pipe.	Revolutions of blowing engines.
1	.80	.25	.34	368*a*.
2	.87	.05	.41	535
3	.79	.10	.44	502*b*.
4	.67	.10	.50	442
5	.72	.15	.41	424
6	.65	.15	.52	368
7	.83	.15	.52	397
8	1.05	.15	.56	512
9	.78	.20	.51	490*c*.
10	.92	.15	.64	470
11	.79	.10	.63	475
12	1.17	.10	.68	500
13	1.20	.10	.68	510
14	.72	.10	.65	484
15	.50	.15	.63	385
16	1.25	.15	.60	518
17	.50	.15	.62	502
18	1.25	.15	.86	520
19	.79	.15	.73	462
20	1.00	.15	.70	486
21	1.10	.15	.70	472
22	.77	.20	.72	408
23	.97	.20	.62	424
24	.83	.15	.67	380

Remarks.

a Started fires with wood and coal at 12·06, and blower engine at 12·11. Water level 5 inches in glass.

b Started steam jet in smoke pipe at 1·30.

c Increased jet and blast at 4·53.

* Barrus' throttling.

TABLE VIII.

LOG OF EVAPORATIVE TEST, APRIL 23, 1895.

Reference number.	Time.	Steam pressure by gauge at boilers.	Barometer, in inches of mercury.	Pounds of fuel consumed.	Pounds of water fed to boilers.	Temperatures.						Air pressure in inches of water.			Revolutions of blowing engines.	Remarks.
						Feed-water, t_1.	Steam by thermometer. At boilers.	Steam by thermometer. At calorimeter.*	In uptake.	Atmosphere.	Fire room.	Ash pit.	Furnace.	Base of smoke pipe.		
1	12·36	161.4	29 96	1,000	....	56	363	273	1,000	53	90	1.17	.15	.69	483	
2	1·06	158.4	.96	1,000	12,491	56	356	277	960	50	90	.63	.15	.69	432	
3	1·36	150.4	.95	1,000	....	56	362	274	750	50	86	.78	.15	.46	372	
4	2·06	154.4	.93	1,000	11,585	56	361	276	900	51	87	.56	.15	.50	350	
5	2·36	158 4	.93	1,000	....	56.5	365	272	1,020	50	94	1 00	.20	.50	450	
6	3 06	158.4	.93	800	11,762	56	360	277	1,000	49	101	1.11	.15	.40	405	
7	3·36	757.4	.93	1,000	....	56.5	356	276	580	49	107	1.06	.10	.41	539	
8	4·06	159.4	.93	800	11,794	56	362	273	720	49	102	1.24	.10	.41	495	
9	4·36	153.4	.93	800	....	55.5	363	271	800	49	95	1.25	.10	.40	545	
10	5·06	161.4	.93	800	11,930	56	363	271	700	49	90	1 04	.15	.50	512	
11	5·36	156 4	.93	800	....	55.5	362	268	860	51	85	.49	.15	.29	385	
12	6·06	149.4	.93	800	10,085	55.5	359	272	800	49	87	.78	.10	.37	380	
13	6·36	159.4	.92	1,000	....	55	361	272	750	50	92	.72	.10	.43	440	
14	7·06	155.4	.92	1,000	10,517	55	364	272	600	52	93	.97	.05	.43	444	
15	7 36	152.4	.92	1,000	....	55.5	363	273	600	55	100	.91	.05	.45	453	
16	8·06	158.4	.93	1,000	11,649	56	364	275	1,000	58	105	.80	1.00	.43	475	
17	8·36	155.4	.93	1,200	....	57	364	272	850	63	112	92	.95	.43	468	
18	9·06	160.4	.94	1,200	11,847	57	365	275	900	63	120	1.07	.10	.43	503	
19	9·36	155.4	.94	1.200	....	58	364	274	900	64	119	.72	.15	.60	397	
20	10·06	158.4	94	1,000	10,501	59	365	274	680	68	109	.90	.15	.56	443	
21	10 36	158.4	.94	800	....	59	363	277	840	71	107	93	.10	.56	462	
22	11·06	159.4	.94	1,000	10,579	59	363	278	900	70	107	1.02	.10	.57	455	
23	11·36	157.4	.94	800	....	60	363	276	900	70	110	.90	.10	.56	445	
24	12·06	150.4	.93	155†	10,608	60	362	272	1,000	72	109	.80	.15	.56	434	

† Wood.

* Throttling.

TORPEDO BOAT DESTROYERS.

By John Isaac Thornycroft, Esq., and Sydney Walker Barnaby, Esq.

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Until the year 1885 the British Navy possessed no vessels specially designed to destroy torpedo boats. In that year it was decided to build a number of vessels for this purpose of about the same size and speed as the torpedo boat, but having a greatly superior gun armament. Torpedo boats then carried, in addition to their torpedo tubes, one or two machine guns of the Nordenfelt or Hotchkiss pattern, firing steel shot between 1 inch and 1½ inches in diameter and between ½ pound and 1 pound in weight. The vessels which were to serve as catchers, Fig. 1, Plate 1, were to be armed with two 3-pounder quick-firing shell guns, and three two-barrelled Nordenfelt guns. They could fire thirty shots per minute ahead and 390 per minute on the broadside. The design provided for an alternative armament of torpedo tubes, and when these were carried the two 3-pounder guns would be dismounted, leaving only the three Nordenfelts. Four such boats were built at Cowes, twenty-five at Poplar, and twenty-five at Chiswick. They were 125 feet long, of about 65 tons displacement, and had a guaranteed speed of 19 knots per hour. This speed was exceeded on the trials of many of them by between 1 and 2 knots. Before their completion the original intention of using them as catchers was abandoned, and they were fitted out as torpedo boats.

In 1886 a new class of catcher, represented by the *Rattlesnake*, Fig. 3, was built. These vessels were 200 feet long, 23 feet wide, of 550 tons displacement, with engines of 2,700 I.H.P., giving a speed of 19 knots. They were armed with one 4-inch gun and six 3-pounder quick-firing guns besides torpedo tubes. It was found necessary to increase the size of the next torpedo boat catchers, as they were then called—the name has since been changed to torpedo gun boat—and the displacement was increased to 735 tons. Between 1888 and 1890 a considerable number of these boats was built, commencing with the *Sharpshooter*. Their length is 230 feet, their beam 27 feet, and they have a draught of 8 feet 3 inches. The engines were intended to develop 4,500 I.H.P., and to give a speed of 21 knots per hour, but difficulties being experienced with the locomotive boilers, it was found impossible to obtain more than about 3,700 I.H.P. and the speed did not exceed 20 knots per hour. Even this power was not developed without difficulty, and in 1892, when eleven new vessels of the type were built, the displacement was increased to 810 tons, chiefly in order to provide more accommodation for machinery. All but one have locomotive boilers, which develop on an average 3,700 I.H.P., giving a speed of 19½ knots. The *Speedy*, Fig. 4, of the same class, but with Thornycroft water tube boilers, obtained an increase of 1,000 H.P. on trial; and the authors believe that in ordinary service, since the stokers have become accustomed to the boilers, no difficulty is found in developing 5,000 I.H.P. Her speed is 20½ knots per hour. In vessels of the *Halcyon* class, Fig. 5, now being built, the displacement is further increased to 1,070 tons, the speed being 19 knots per hour. They have no protection against shot except such as is afforded by coal bunkers surrounding and partly covering the machinery, but their steering gear is below water. Their armament consists of two 4.7 quick-firing guns and four 3-pounder guns, besides torpedo tubes.

This growth in size of the torpedo gun boat has been accompanied by greatly improved seaworthiness, and officers and men can live on board with tolerable comfort. It will be remembered that the *Gleaner* recently crossed the Bay of Biscay in a very severe gale and proved herself an excellent sea boat. But there has been no corresponding increase of speed in the torpedo gun boats, while the speed of the torpedo boat has advanced rapidly.

The first torpedo boat was built at Chiswick for the Norwegian Government in 1873, and its speed was 15 knots per hour. The next advances were made by boats built at Chiswick in 1874 and 1877, when speeds of 18.2 knots and 18.5 knots per hour were successively attained, the latter by the *Lightning*, the first British torpedo boat. In 1878, Messrs. Yarrow raised the record to 21.93 knots, in 1880 to 22.16 knots, and in 1885 to 25.1 knots per hour. In 1887, the *Ariete*, which was fitted with water tube boilers, was built at Chiswick, and she attained a speed of 26 knots per hour. In 1890, a Schichau boat is said to have reached 27.4 knots per hour, but under what conditions is not known.

There is obviously a great disparity between the speed of the modern torpedo boat and that of the torpedo gun boat. It is true that the advantage possessed by the torpedo boat, although amounting to 6 or 7 knots per hour in smootn water, is considerably reduced in a rough sea, and there is no doubt that in certain conditions of weather the large gun boats of the *Speedy* type will prove formidable foes to torpedo boats. But the want has been felt of vessels having a speed equal to that of the fastest torpedo boats in all weathers, and it has been supplied by the introduction of a new type known as Torpedo Boat Destroyers.

These are virtually enlarged torpedo boats, the increase in size being determined by the conditions laid down by the Admiralty, which were that the speed was to be at least 27 knots, and that a powerful gun armament was to be carried. The result is represented by vessels of the *Daring* type, Fig. 2, Plate 1, of which forty-two are under construction. The *Daring* is 185 feet long, and has a beam of 19 feet with an extreme draught of 7 feet. The total weight of the vessel is approximately equal to the weight of the machinery of the *Halcyon* class, but her indicated horsepower is 31 per cent. geater than that of the *Halcyon*. The armament consists of one 12-pounder quick-firing gun mounted on the conning tower, and five 6-pounder quick-firing guns, four of which are on the broadside and one on the center line aft. Figs. 6, Plate 1, show a design in which five guns can fire in the line of the keel ahead. There would be two other guns on the broadside which are not shown. A 12-pounder is mounted on the conning tower, the smaller guns being 1-pounder Maxim guns with automatic belt feed. It is possible that this may be too small a gun to stop a torpedo boat, but upon this point the authors offer no opinion, as it could only be decided by trial. It is said to be capable of penetrating 1½ inches of iron at 600 yards, and can fire 200 rounds per minute if required. This rapidity of fire would be of great service in keeping down the fire of the enemy. It may be objected that bow guns are unfavorably placed on account of the spray which comes on board even in moderate weather when the boat is driven at high speed against a head wind. The authors believe that a horizontal canvas screen arranged as shown in Figs. 6 would protect the men at the guns from the spray, and might prevent its coming on board altogether. The screen would be rigged out on hinged stanchions at the level of the deck, and its height above the water would enable it to be retained in position in any but very rough weather, when it could be readily stowed by turning back the stanchions supporting it.

All of the Chiswick vessels have now passed their official trials with the following results in regard to speed on three hours' trial:—

	Knots per Hour.
Boxer,	29.175
Ardent,	27.973
Bruizer,	27.970
Decoy,	27.763
Daring,	27.706

Fig. 7 is a progressive speed curve of the *Daring* at about her designed displacement. Changes in the machinery after she was laid down, in order to obtain greater power and a more elaborate fitting out of the vessel required by the Admiralty than was contemplated by the authors when the design was prepared, caused her to be somewhat more deeply immersed when officially tried. Three runs were to have been made at each speed, but after the first and second of the last series had been completed, giving a speed of 28.2 knots and 28.6 knots per hour respectively, the air-pressure in the stoke holds was increased and the steam was raised to the full pressure that the safety valves would hold, so that these were blowing off during the whole of the final run. The engines responded to the higher pressure with an increase of ten revolutions per minute, and in this run, made against the direction of the tide, but in practically slack water, a speed of 29.268 knots per hour was attained, the engines developing 4,735 I.H.P.

On the 8th January, 1895, the *Boxer* with her full load on board attained a speed of 29.314 knots as an average of six runs on the measured mile. As the authors believe this to be the highest average speed hitherto attained by any vessel, it may be of interest to give particulars of these runs.

Steam-pressure.	Vacuum.	Mean revolutions per minute.	Time.	Speed.	First mean.	Second mean.
Lbs. per sq. in.	*Inches.*		*Mins. Secs*	*Knots*	*Knots.*	*Knots.*
210	26¾	409	2 11·4	27.397	28.926	
210	26¾	414	1 58·2	30.456	29.312	29.119
210	27	418	2 7·8	28.169	29.442	29.377
210	26½	418	1 57·2	30.716	29.420	29.431
210	26½	416	2 8·0	28.125	29.239	29.329
210	26½	413	1 58.6	30.354		
						29.314

The mean air pressure in the stoke holds was 2½ inches. During the official trial on the 25th January the mean speed of a three hours' run was 29.175 knots per hour.

The propulsive coefficient is between 0.60 and 0.63, a higher value than is generally obtained in large ships. One explanation which has been given of the apparently superior performance of small vessels, is that the indicator does not give a correct measure of the power developed by very fast running engines, but underlogs it. As the size of the engines is increased and the rate of turning diminished, an allowance has to be made for reduced propulsive efficiency. If the indicator could always be depended upon, the Admiralty coefficient $\frac{V^3 D^{\frac{2}{3}}}{I.H.P.}$ should slightly increase in value in the case of similar vessels driven at corresponding speeds as the dimensions are increased. This is because the effect of surface friction is less on the larger vessel. But the smaller propulsive efficiency due to the more accurate measurement of the power may cause the larger vessel to give an apparently inferior performance.

The curve of Admiralty coefficients $\frac{V^3 D^{\frac{2}{3}}}{I.H.P.}$ is shown in Fig. 7. It is a maximum at a speed of 12 knots, and falls to its lowest value at about 24 knots per hour, the speed at which the greatest wave making occurs. Beyond 24 knots it rises gradually, and small increments of power give a considerable increase of speed above 27 or 28 knots per hour.

The wave profile at 28 knots per hour is shown in Fig. 8, Plate 1. It will be noticed that there is very little squatting by the stern. The large area of the load water plane at the after part of the vessel prevents any great change of trim at that place, and the immersion of the stern is actually less at full speed than when at rest, because the water leaves it perfectly cleanly at the abrupt corner formed by the buttock lines.

Figs. 9 show the stability curve with all weights on board and 30 tons of coal in the bunkers. The metacentric height in this condition is 2.48 feet. The righting moment is a maximum at 46°, and vanishes at 95°. With the bunkers empty the metacentric height is 2.58 feet, and stability vanishes at 96°. With bunkers full the metacentric height is 2.21 feet, and the vanishing angle 90°. There is a noticeable change in the conditions of stability at full speed. The vessel appears to be more tender; and although this impression is perhaps chiefly due to the greater heeling effect of small movements of the helm at high speed, the stability is actually reduced as compared with the normal still water condition. The change in the water line, which falls in the wide part of the vessel amidships and rises at the finer parts of the bow and stern, lowers the metacenter. Vessels of small initial stability and of a form which, when driven at high speed, causes the water to pile up at the bow and stern and fall considerably amidships, have been known to become unstable when so driven. The change in metacentric height due to the wave profile in Fig. 8, Plate 1, is only 2 inches, assuming that the hydrostatic pressure at each immersed section remains unchanged by the wave motion. As the effect of the wave motion must be to increase to some extent the pressure on those sections where the immersion is reduced, and to reduce the pressure on those sections where the water is raised, the fall in metacentric height cannot be greater than that stated.

In Fig. 10, Plate 1, W W is the curve of weights. Upon a base line proportional to the length of the vessel, ordinates are set up at intervals of 5½ feet, representing the weight of a section of the vessel 5½ feet long, with all its contents. A curve drawn through those ordinates encloses an area proportional to the total weight or displacement of the vessel. B B is the curve of buoyancy, ordinates at any point representing the immersed area of the corresponding section. The areas of the curves of buoyancy and weight are equal. When the curves cut one another the sections are said to be waterborne. It will be seen that for 20 feet from the bow the weight exceeds the buoyancy. The conning tower with the 12-pounder gun upon it, the three boilers and the engines cause the curve of weight to show above the curve of buoyancy. The pinnacle occurring in the curve at the after end of the engine room is caused by the accumulation in the same section of the weights of four cylinders, tanks and hot wells. The hump at the stern represents the combined weight of rudders, screws, shaft brackets and steering engine. From the curves W W and B B the curve of loads L L is constructed, and this curve passes below or above the line according as the weight exceeds or is in defect of the buoyancy. It, of course, crosses the line at waterborne sections. S S and M M, the curves of shearing forces and bending moments in still water, are deduced from the curve L L. The maximum shearing forces occur at waterborne sections and the maximum bending moments where the curve of shearing forces crosses the line. The maximum bending moment in still water is a hogging moment of 236 foot tons. The condition of loading is with all sea-going weights on board and 30 tons of coal in the bunkers. In Fig. 11 the

Daring is shown floating on the crest, and in Fig. 12 in the hollow, of a wave of her own length and 9¾ feet high. In the former case a hogging moment is produced equal to $\frac{1}{27.8} \times W \times L$, and in the latter a sagging moment equal to $\frac{1}{20.3} \times W \times L$, W being the weight of the vessel in tons and L its length in feet. At the section where the greatest bending moment occurs the stress upon the material amounts to 6.4 tons per square inch, so that there is an ample margin of strength even under such trying conditions as those illustrated. Figs. 13, Plate 1, show the two balanced side rudders. Their combined area is $\frac{1}{27.7}$ of the area of the immersed longitudinal vertical section of the vessel. The screws revolve within 3 inches of the inner faces of the rudders, which are curved to a radius somewhat greater than that of the propellers. The rudder heads lie in the same athwart ship plane as the screws about which the rudders swivel. When the helm is put over, the water from the screws impinges upon them both when going ahead and astern, and in the latter case the vessel is thoroughly under control. When the helm is amidships, portions only of the rudder surfaces are in the screw race, and the friction upon them is less than it would be if the same amount of total surface were disposed in the form of a single rudder at the stern. It has been found by experiment that they offer the least resistance to the progress of the vessel when they are inclined to one another at an angle of 7°, the after edges being brought together. As the water passing the inner surfaces is moving at a higher velocity than that passing the outer surfaces, the normal pressure upon the outside is greater than the pressure upon the inside. This normal pressure has a small component in a fore-and-aft direction, due to the inclination of the rudders, which assists to propel the vessel. The propelling power of the side rudders has been proved by testing the speed of the vessel with one of them removed. The speed has always proved to be unaffected, showing that the resistance of the second rudder, which is considerable, is compensated by the forward thrust of the water upon its external surface.

The steam steering gear is shown in the plan, Figs. 13. The rudder heads pass through stuffing boxes in the bottom of the vessel, and the weight is borne upon brackets secured to the deck. Toothed quadrants, attached to the lower parts of the rudder heads, are driven by worms actuated by gear fitted to a shaft from the steering engine. By placing one worm on the after side of the port rudder and the other on the forward side of the starboard rudder, nearly all the stress is taken off the engine seating. The quadrants are either thrust asunder or drawn together according as the helm is put to starboard or port, and the thrust, instead of tending to move the shaft endwise, only puts it into compression or tension. The valves of the steering engine are worked from the wheel forward by means of a shaft supported on roller bearings, which makes four turns to one of the steering wheel. Speeded up in this way, a shaft of very small diameter will transmit the necessary power. The times of turning circles were as follows:

	Min.	Sec.
Head to port,	1	27
Stern to port,	3	30
Head to starboard,	1	29
Stern to starboard,	3	30

The diameters of the circles were not measured, but were estimated by the Admiralty officers at three and a half lengths when turning ahead and five lengths when turning astern. The authors believe that the time of turning and the diameter of the circle ahead are unusually small for a vessel of such high speed and of 185 feet in length. The power of turning rapidly must be of considerable advantage to a destroyer when chasing a torpedo boat. The extreme helm angle is 35°. The vessel heels slightly inwards when turning at full speed, showing that the pressure upon the rudder is more than sufficient to counteract the centrifugal force tending to heel the vessel outwards. That the pressures upon the rudders are enormous at full speed may be judged from the size of the rudder heads, which are of solid steel 7 inches in diameter. The single rudders fitted to some of the destroyers have been carried away.

The shape of the stern at the water surface naturally suggests a fear that there would be slamming beneath it. Extended experience has, however, shown that there is no tendency to slam when under way. This is partly due to the action of the screws, and partly to the fact that the great width of the stern at the water surface renders its vertical movement very limited. This tendency of the stern to follow the water surface makes it possible to place the screws higher than would be prudent if the stern were of the usual form, and the draught of water is very small in the *Daring*. It is less than that of most torpedo boats, which cannot, therefore, escape pursuit by taking to shallow water.

To render torpedo boats and destroyers as nearly invisible as possible at sea, it has generally been assumed that a uniform tint is the best, and in the British Navy a dead black is preferred. If the coloring of birds which are difficult to distinguish on the sea or shore be examined, it will be found that their form is concealed by irregular patches of color. Although the background against which they show may admit of the outline of one part being visible, other parts will match with it and will not be seen. It is possible that improvements may be made in the direction of rendering these craft less visible than at present. The destroyers have been purposely made to resemble torpedo boats as closely as possible in order that their real character may not be immediately detected by their quarry. This can only be said to have been accomplished however in those which have no more than two funnels, as no disguise is possible when three or four funnels can be discerned.

The *Daring* has two sets of three-stage compound engines, each having four cylinders. The high pressure cylinder is 19 inches in diameter, and the intermediate and the two low pressure cylinders are 27 inches in diameter, with a stroke of 16 inches. At 389 revolutions, which was the mean obtained during the six runs on the official trial, the piston speed was 1,040 feet per minute. The engines are of a novel design, and each set is divided into two parts, the high and intermediate pressure cylinders bolted together forming one part, and the two low pressure cylinders similarly connected forming the other. It will be seen, Figs. 14 and 15, Plate 2, that the cylinders forming each pair are inclined in opposite directions from the vertical and partly overlap each other. The cranks in each pair are nearly opposite and have no bearing between them. By this means two adjacent cylinders have their reciprocating parts tending to balance one another so far as vertical movements are concerned. The two low pressure cylinders being of the same size, the balance between them is almost complete. As the cranks are not quite opposite, their weight and that of the connecting rods require a small counterbalance weight. In the forward pair of cylinders the reciprocating weights of the intermediate cylinder are in excess, and a counterbalance weight is also required. The forward and the after pairs of cranks are in effect at right angles to each other. Figs. 17, Plate 2, show an inertia diagram prepared by Mr. Mallock which gives the amounts and positions of the balance weights required. In diagrams I and II the curves marked 1 and 2 indicate force at the axis of the shaft at the cranks and eccentrics, those marked 3 the resultant force at the axis of the shaft at each pair of cranks and eccentrics, and those marked 4 the resultant couple due to the distance between the cranks. Small black circles show the positions of the cranks and the direction of the resultants when the cranks are in the positions indicated. The revolving counterweight for resultant force is marked R.W.F.; that for the resultant couple, R.W.C.; the bob-weight for resultant force, B.W.F.; and that for the resultant couple, B.W.C. The balance weights A and B and the bob-weights C and D are 570 pounds, 510 pounds, 215 pounds and 216 pounds in weight respectively. With regard to vibration in a fore-and-aft direction, there is a couple tending to rotate the shaft in a vertical longitudinal plane around a center between any two adjacent crank pins, but the cranks have no bearing between them, and are therefore so close together that the effect is slight. The angle between the adjacent cranks is so arranged that the pistons reach the opposite ends of the cylinders simultaneously, and the pressure upon the bearings is relieved throughout the stroke. The stress on the columns is in like manner reduced by this arrangement, and it will be seen that the columns are formed by simply prolonging the main bearing bolts to support the cylinder, Fig. 16. The inclination of the cylinders to each other introduces a horizontal disturbing force at right angles to the shaft. The descending piston of the high pressure cylinder, and the ascending piston of the intermediate cylinder, are moving in the same athwartship direction. Their effect is partly, but not entirely, neutralized by the movement of the slide valves, and, as the bob-weights described by Mr. Mallock are not fitted, the rotating weights are lighter than is necessary to neutralize completely the horizontal components of the inertia forces; and consequently a horizontal vibration of the vessel is observed at certain speeds. This disappears at full speed, and the vessel being stiff in this direction the effect is never more than slight. In Fig. 7 is given a curve of indicated thrust calculated from the results of the progressive trial of the *Daring*. The indicated thrust at zero speed, which is a measure of the initial friction of the engines, amounts to 1,750 pounds. The initial friction of the *Speedy's* engines deduced in the same way is about 2,800 pounds. Both engines were fitted with equal care, but those of the *Speedy* are of the usual three-crank type, and the authors believe that the friction of the engines of the *Daring* is less than the lowest that can be obtained with engines of the ordinary type. They attribute this to certain features in the design, and they believe that an examination of these features will show that there was justification for expecting an improvement in this respect. The friction of the crank pins, due to the direct pressure on the pistons, cannot be reduced to any considerable extent by any expedient that can be adopted, but a considerable portion of the total friction of the crank shaft is due to the distortion which takes place in certain portions of the shaft when twisting moment is transmitted through a crank. Two models (exhibited), Figs. 18 and 19, have been prepared to show the effect of this distortion upon the pressure on the bearings of the crank shaft. Figs. 18 represent a single-throw crank through which a twisting moment is transmitted, and it will be seen that the crank pin is twisted and the webs are bent.

The twisting of the crank pin has the effect of displacing the center line of parts of the shaft, and the bending of the two webs connecting the pin with the shaft causes a further displacement of the same part of the shaft in the same direction. If for the sake of simplicity it be first assumed that the bed plate is perfectly stiff, and that the bearings fit the shaft so as not to allow of any motion other than rotary, it will easily be seen that any turning moment acting on the shaft will tend to produce a pressure on the bearings equivalent to that moment divided by the length of the throw. As the action is repeated at every crank through which the turning moment is transmitted, each additional crank so placed as to be subject to distortion adds to the friction of the shaft. The assumption that the crank shaft is flexible while the bed plate is quite stiff is not correct, but the latter is probably in all cases stiffer than the shaft, and the pressure on the bearings is believed to be more than half of that which it would be if it were perfectly rigid. In the models the shafts have purposely been made with a great amount of elasticity in order to show better the effect described. One of the bearings is disconnected from the bed plate, and the motion imparted to it by turning the shaft is clearly seen. The direction of the motion depends upon the position of the cranks. If the bearing were quite free and the turning moment uniform, it would describe a circle about the true center line of the shaft during each revolution. Figs. 19 show a shaft in which two cranks are adjacent, and the throws equal and opposite with no bearing between them. In this case there is no appreciable tendency towards a displacement of the shaft. If the effect of the transmission of the turning moment of the high and intermediate pressure cylinders through the after pair of cranks be considered in detail, it will be seen that the bending of the web of the first crank, together with the twisting of the pin, tend to move a point in the center of the intermediate web from the true center line of the shaft; but the distortion of these parts in the second crank is equal in amount to that in the first, and therefore has the effect of preserving the shafting in a continuous straight line. All pressure upon the after bearings due to distortion of the crank by the forward engines is therefore avoided.

The cylinders are unjacketed. There are a piston valve on the high-pressure cylinder taking steam in the middle and flat valves on the other three cylinders. The exhaust takes place through the back of the flat valves, and the directness of the passage is found to have an important effect upon the vacuum obtained in the low pressure cylinders. The indicator cards show a much better vacuum than that usually found in the case of high speed torpedo boat engines fitted with either piston valves or with D slide valves. The condenser is of rolled brass, with brass tubes through which water is circulated by a centrifugal pump assisted by a natural flow due to the velocity of the vessel. At all but the highest speeds this natural flow is sufficient of itself to maintain a vacuum. The air pump is single acting and is driven by the main engines. A Weir pump in the engine room, drawing from a feed tank common to both engines, returns the condensed water to the boilers. Auxiliary feed pumps are fitted in the stokehold.

The boilers are three in number and of the Thornycroft water-tube type. The total tube surface is 8,892 square feet. The heating surface, which is obtained by deducting from the total surface such parts of tubes as are not exposed to heat, is 7,890 square feet. The grate surface is 189 square feet. The boilers, Figs. 20, Plate 2, are not quite the same as those of H.M.S. *Speedy*, but have been modified in order to have two furnaces in each and to obtain a greater amount of fire grate in the available space. Three of the new *Daring* boilers are doing the work of eight in the *Speedy*. 23.3 I.H.P. is developed per foot of grate and 1.79 feet of heating surface are required per I.H.P.* The tubes are of steel and are galvanized on the outside. The products of combustion leave the fire box through openings between the tubes at the bottom of the inner wall, pass among the tubes and escape through openings between them at the top into the central flue, through which they find their way to the up-take

* The power taken is not the maximum, but the mean I.H.P. developed during a three-hours' trial.

and funnel placed at the end of the boiler. A row of down-take tubes of large diameter connects the upper and lower vessels.

The water level is automatically maintained at a constant height by means of a float in the upper vessel which regulates the opening of a valve in the internal feed pipe. The float being within the boiler, none of its moving parts require to work through stuffing boxes. It can in this manner be made more sensitive to small changes of water level. When stuffing boxes are employed, no movement of the float can take place until the change in its buoyancy due to a rise or fall of water is sufficient to overcome the friction of the stuffing box. Means are provided for altering from the outside the amount by which the valve is opened for a given position of the float; so that the quantity of feed admitted at any given water level can be adjusted to suit the rate of evaporation taking place at the time. This arrangement is shown in Figs. 21 and 22. It has acted well, and its introduction has greatly improved the working of the boilers in groups. With a steady water level automatically maintained, the stokers are able to fire with greater regularity and more steam can be made. No leakage has at any time occurred with these boilers; and since the float gear was fitted and the feeding thereby rendered steady, no priming has been experienced. In Appendix I is given a report by Prof. D. S. Capper upon a series of tests made by him with a model of the boiler.

The total weight of the boilers with water and mountings complete including up-takes, but without funnels, is 48.5 tons. The indicated horse power per ton of boiler is 91. The total weight of machinery and water, including spare gear, auxiliary machinery, funnels and up-takes is 115 tons, which is equivalent to 58½ pounds per horse power indicated by the main engines.*

Some difficulty was at first experienced with the propellers. A series of experiments carried out by the Admiralty upon the

* The weights of machinery include all items included in the tables given in the appendix to Durston on "The Machinery of War Ships," Minutes of Proceedings Inst. C. E., vol. cxix, pp. 32–46. Air compressors, steering and electric light engines, oil tanks, voice tubes and telegraphs in engine room, floor plates, ladders and gratings are classed as machinery.

torpedo gun boats had resulted in these vessels being fitted with narrow bladed screws, and the first screws of the *Daring* had the same ratio of developed area to disk area as those of the *Speedy*. The blades were of elliptical form, the minor axis of the ellipse being $\frac{4}{10}$ of the major axis. As the results obtained were very remarkable, the authors think it may be of interest if the screw trials are described in some detail. Three screws having the same amount of blade surface but varying slightly in diameter and pitch gave results of a similar character. Fig. 23 shows the curve of slip so obtained. The performances of the screws were so nearly alike that one curve only is shown for them, the points for each being marked 1, 2, 3, respectively. The slip was too great at all speeds, but at 22 knots per hour it commenced to increase very rapidly, rising to nearly 30 per cent. at 24 knots. The pitch of the screws was then somewhat reduced, and the result is shown in the slip curve marked 4. There was a decided reduction of slip at moderate speeds, but instead of becoming less at speeds above 25 knots per hour, as was expected, it continued to increase, and at 25½ knots, which was the highest speed that could be obtained, it rose 23.7 per cent. The authors then arrived at the conclusion that the bad performance of the screws was due to the fact that too large a thrust was required from them per unit of area. The greater part of the acceleration of the screw race is produced by negative pressure on the forward side of the blades. If the whole thrust of the screw be divided into two parts, one part due to negative pressure on the forward side and the other to positive pressure on the after side, the negative exceeds the positive pressure in all cases except the limiting one in which no rotation is given to the race, a condition in which they become equal. The only force available for producing this acceleration in front of the screw is gravity. The recession of the helical surface as it revolves relieves the pressure of the water upon its forward face, and the water can only follow it up with the velocity which is due to the head above it. At the very small depth below the surface at which the screws work in the *Daring*, a few inches only, the weight of water over them may almost be neglected and the head be taken as that due to the pressure of the atmosphere. 15 pounds per square inch is therefore the maximum thrust which can be obtained from the acceleration produced by atmospheric pressure close to the surface of the water. If the surface is broken and air admitted, the velocity which can be imparted to the water in advance of the screw is very small indeed, being limited to that due to the head of water above it. If it be assumed that six-tenths of the whole thrust is produced in front of the propellers of the *Daring*, then a negative pressure of 8½ lbs. per square inch of projected blade surface is required by No. 4 screws at 25½ knots per hour. The thrust at the center of the propeller is probably much less than at portions nearer the circumference, and it may well be that at the most effective part of the blades it approaches more nearly to a state of things in which the pressure is so low that cavities are formed behind the screw blades, filled with air and vapor boiled from the water. This view was confirmed by the very serious vibration of the stern which occurred when the engines were driven at full speed, although when the screws were removed the engines failed to shake the vessel when run at the same number of revolutions, showing that the vibration was caused by some irregular action of the propellers.

A pair of screws was made of the same diameter as No. 3 and of practically the same mean pitch, but having the blade surface increased 45 per cent. These gave a very satisfactory performance, as shown by the slip curve marked 6, Fig. 23, and no further changes were made. It will be seen that the slip is the same as that of No. 4 screws at about 19 knots per hour, but at higher speeds is much less. It reaches a maximum of 17¾ per cent. at 24 knots and then falls to 15¾ per cent. at 29¼ knots per hour. Comparing these screws with No. 3, from which they differ only in blade area, it will be seen that at 24 knots per hour the slip is reduced from 30 per cent. to 17¾ per cent., and the indicated horse power from 3,700 to 3,050. The number of revolutions per minute required to obtain 24 knots per hour with No. 3 gave 28.4 knots with No. 6. The excessive vibration also disappeared. The pitch of all the screws was variable, increasing from the leading to the following edge as is usual with Thornycroft screws. The slip is measured from the mean of the pitches of the fore and after edges at the middle of the blade. The effective pitch of the wide bladed screws is somewhat greater than the mean thus obtained, that is, they do not turn so fast as screws of the same size but of uniform pitch equal to the nominal mean pitch. The slip curve of No. 6 exhibits a tendency to flatten at speeds above 27 knots per hour, and the authors are of opinion that these screws would break down in the same way as did Nos. 3 and 4, if pressed to a much higher speed. Above 28 knots or 29 knots per hour greater area is required. At 29¼ knots per hour the mean negative pressure, assuming it as before to be six-tenths of the whole thrust, is 7¼ pounds per square inch. "Cavitation," as Mr. Froude has suggested to the authors that the phenomenon should be called, appears to manifest itself when the mean negative pressure exceeds about 6¾ pounds per square inch, or when the whole thrust exceeds 11¼ pounds per square inch. This is with blades of elliptical form, but it will probably vary somewhat when the surface is differently distributed.

Results in strict accordance with those of the *Daring* were obtained contemporaneously from the trials of two torpedo boats. Nos. 91 and 92 are sister vessels and had screws of the same diameter and pitch, being made from the same drawing, but the surface of the screw of No. 92 was about 40 per cent. more than that of No. 91. At 24 knots per hour, the boat with the narrow blades required 16½ per cent. more power than the other, and the slip of the screw of No. 91 was 20 per cent., while that of No. 92 was 6 per cent. only. The negative pressure in the case of No. 91 is 9.8 pounds per square inch, and in that of No. 92 it is 6.72 pounds, the latter figure, it will be observed, agreeing very closely with that at which the screws of the *Daring* commence to fall off in efficiency, viz., 6.75 pounds. There seems to be more than a coincidence in these figures, and the results appear to show that a new condition of things has been entered upon. The analysis of the speed trials of a number of vessels built at Chiswick shows that in no previous case has the negative pressure exceeded 7 pounds per square inch except in No. 93 torpedo boat and in the *Speedy*, where it amounted to 7.9 pounds and 7.4 pounds respectively, and it is probable that in No. 93 the blade area is too small. The vessel passed out of Messrs. Thornycroft & Co.'s hands before the experiments described had taken place, or wider bladed screws would have been fitted and tried.

The surface used in these calculations is the projected surface, because the thrust dealt with is sternward only. The improvement obtained with No. 4 screws at moderate speeds as compared with Nos. 1, 2 and 3 was probably due to the greater projected area obtained by twisting the blades to a finer pitch. More developed blade area is required for screws of great pitch ratio than for those in which the pitch ratio is small; because the projected area of a given screw is inversely proportional to the pitch ratio, and also because the ratio of negative to positive pressure becomes greater as the pitch ratio is increased.* Mr. Normand has described what he calls the rupture of the column which occurs when air finds its way from the surface to the screw. He made some experiments with a moored vessel and ascertained the thrust obtainable with different immersions; but he dealt only with the case of free communication between the atmosphere and a screw or rudder by vortices or otherwise, when rupture takes place as soon as the speed at which the water is required to fill the void behind the propeller or rudder exceeds 14.5 feet per second or 8½ knots per hour, at a depth of 1 meter.

It is apparent that if the authors' reasoning is correct, the speed of vessels has now approached within measurable distance of that at which propulsion by screws depending upon the reaction of water, becomes inefficient. For a given pitch ratio and slip, *i. e.*, at what is known as "given abscissa value," the thrust per unit of area varies as the square of the speed. Since the total thrust required to propel a ship at a given speed is a fixed quantity depending upon the resistance, it follows that cavitation can only be avoided at very high speeds, or, to be more exact, at speeds such that the critical ratio of thrust to area is reached, by increasing either the immersion of the screw or its blade area. The immersion is usually governed by considerations of draught of water; and, provided it is sufficient to prevent air from penetrat-

* Minutes of Proceedings Inst. C.E., vol. cii, p. 87.

ing from the surface, it is not practicable to obtain much benefit by lowering the screw. Increased blade area may be obtained in three ways. 1st. By increasing the ratio of blade area to disk area. 2d. By reducing the abscissa value, or, in other words, employing a larger diameter of propeller working at less slip than that theoretically best for the given conditions. 3d. By increasing the pitch ratio, which involves a larger diameter with a reduced rate of revolution. Either course tends to a waste of power if pursued beyond somewhat narrow limits, and it appears inevitable that reduced efficiency must be submitted to as the speed of vessels is increased.

APPENDIX.

TESTS OF A MODEL THORNYCROFT BOILER.

ENGINEERING LABORATORY, KING'S COLLEGE, LONDON,
15th March, 1895.

MESSRS. J. I. THORNYCROFT & Co., Chiswick.

Dear Sirs: I have made a series of tests with the model boiler which you sent to me for trial, and have determined its efficiency for eight different rates of steaming at atmospheric pressure. The boiler with four rows of water tubes each side and a total heating surface of 12.4 square feet contains 4.1 pounds of water up to datum level. Gauge marks were placed at each end of the steam drum and the water level sighted from end to end through the glass plates with which it was provided. In this way the level could be determined with great accuracy. With one exception the trials lasted for over half an hour; observations of gas and feed water with feed and funnel temperatures being taken every five minutes.

Gas.—The gas was measured by a standard gas meter made by Messrs. Alex. Wright & Co., which has been tested and certified correct by the Standards Department of the Board of Trade. This identical meter was used on the Society of Arts motor trials, and has a dial which can be read to the $\frac{1}{100}$ cubic foot. The pressure is measured by an ordinary water gauge, and the temperatures of both inlet and outlet by standardized thermometers.

Water.—The feed was supplied from the rectangular copper tank accompanying the boiler. For measuring the quantity used, a float was provided graduated in pounds and half-pounds. By subsequent calibration I have found these graduations correct. Throughout each trial the level of the water in the boiler was maintained as nearly constant as possible, special care being taken that it should be brought to the datum line at the end of each five minutes' interval when the observations were taken.

Temperatures.—The feed and funnel temperatures were measured on thermometers which have recently been standardized in my laboratory. The feed water was allowed to stand for some time before use in buckets close to the boiler, so that its temperature was very steady at that of the room. The temperature of funnel gases was measured at the hottest point just below the level of the top of the steam pipe.

Efficiency.—For calculating the boiler efficiency the thermal value of the gas has been assumed equal to 19,000 B.T.U.'s per pound. This is the mean thermal value obtained from a number of analyses recently made for me by Mr. G. N. Huntly. Individual values did not differ from this mean by 2 per cent. in any case, although an interval of more than a year elapsed between the first and last observation. From the same analyses the value of K (difference between Kp and Kv) was determined = 130, and this value has been used for the calculation of the specific volume of the gas. For this purpose the temperature and pressure at the meter were observed during each test and the corresponding specific volume of the gas found.

The first trial made without any funnel gave such anomalous results that a funnel 10 inches high was added for the subsequent experiments. Without a funnel the efficiency was only 38.8 per cent. when burning over 70 cubic feet of gas per hour.

It was incidentally found that any sudden variation in the rate of feed made a very marked reduction in the evaporation, and consequently in the efficiency. An accidental lowering in the water level at the time of refilling the feed tank made a rapid addition of feed necessary to bring the water in the boiler up to datum level in time for an observation to be made. It was found that the evaporation during the subsequent five minutes was reduced to exactly one-half its mean value for the rest of the trial. This point was therefore carefully watched, with the result that any considerable irregularity of feed was invariably found to be accompanied by a perceptible slackening of the violence of ebullition, and, if aggravated, by a diminution in the rate of evaporation during the following interval.

The results of the experiments have been plotted on a base representing rates of transmission per square foot of heating surface. It will be noticed (Fig. 24) that the line joining the tops of the ordinates representing efficiencies per cent. is very closely a fair curve. The efficiency increases in value as the rate of transmission is increased up to a maximum value of 86.8 per cent. when the rate of transmission is 22.35 B.T.U.'s per square foot per minute. It then gradually decreases in value until a rate of transmission of nearly 39.5 B.T.U.'s per square foot per minute is reached, when the efficiency is 68 per cent. From this point the efficiency very rapidly falls off, showing that the air supply is not sufficient for the perfect combustion of the gas. Some means for artificially increasing the air supply would be beneficial beyond this point.

A very valuable fact, which is for the first time shown by these experiments, is that the economy of model boilers may be under certain conditions as great as that of full sized boilers of the same type. In some trials made by Prof. Kennedy, and recorded in the Minutes of Proceedings of the Institution of Civil Engineers, Vol. xcix, session 1889–'90, a precisely similar efficiency of 86.8 per cent. was obtained with a Thornycroft boiler having 1,837 square feet of heating surface at a rate of transmission of 23.8 B.T.U.'s per square foot heating surface per minute. Should this comparison prove capable of general application, very considerable advantage might be derived from model boiler experiments.

A table showing the results of the eight trials is appended; and a diagram giving the efficiency curve, quantities of gas used, and water evaporated for different rates of transmission (Fig. 24) is also added.

I am, Gentlemen, yours faithfully,

D. S. Capper.

TABLE.

Date.	Feb. 26.	Feb. 26.	Feb. 25.	Feb. 25.	Feb. 25.	Feb. 26.	Feb. 28.	Feb. 28.
Duration (minutes)	45	50	30	45	40	50	20	30
Atmospheric pressure (lbs., per square inch)	14.67	14.71	14.66	14.66	14.66	14.64	14.75	14.77
Meter pressure (lbs. per square inch)	14.74	14.78	14.73	14.73	14.72	14.71	14.82	14.88
Gas per hour (cubic feet)	12.01	19.69	31.9	46.3	55.2	70.98	81.8	101.84
Gas per hour (lbs.)	0.385	0.633	1.01	1.47	1.77	2.27	2.60	3.25
Thermal equivalent at 19,000 B.T.U. per lb.)	7,315	12,030	19,190	27,930	33,630	43,090	49,320	61,690
Equivalent in lbs. of water per hour from and at 212° F.	7.58	12.45	19.82	28.91	34.8	44.6	51.06	63.85
Temperature of feed (°F.)	48.0	48.0	52.0	51.0	43.0	48.0	46.5	52.5
Factor of evaporation	1.170	1.170	1.165	1.167	1.175	1.17	1.171	1.165
Feed water (lbs. per hour)	4.2	8.34	14.79	20.4	22.8	25.92	27.00	28.392
Equivalent from and at 212° F.	4.91	9.76	17.23	23.81	26.96	30.33	31.62	33,084
Temperature of funnel gases (° F.)	......	......	228	238	220	227	252	245
Heating surface (sq. feet)	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Water evaporated in lbs. per square foot of heating surface per hour	0.338	0.675	1.195	1.64	1.85	2.09	2. 1	2.29
Mean rate of transmission of heat (B.T.U. per sq. foot heating surface per minute)	6.475	12.66	22.35	30.9	35.0	39.38	41.05	42.95
Efficiency of boiler (per cent.)	64.7	78.5	86.8	82.2	77.5	68.0	61.9	51.8

In the discussion which followed the reading of this paper, Mr. Yarrow gave the following particulars of the progressive trials of the *Hornet*, the displacement being 220 tons:

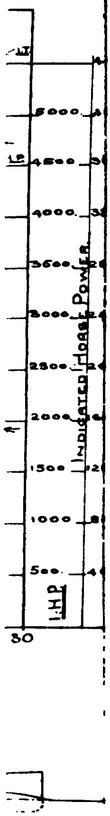
Speed, knots, . .	11.3	16.7	23.4	27.6
I.H.P., . . .	207	1,200	2,700	3,884

The propellers were 6 feet 6 inches in diameter and had a uniform pitch of 8 feet, and a total developed area of about 1,700 square inches. In the *Hornet*, the maximum speed was obtained with a slip of 11 per cent., and in the *Havock*, a maximum speed of 26.5 knots, with 9 per cent. slip.

Prof. D. S. Capper observed with reference to the series of trials which he had made with the model Thornycroft boiler exhibited, that it had at first been intended merely to determine the efficiency of the model so as to compare it with a full sized boiler of the same type. The boiler had a heating surface of 12.4 square feet, and when filled to working level contained 4 pounds of water. A complete report of the trials with a table of the results was given in the appendix to the paper. One of the first trials made was that given in the third column of the table. With a mean rate of transmission of 22.35 British thermal units per square foot of heating surface per minute, the water evaporated per square foot of heating surface per hour was 1.195 pounds, and the efficiency was 86.8 per cent. On comparing this with the trials made by Dr. A. B. W. Kennedy on a Thornycroft boiler having 1,837 square feet of heating surface, with a rate of transmission of 23.8 British thermal units per square foot heating surface per minute, and water evaporated equal to 1.24 pounds per square foot of heating surface per hour, it appeared that the same efficiency had been obtained. This result was so striking that a series of trials at progressive rates of steaming had been carried out. The trials were all conducted at atmospheric pressure, the arrangements not being such as to permit of working at high pressures. It might also be pointed out that there was no means at hand for artificially increasing the air-supply, and consequently the rate of transmission of heat, *i. e.*, the rate of steaming, could only be increased by increasing the gas supply. He thought the result of that would clearly be seen in the efficiency curve, Fig. 24. The 100 per cent. efficiency line was shown on the diagram, and the curve crossing it showed at each rate of steaming the efficiency as compared with perfect efficiency; starting with a rate of transmission of 6.4 British thermal units per square foot per minute, an efficiency of 64.7 per cent. was obtained, from which point the curve rose gradually up to its maximum value, 86.8 per cent. as already stated. After the maximum was reached, the efficiency decreased more and more rapidly until at a rate of transmission of 42.95 British thermal units per square foot per minute, it was 51.8 per cent. In Dr. Kennedy's trials that fall was not nearly so rapid, for at a rate of transmission of 158 British thermal units per square foot per minute he had obtained an efficiency of 66.6 per cent. This divergence was most probably due to the incomplete combustion of the gas in consequence of deficient air supply in the experiments with the model after the maximum point had been reached. There were distinct signs that this was taking place during these trials. He thought it was highly probable that if experiments were carried out with a properly arranged artificial air supply, the curve of model efficiencies would approach much more closely at its latter end to that of the full sized boiler.

The first part of the curve was the most interesting and important, and clearly showed that in this case at least, experiments with a model having less than 12½ square feet of heating surface were comparable with the results obtained with a boiler having a heating surface nearly 150 times as great. The thermal value of the gas used had been taken as 19,000 British thermal units per pound, this being the average of a number of analyses made by Mr. G. N. Huntly. These analyses differed little, although the samples were taken at long intervals—the last of them within a month of the trial. He thought that value could be adopted as accurate, although the gas was not analyzed during the trials. Taking that figure, 1 pound of gas was equivalent in heating value to 1.32 pounds of carbon; and at its maximum efficiency the model boiler therefore evaporated 13.02 pounds of water from and at 212° F. per pound of carbon value. That was a remarkable result in a boiler of the size referred to, and seemed to indicate that the type of boiler under consideration was as efficient on a small as on a large scale.

It had been pointed out by the authors that they had invariably found when the speed of the engine exceeded a certain amount, the power seemed to be underlogged. It was a very interesting matter, which called in question the accuracy of the indicator. He would like to hear how far it was found that the power was underlogged, or that it was suspected of being underlogged. It was difficult to carry out experiments with an indicator in such a way as truly to compare its indications with any scientific standard when running at a high speed, and thus to determine its errors under working conditions. He had made a number of experiments bearing on that point on an apparatus he had devised for the purpose. A steam cylinder was suitably connected with a mercurial column so that pressures in the cylinder could be read directly in inches of mercury. He had found that if the pressure was suddenly applied by opening the cock of the indicator, the pressure recorded by the latter was invariably less than the true pressure as shown on the column. And that this difference was not due to any drop in the pressure of the steam cylinder on opening the indicator cock, was shown by the indications of a gauge attached to the cylinder. He was aware that gauge readings were not to be relied on for absolute readings; but for checking differences of pressure they could be made to all practical requirement reliable. Those results seemed to point in the same direction as the underlogging of power recorded by the authors, but his experiments, though extensive, were not sufficient in number and range to warrant him in asserting definitely that similar results would always be obtained. He thought the authors were to be congratulated on having pointed to a limit being possibly obtained, in one direction at least, in the complicated problem of propellers; and the results which had been shown in connection with cavitation were extremely interesting and valuable.


5000
4500
4000
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I.H.P
INDICATED HORSE POWER
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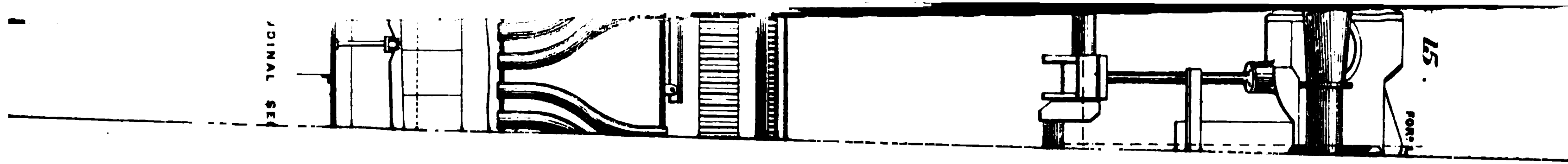
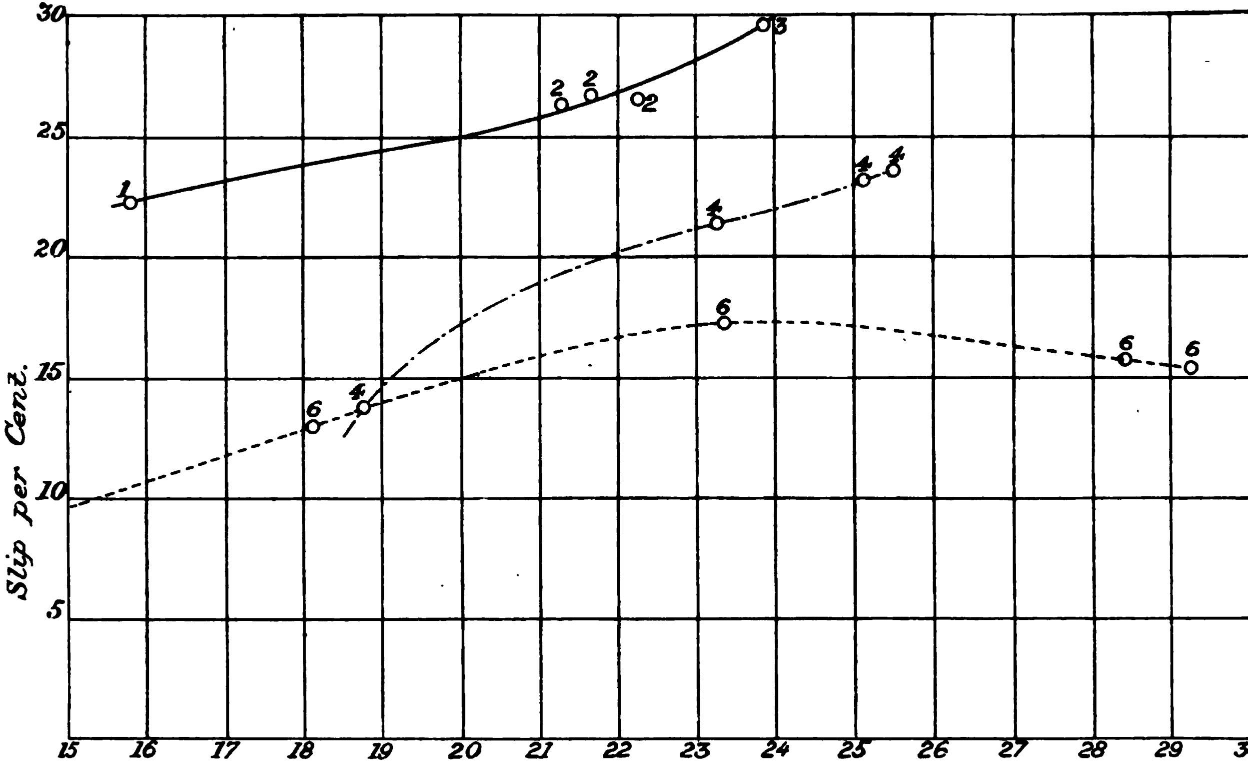
15



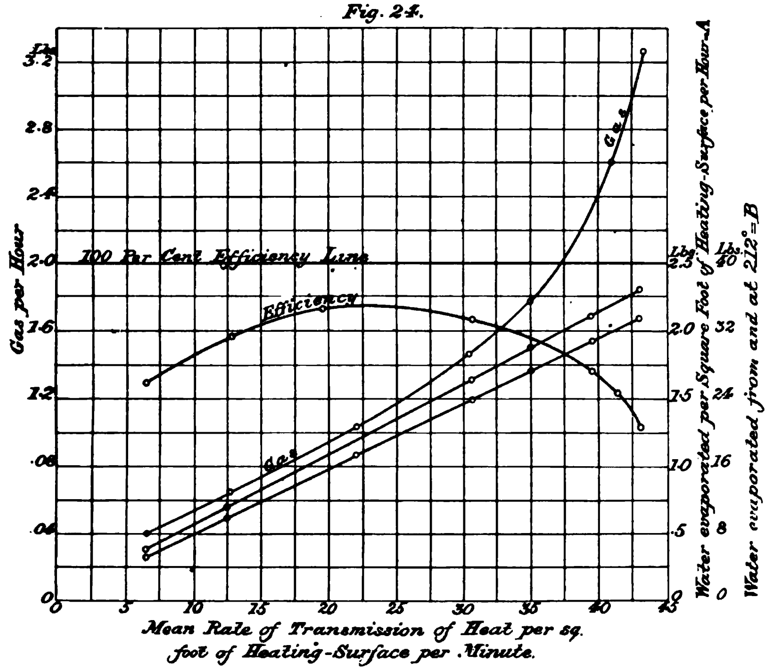
H.M.S. 'Daring' — Curves of Slip per Cent of Propellers.

Fig. 23.



H.M.S. 'Daring'—Curves of Slip per Cent of Propellers.

Fig. 24.


Lbs.
3.2
2.8
2.4
2.0
1.6
1.2
.08
.04
0
Gas per Hour
100 Per Cent Efficiency Line
Efficiency
Gas
Gas
0
5
10
15
20
25
30
35
40
45
Lbs.
2.5
2.0
1.5
1.0
.5
0
Lbs.
40
32
24
16
8
0
Water evaporated per Square Foot of Heating-Surface per Hour-A
Water evaporated from and at 212°=B
Mean Rate of Transmission of Heat per sq. foot of Heating-Surface per Minute.

EXPERIMENTS TO DETERMINE THE CAUSES OF STEAM PIPE EXPLOSIONS ON BOARD GERMAN NAVAL VESSELS.

Conducted at the Royal Dockyard, Wilhelmshaven, and Reported in the "Marine Rundschau."

Translated by Wm. Wachsmann, Esq., Associate.

The frequent bursting of steam pipes has led to the investigation of the causes of these accidents.

In most cases the explosion has taken place while admitting steam into the pipe system, as for instance on H. I. M. S. *Siegfried*, March 18, 1892; on H. I. M. S. *Wacht*, June 20, 1889; on H. I. M. S. *Prinzess Wilhelm*, August 9, 1891; on the same ship on November 7, 1893, when a stop valve in the main steam pipe exploded; in a boiler plant at Ferranti's, Deptford, England, July 9, 1889; on the S. S. *Jumma*, December 13, 1890; in a boiler plant of the new mill in Zuellichan, near Stettin, Germany, in 1860, etc.

From these examples the supposition arose that possibly water, contained in the pipes, caused water hammer. On this supposition, the following tests were made.

I. PREPARATION FOR THE TESTS.

(*a.*) *Arrangement of the first experimental pipe.*—A pipe was taken consisting of 2 lengths, each 6.5 feet long, 5.9 inches inside diameter, and 0.197 inch thick, and the ends tightly closed by flanges. To one of these flanges a .7874-inch stop valve was bolted in such a manner that the lower edge of the hole of the valve was in line with the inner side of the pipe, so that when the pipe was put in proper position the steam would enter at the lowest point.

To the other flange on the pipe a blow off or water drain cock 0.4724 inch in diameter was secured, and in the center of this same flange, a high pressure gauge (registering to 2,133 pounds) with a maximum hand. Vertically above the drain cock an air cock was fitted so that water could be blown off at the lowest and air at the highest point of the experimental pipe. Later, a second pressure gauge was placed on the upper side of the pipe 22.83 inches from the flange containing the steam inlet valve.

The stop valve on the experimental pipe was connected by a 0.7874-inch pipe to a valve in the main steam pipe of the machine shop boiler, which carried a pressure of 70 pounds. The experimental pipe was inclined upwards from the steam inlet valve, so that if any water were present the steam would have to pass through it.

(*b.*) *Arrangement of second experimental pipe and its alterations.*—The second pipe was made up of parts of the old steam pipe of the hulk *Bismarck.* It consisted of three pieces 12.2 inches in inside diameter and about 0.236 inch thick. Attached thereto were four maximum pressure gauges, capable of registering to 2,133 pounds, an air cock, and a water drain cock, 0.7874 inch in diameter, as shown in Fig. 1.

This pipe was then connected by a pipe, 3.15 inches in diameter, with the main steam pipe of the machine shop, a 3.15-inch valve being inserted near the main steam pipe.

The first change in this pipe, which is shown in Fig. 2, was the removal of that part of the pipe which was bent upwards and the insertion of a 1.97-inch stop valve to connect with the 3.15-inch pipe.

After the bursting of this pipe near the flange opposite the steam inlet, and after the steam gauge on this flange had been destroyed for the second time, the damaged part of the pipe was cut off, the flange brazed on again, and the blank flange again secured in place minus the pressure gauge. The pressure gauge III was then placed near this flange on the side of the pipe.

This second change is shown in Fig. 3.

II. PROGRAMME OF THE TESTS.

1. Pipe *without* water, air cock closed and the drain cock open.
2. Pipe *without* water, air cock open and the drain cock closed.
3. Pipe *without* water, air and drain cocks open.
4. Pipe *without* water, air and drain cocks closed.
5. Vacuum in pipe and *some* cold condensed water formed by creating vacuum, air and drain cocks closed.
6. Vacuum in pipe, and the latter *filled with water* to about one-third of its cubic capacity, so that the point where the steam entered was under water in the first pipe, it being made to incline towards that point. In the second pipe the water filled that part of the pipe as indicated by the shaded surface. Air and drain cocks were closed.
7. Pipe *without* vacuum *filled with water* as under 6, air and drain cocks closed.
8. Pipe *without* vacuum *filled with water* the same as under 6, air and drain cocks open.

III. METHOD OF MAKING AND RESULTS OF THE TESTS.

(*A.*) *With the first pipe.*—Steam was admitted to the pipe to be tested by rapidly opening the stop valve on the main steam pipe of the boiler, the influx of steam having been regulated beforehand by adjusting the stop valve on the flange of the experimental pipe. Beginning with one fifth of the area of this valve, the opening was increased one-fifth in each of the succeeding tests.

In order to get reliable results, the eight tests in the programme were repeated several times with the same valve opening.

In carrying out tests 1 to 4 no hammering in the pipe or motion was observed, whether the filling of the pipe with steam was retarded or accelerated. The pipe became heated, slowly or quickly, according to the rapidity with which it filled with steam, until it became thoroughly warmed and the pressure gauges on the pipe indicated the steam pressure in the boilers.

As soon as a vacuum formed and a small amount of condensed water was present in the pipe (Test No. 5), light hammering was observed when steam was admitted; this was not, however, indicated on the pressure gauges but caused only a slight movement of the pipe. This hammering and the backward and forward movement of the pipe became more intense, the greater the quantity of water present (Tests Nos. 6 and 7), manifesting itself in distinct blows and at shorter intervals and causing the maximum hands of the gauges to indicate different pressures varying between 128 and 242 pounds.

Whether the vacuum in the pipe (Test No. 6) had any influence on the action of the steam when it was admitted, could not be determined by any of the trials.

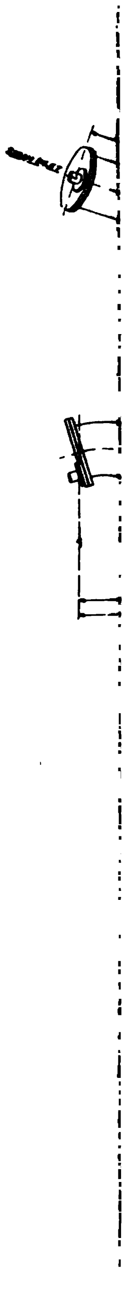
The heaviest hammering as well as the greatest movement of the pipe, which also continued for some length of time, were observed when the pipe was about one-third full of water and both air and drain cocks kept open (test No. 8), and for all five openings of the valve.

During these tests, there was a uniform discharge of water from the drain cock and of air from the air cock, for a longer or shorter time (depending on the opening of the stop valve in the pipe), and the accompanying forcible hammering.

For instance, with $\frac{1}{5}$ opening of stop valve the first hammering was noticeable after 4 minutes; at $\frac{3}{5}$ opening, after 30 seconds; and 15 seconds after the valve was wide open, powerful hammering and violent motion of the pipe set in; in each case accompanied by an impulsive discharge of water and air and later by steam from the air and drain cocks. These phenomena are due to the fact that the steam is condensed by the water present, and only when the water has attained the temperature of the steam does the impulsive action of the latter set in.

The pressures observed on the gauges at the end of each trial (test No. 8) fluctuated between 284.5 and 1,066.75 pounds. At one time the greatest pressure would be observed on the gauge tapped in the flange, and then on the one attached to the side of the pipe.

(*B.*) *With the second experimental pipe.—a. According to the first arrangement.*—To establish the action of steam in bent piping of large diameter, the same tests as above were made with the second experimental pipe, arranged as shown in Fig. 1. Steam from the 3.14-inch supply pipe was admitted into that part of the pipe which was inclined upwards.



In testing the pipe when empty, with or without vacuum, the same observations as before were made.

When the pipe was $\frac{1}{8}$ full of water as indicated by the shading in the sketch, the action of the steam was entirely different from that observed in the first experimental pipe. Only single blows occurred in the pipe, which were insignificant in comparison with those observed in the first pipe.

The greatest pressures observed in any of these tests, the cocks being open and steam admitted suddenly, was 426.7 pounds on gauge I, 113.7 pounds on gauge II, 199 pounds on gauge III, and 113.7 pounds on gauge IV. In opening the stop-valve slowly, the hammering was so insignificant that the maximum pressures indicated on all the gauges at the end of the tests was the same as the boiler pressure. The great difference in the results of these tests and those with the first pipe, suggested a modification of this pipe according to the arrangement shown in Fig. 2.

b. According to the second arrangement.—The same general results were obtained as with the first experimental pipe for the 8 tests of the programme and with the different openings of the stop valve, the only difference being that the intensity of the hammering in some of tests caused accidents, which, in some instances, resulted in breaking the new heavy ropes which were used for holding the pipe.

On August 14, when the stop valve was $\frac{3}{5}$ open, the pipe being filled with water, as shown in the sketch, and with the air and drain cocks open, the threads of four nuts on the securing bolts in the end flange were sheared off, the flange itself was much bent, the gauge tapped into it destroyed, and the pipe in the neighborhood of this flange bulged outwards. The pressure shown by gauge I was 483.5 pounds, by gauge II, 384 pounds and by gauge III, 924.5 pounds.

On August 22, with $\frac{3}{5}$ opening of the stop valve, and after the steam had been turned on for 65 seconds, the pipe burst 3.9 inches from the end flange for a length of 8.26 inches. The pressures in this case were 313 pounds on gauge I, 185 pounds on gauge II, 853.3 pounds on gauge III, while the limit of 2,133 pounds was exceeded on the gauge in the flange. After this accident the damaged portion of the pipe was cut off and the repaired pipe used for further tests.

c. According to third arrangement.—The same observations were made as with the first pipe and the arrangement *b* of the second pipe.

To determine at what water level violent hammering takes place, the height of water was gradually diminished by stages, 1.18 inches, 0.78 inch and 0.39 inch, until it reached the line shown in Fig. 3 (6 inches deep at the steam inlet end). At this level, motion of the pipe was still observed, but the hammering had nearly ceased, so that it had no effect on the gauges.

At a level of 6.69 inches, the hammering was still so very violent that the maximum pressures observed, September 25, were, on gauge I, 853.3 pounds; gauge II, 497.8 pounds; gauge III, 853.3 pounds; and, October 3, on gauge I, 568.9 pounds; gauge II, 497.8 pounds; whilst the screw tap on gauge III was torn off.

By increasing the original water level of 9 inches to 9.84 inches, measured at the flange where the steam entered, the two bolts vertically opposite each other in the end flange were broken and the first section of the pipe near the intermediate flange ruptured by two splits, 2.3 and 3.9 inches long. After this, the pipe was useless, and no further tests were made.

In none of the tests could the water in the pipe be entirely ejected, even after a long period of blowing off and after the pressure had fallen to that in the boiler. In most of the cases, the water level was 3.14 inches high, measured at gauge I.

IV. DEDUCTIONS FROM THESE TESTS.

As a result of these tests, it is shown that destruction of a completely drained, although entirely cool, pipe cannot occur, whether the stop valve near the boiler under steam is opened gradually or in a sudden, careless manner, because hammering, which alone can cause an explosion, does not follow.

But it is to be observed that a rapid filling of the pipes with steam may prove disastrous, for the sudden heating up of the various parts may cause rupture due to unequal stresses on and resistance of the material.

When, however, a large quantity of water is contained in the pipes and the steam is forced to find its way through it and to carry it along, an explosion may occur, even if the stop valve is opened in the slowest and most careful manner.

If there is so little water in the pipe that steam need not force its way through it, no disastrous hammering will occur, nor will the water present be carried along by the steam when the stop valve is opened, as was demonstrated by the amount of water left in the pipe after the end of all tests.

The results of the tests with the first arrangement of the second experimental pipe lead to the conclusion that where water has accumulated in U bends of pipes, if the stop valve is opened gradually, the entering steam will distribute itself at once uniformly over the surface of the water, and by virtue of its pressure, which, in spite of the original condensation, is not only maintained but steadily increased, will prevent any agitation of the water, and, consequently, hammering. If, however, a sudden change of pressure and a rapid influx of steam occur, then the water will be agitated and, once in motion, it will cause violent and dangerous hammering in the pipe. Therefore, steam pipes with pockets are to be avoided.

The variation of the pressures indicated on the gauges after all the tests, leads to the conclusion that the water is thrown backwards and forwards, wave-motion like, caused by the influx of steam, and that the pressure is greater or less, depending on the intensity with which the moving mass of water strikes the opening to which the gauge is attached.

ERRATA IN THE PAPER ON "TEST OF WOUND COPPER PIPES" IN THE AUGUST NUMBER OF THE JOURNAL.

Page 518. Change the formula at the foot of Table I to

$$t = \frac{pD}{5{,}689} + 0.059.$$

Pages 518 and 519. Cross out the word "Pounds" in the last column headed "Factor of safety."

Page 521. Change the reference marks † and ‡ in the fourteenth column of Table IV to the seventeenth column, same lines.

LIQUID FUEL FOR NAVAL PURPOSES.

By Passed Assistant Engineer John R. Edwards, U. S. Navy.

[One of a series of lectures delivered at the Naval War College, Newport, R. I., August, 1895.]

INTRODUCTORY.

Intimately connected with the boiler question is the subject of fuel, for the efficiency of the steam generator depends to a considerable extent upon the combustible used. In the Pocahontas and Cumberland varieties of bituminous coal, and in several anthracites, we have fuels which are superior to that mined by any other nation except England. The better the coal, the more quickly it will deteriorate, for the hydro-carbons will volatilize unless exceeding care is taken. In the bunkers of a modern war vessel, the coal is subjected to a light roasting, for with the protective deck just over the boilers, and forming the flooring of the bunkers, the coal must be quickly impaired. A squadron investing any of our ports will therefore suffer from the impairment of her fuel, for even with banked fires under all furnaces the bunkers will be heated up to some extent. We shall therefore be on an equality with any nation which attemps to blockade our ports, so far as the efficiency of coal is concerned.

This is an experimental age, and no nation can be said to have solved the fuel question for war ships until it has satisfied itself concerning the worth of petroleum residuum as a combustible.

War vessels must have the best fuel within reach. It is not a question of finance. It is one of strategy and necessity. To gain a half knot speed for their war vessels, the Japanese bought Welsh coal of medium quality, and it cost them over six times as much as coal from their own mines would have done.

AMERICA'S KNOWLEDGE OF THIS SUBJECT.

Some of our officers labor under the great mistake of believing that our country has done nothing to find out the advantages and disadvantages of this combustible. The greatest corporation in the world, the Standard Oil Company, has a direct interest in this matter, and the money expended on the Continent in the investigation of this question, is but a fraction of that incurred indirectly by the Oil Trust. The Bureau of Steam Engineering has also made an exhaustive series of experiments with various qualities of unrefined petroleum and its residuum.

The steam furnished by all the boilers at the Columbian Exposition, also at the California Mid-Winter fair, was generated by liquid fuel. It may surprise our people to be told that we have had more success in America in burning this combustible than they have had anywhere else, except in Russia, and our Naval officers will be more than astonished to learn that a Naval Engineer on the retired list is without a peer in his knowledge of this subject.

NAVAL ENGINEERS DESIRE ITS SUCCESSFUL INSTALLATION.

Fleet Engineer Quick, of the Royal Navy, voices the sentiment of every Naval engineer when he tells of the wish and hope that the burning of liquid fuel may be a success. But he realizes that claims are not results, and so he says: "In these days of rapid development of machinery we are all of us tempted to wish that a vast leap forward could be made at once, so that we may have our power produced without the use of coal and steam on board ship. For more than thirty years the hope has been indulged that the use of liquid fuel would enable us to avoid the horrors of coaling ship; but even to-day we seem to be far off from this step forward being taken. Those who have had to superintend the coaling of a man-of-war in a tropical climate, when the steam has been up and the coal has been old and dusty, can alone realize what an immense blessing liquid fuel would be to all on board, if it could only be brought into constant use. But there are certain objections to its employment on board vessels of war, which objections do not apply to its use on merchant steamers or fast mail boats, so that we must expect to see it employed successfully in the mercantile marine before it is used in vessels designed for fighting. It is true that those enterprising people, the Italians, are making strong efforts to introduce it into their war ships, but it is not impossible that an action at sea, in which high explosive shells may be used, may very much alter their views on this subject."

ADVANTAGES AS A FUEL.

Here are some of the advantages claimed for the burning of the residuum of petroleum:

1st. The saving of labor. As the oil is forced by pressure directly to the burners in the fire box of the furnace, all the handling of coal and ashes is done away with. In action it might be impossible to throw the ashes and cinders from the coal overboard.

The more perfect combustion of liquid fuel prevents the formation of residuals and smoke. Consequently, ashes and cinders do not occur, and the furnaces need not be cleaned, nor need the flues be swept. The first circumstance is of the greatest importance with regard to torpedo boats, which generally have only one furnace the grates of which, after a six hours' coal fire, at most after ten, are covered with clinker. It then becomes imperative to clean the grates if the steam pressure and speed are to be kept up.

2d. The saving in room. If this combustible were absolutely to be depended upon, the fire rooms could be made much smaller. But he would be a bold designer who would not make provision in an emergency for using coal. A saving will be effected, however, in some of the space now taken up by the bunkers.

The greater power of evaporation of liquid fuels, which is in the proportion of 7 to 4 to that of coals, enables steamers either to reduce the weight of the fuel they take on board, when the same distance is to be steamed as in the case of coal fuel, or else enables steamers to steam a longer distance when the same quantity of liquid fuel is taken as would have been required if coal had been used.

3d. The saving in men. The fire room force would be materially reduced if oil can be successfully consumed. On board torpedo boats one-half the fire room force now required could be dispensed with. As the men would have little physical work to do, they would keep better health in bad weather, whereas at present it is known that the firemen are the first to become exhausted.

4th. Preservation of the boilers. It is said that the fiercest action of the flame is upon the crown of the furnaces and not upon the ends of the tubes, and that where the boiler is strongest, the heat is the greatest.

5th. The rapidity and cheapness with which they can be brought on board. These, according to Tweddell, are so great that the steamers of the Caspian can ship from 800 to 1,000 tons of fuel in from three to four hours, a period which could be still more reduced if a few arrangements still wanting were introduced. A torpedo boat, therefore, which required at most about 21 tons of liquid fuel, could be made ready in a few minutes, and a whole flotilla would require no more time than it takes to coal a single boat at present.

6th. The storage of the oil in such parts of the vessel as are unfit for cargo. Such parts are the water ballast tanks of large cargo carrying steamers, the double bottoms of ironclads, as well as the keel spaces fore and aft of boilers and engines on all steamers. Besides, by filling up these spaces it will become possible to make the engine rooms more convenient and spacious, by reducing the bunkers, especially in the case of smaller vessels.

7th. The fires can be started more quickly and extinguished almost instantaneously. If well regulated, it is absolutely free from smoke. The control of the fires is an important matter, and particularly would this be the case on a torpedo boat. With such a fuel there would be no occasion to suddenly open the safety valve at an inopportune time. The abolition of smoke would be a practical as well as tactical advantage. The torpedo boat that does not betray itself by a column of smoke is very difficult to discover on the horizon, and will, therefore, have an enormous advantage, as it will itself be able to distinguish all larger vessels by their smoke columns. As, however, a sudden stoppage of the air current will produce enormous dense smoke columns in cases where liquid fuels are used, it has even been suggested by a Naval captain that this circumstance should be utilized with a view of establishing a code of smoke signals, for long distances, on the Morse system.

8th. It can be adapted to any construction of boiler without material change in the existing arrangements for firing with coal, in fact, coal and oil can be used alternately if so desired. To burn oil alone, the fire bars have simply to be taken out or covered with thin slabs and cinders, the furnace doors have to be provided with holes for introducing the nozzle of the pulverizers, and the steam pipes and oil pipes have to be connected respectively with the boiler and oil tank. When oil is used, the stokers need not exert themselves much, whereas, where coals are used they have to work very hard, and must come on deck every few minutes to get a breath of air. For tropical climates, therefore, liquid fuel would have great advantages.

9th. The greater manœuvring capacity of the engines which is attained by the possibility of suddenly increasing, reducing, or stopping the fires. In case of coal fires, if it be desired to suddenly shut off the steam, and the safety valve is not to be used, the fire and smoke box doors have to be opened, and the cold air must be admitted directly into the boiler, which is exceedingly bad for the latter.

10th. The ease and exactitude with which the oil can be measured, when it is taken on board, as well as when it is being burned, should end all complaints of short weights in coals, which one hears so frequently now, and should also insure a better verification of the consumption of fuel during trial.

There are other advantages claimed:

(*a*) Increased radius of action.

(*b*) Better stability with fuel stowed in bottom of boat.

(*c*) Absence of necessity of having compartments open.

In general it may be said that one's imaginative power has become weakened when a new advantage cannot be found for the successful use of liquid fuel on naval vessels.

VALUE OF OIL AS COMPARED WITH COAL.

In the "Report of experiments in burning fuel oil" made by officials of the Baldwin Locomotive Works, it is stated that: "To determine the value of oil, it is necessary to know the evaporative power of the boiler for each pound of fuel burned, which depends greatly upon the ratio of heating surface to grate surface, and the volume consumed in a given time. These conditions do not seem to affect the consumption of oil, the evaporation being about the same per pound of oil for all rates of combustion, it being impossible to consume the oil without a proper supply of air, and, as no smoke is made, no unconsumed fuel goes out of the stack, as in the case with soft coal. The following formula will enable any one desiring to use oil to obtain a correct idea of its value, as compared with coal as fuel:

$$\frac{(\text{Cost of coal per ton} + \text{cost of handling (say 50 cents)} \times 10.7 \times 7}{2{,}000 \times \text{evaporative power of coal}} =$$

price per gallon at which oil will be the equivalent of coal. It must be remembered in these computations that the cost of both oil and coal is considered at the place where they are delivered to the engine, and not at the place where they are purchased by the railroad company."

COMMERCIAL APPICATION.

This lecture will only incidentally touch the commercial side of this question. The industrial applications of liquid fuel are vast in their possibilities. Some promoter may find some such wonderful use of it on shore, as Captain Curtis suggested at sea, when he proposed to signal with the clouds of smoke that would issue from the funnel when the fires would be suddenly checked.

Its commercial success on shore will depend to a great extent on its cost. And the cost will be determined everywhere by the proximity to the wells, and cheapness of transportation.

The "Shipping Gazette" of May 19th, 1894, says: "It has just been announced that the experiments which were carried on last year on the *Caledonia* will not be continued this season. Blast furnace oil—the only available liquid fuel—has risen so much in price as to be more costly than coal for a given amount of steam generating work."

With reference to the use of liquid fuel on locomotives, it is interesting to refer to the results obtained in England by Mr. James Holden, Locomotive Superintendent of the Great Eastern Railway, by the process invented and adopted by him. On the locomotive using liquid fuel there is an absence of constant and laborious firing; the requisite pressure of steam is easily obtained by an almost imperceptible movement of the injector valve; there is an absence of smoke, and a great uniformity of pressure.

In the inaugural address of the President of the Society of Engineers, in February, 1894, he gave a description of these locomotives and their working cost. He stated that an express engine using 35.4 pounds of coal per mile, consumed under similar circumstances 11.8 pounds of coal and 10.5 pounds of liquid fuel, or a total of 22.3 pounds of fuel.

The advantages of the Holden system are summed up as follows:

1st. With an ordinary grate, steam can be easily raised without working the injector.

2d. Fuel can be interchanged according to the state of the market.

3d. With a thin coal fire, oil can be shut off at will without running the risk of chilling the fire box.

4th. When standing, the coal fire will maintain steam.

For several years a number of locomotive engines on the Great Eastern Railway have used liquid fuel, and one of these engines is recorded to have traveled 47,000 miles without a single failure or accident. But the great difficulty in extending the use of liquid fuel in England is the impossibility of obtaining a sufficient supply at a low cost, otherwise it would be very generally used, considering the great calorific effect and the practical advantages of its application.

It has been very recently stated that since the introduction in the naval ships of liquid fuel, the cost in Italy has increased one hundred and fifty per cent. (150 per cent.).

One of the highest officials of the Pennsylvania Railroad asserted that the great cost attending its use was a bar to its introduction in the locomotives of that road.

On the other hand, there are some places where it can be secured more cheaply than coal.

The question of cost, therefore, depends upon location.

A great writer upon this subject has said: "We must look for the best results from petroleum, both economically and technically, in those uses where the improved product of the manufactured article more than counterbalances the difference in price of the two kinds of fuel."

CHIEF ENGINEER SOLIANI'S MONOGRAPH ON LIQUID FUEL.

Undoubtedly one of the best articles that has been published on this subject is the paper of Chief Engineer Soliani of the Italian Navy, which was read at the International Engineering Congress. He starts in with the various kinds of petroleum used, gives the chemical composition, what its actual calorific value as fuel is, and then goes on to tell about the experiments in Russia, where it was first used on vessels in the Volga region and on the Caspian Sea. He then gives us the pulverizing process adopted by Mr. Urquhardt, and then brings us down to to-day's actual modern experience in the Italian Navy.

A careful study of this paper shows:

1st. That the only form of liquid fuel which is absolutely safe for use on board ship is what is known as petroleum refuse, which is a thick viscous fluid of about the consistency of tar or very thick molasses. This has to be sprayed or pulverized, either by jets of air or steam, for use in the furnaces.

2d. The pulverizers form the principal element in the whole arrangement for burning liquid fuel, and many kinds have been used or tried, or simply patented. The Russian pulverizers are all worked by steam, and they appear to be the best, because a pulverizer using steam may be worked well with air, or any other suitable gaseous fluid with little or no alteration.

3d. Where pulverizers are not used a compressor for forcing the air is employed. Its great weight and space occupied forms a very serious objection to the compressor.

4th. That the use of liquid fuel by the Russians is almost confined to the Volga region and the Caspian Sea. There the wood is scarce and costly, and also very bulky. Coal is extremely expensive. One very remarkable fact in connection with the use of liquid fuel on Russian vessels is that the difficulty with marine boilers of making up the waste of steam entailed by the pulverizers does not exist for the steamers running along the Volga River. It is lessened, in case of the sea steamers, by the fact that the great bulk of the Caspian trade is from Baku and other ports south to Astrakhan, where fresh water is available in abundance, and can be stored by the steamers both for outward and homeward passages.

5th. Italy, on account of its position and of its deficiency of coal, was naturally interested in the matter. And that country, which even our naval experts have, in years past, mistakenly reported as having adopted this fuel for its war vessels, confines the practice to a few torpedo boats. For their large vessels they do not contemplate the regular use of liquid fuel. Pulverizers, however, are fitted in order that they may be held in readiness for the same object as forced draft.

6th. The system of mixing petroleum spray with the coal seems to be on the increase in the French and Italian navies, and furnishes a ready means of rapidly increasing the steam pressure and speed, above that of the natural draft.

7th. That the measure of success in the burning of liquid fuel will depend upon the efficiency and durability of the pulverizer. Less than three years ago the Italians believed that they had solved this question for naval purposes by the invention of the Curriberti atomizer. They are now rather doubtful about this sprinkler satisfying all their wants. The French, who are following them more closely than any other nation, are about to use their own pulverizers.

QUANTITY OF RESIDUUM THAT CAN BE SUPPLIED.

Some of our officers believe that there is an unlimited supply of this liquid fuel. It must not be forgotten that the residuum is only one of the substances secured from the natural oil.

The treatment of natural petroleum in order to separate it into commercial products, consists in distilling the crude oil in retorts of suitable construction, and condensing the products passing over at different temperatures.

Thus, roughly speaking, the products may be divided into three groups:

First. The volatile oils passing over at temperatures up to 150 degrees centigrade.

Second The illuminating oils passing over from 150 to 300 degrees centigrade.

Third. The residiuum. In the Baku oil, the residuum is about one-tenth of the entire substance.

An exceedingly liberal estimate of the production of residuum which could be utilized for fuel places the amount within three and one-half million (3,500,000) tons. Assuming a ton of residuum to equal in calorific effect two tons of coal, we have a supply of liquid fuel equal to seven million (7,000,000) tons, a very insignificant quantity as compared with the consumption of coal in the world.

In order to compete as fuel, the production of petroleum will have to be greatly increased. This increased production will have to come from fields lying on the seacoast where it can be shipped in tank steamers and be carried at a reasonable cost. Unless there was a demand for the illuminating and lubricating oils from the petroleum, the residuum would have an excessive value.

There is no one who has made a more protracted and scientific investigation of its capabilities than Mr. Isherwood, and this is the result of his observations on liquid fuel as a combustible for naval purposes. In summarizing the work of the Experimental Board of which he was president, he writes:

"The experiments in question embrace those made with Col. Foote's apparatus at the Charlestown Navy Yard, and those made with other apparatus on different boilers in the New York Navy Yard, all of them, I believe, of considerable value, but never reported in full with the exception of one made about ten years ago, and which is now on the files of the Bureau of Steam Engineering. In every case the patentees abandoned the trials before they were completed, owing to the failure of their apparatus.

"The liquid oil has, in all cases, to be transformed into oil gas before it can be burned. This transformation can be made by the direct application externally of heat to the liquid, but the temperature of the oil on the vaporizing surface is higher than the temperature required to decompose it, the result being deposition of solid carbon in the form of coke which soon fills the vaporizing vessels and renders them useless. This coke is frequently so hard that cold chisels can scarcely detach it, and if thrown into a fire even in small fragments, it burns with excessive slowness, like graphite. Whenever the vaporizing vessel is subjected to a high temperature like that of a boiler furnace, the decomposition of the oil and deposition of coke go rapidly on, so that in the course of a few hours any vessel of practicable size is filled by it. All apparatus exposed to anything like furnace or flame temperature will inevitably fail from these causes in the future as they have in the past. To make trials with such devices will merely serve to confirm this fact. The smaller the vaporization vessel, and the higher the temperature to which it is exposed, the more quickly will it fail.

"A very large number of apparatus has been invented embodying substantially this principle or mode of direct vaporization of the oil, the only difference being unimportant variations of detail to render the inventions patentable, and in all cases the vaporizing vessel has been necessarily small in order that the pressure heat could be employed in the oil vaporization, and the highest possible temperature was used in order that a sufficient quantity of the oil might be vaporized in a given time. None of of the apparatus, when pushed to the maximum will last more than half a dozen hours.

"It is quite possible, however, to vaporize the oil by the indirect application of heat by means of steam or water intervention, so that the temperature of the vaporizing surfaces will be below the temperature of decomposition of the oil. This would be manufacturing oil gas in a costly manner, and the gas could afterwards be burned in jets in a furnace like illuminating gas, but it would not be "burning petroleum," or any oil in the proper sense. The vaporizing apparatus to produce the requisite quantity of gas per hour for any considerable power would have to be enormously bulky, heavy and expensive; in fact, a complete gas making plant itself, and I do not believe after the gas is obtained that a sufficient quantity of it could be consumed per hour by any practicable arrangement of jets in a furnace to produce as much heat as could be obtained from coal burned at the maximum in the same furnace. Further, as the metal of the jets would be exposed to the high temperature produced by the combustion of the gas, the latter would be decomposed in them and they would quickly become stopped by the deposited coke. The heat from each jet would be directly radiated upon the metal of the surrounding jets and produce this effect. In fact, I have produced it in my experiments by exposing a small diameter iron tube through which common illuminating gas was passed to the heat of a row of alcohol lamps placed beneath it, when after a few hours the pipe became completely filled with coke; with oil gas this result would happen sooner. To make any such system an engineering success (which is very different from a commercial success) the metal of the jets and their connections must be thoroughly shielded from temperatures as high as that of the oil decomposition.

"The only method that has been attended with any success is that of 'atomizing' or spraying the oil by means of steam under sufficient pressure for the purpose, used in an injector placed outside the furnace, so as not to receive the high temperature of combustion. The oil in fine spray, excessively comminuted, is thus squirted into the furnace where it is decomposed at large and its constituents separately consumed. An ordinary Giffard injector is employed, and the smaller its nozzle the better it works. Even in this case, however, the injector will fill with coke after a considerable time, and requires to be unscrewed from its pipe and cleaned out, another being substituted meanwhile. In this manner oil fuel can be satisfactorily burned. All other methods have failed. Generally a bed of incandescent coal is required on the grate of sufficient extent to inflame the atomized or sprayed in oil, but even this is not absolutely necessary though a great convenience, and its rate of combustion is excessively slow.

"Although the injectors are sufficiently durable, and the combustion of the oil satisfactory, the fatal objection to the system, and it seems an insuperable one, is that not enough oil can be burned in a furnace to produce the requisite supply of steam per hour from a boiler; nor can this difficulty be overcome by multiplying the injectors spraying into a furnace.

"The difficulty arises from the fact that the oil is not sprayed in pure atmospheric air, but into air greatly contaminated with steam and carbonic acid gas. In the combustion of coal on a grate pure atmospheric air enters beneath the coal, and its oxygen is nearly all absorbed in the lower strata of coal, the unconsumed air mixed with the gases of combustion rising through the upper strata. The rate of combustion of the coal is a maximum in the lower layers, the part resting immediately upon the grate, and diminishes very rapidly as the upper layers are approached, being comparatively small at the top layer, where, indeed, in many cases it is almost nothing. A piece of dry wood resting on the incandescent coal of a furnace will long remain unconsumed; it will distill and char, but not burn if air be prevented from entering above the bed of coal through the furnance door. Now, one-half of the gases above the coal is unconsumed air, but the effect of the other half of intermingled steam and carbonic acid gas with it is almost entirely to prevent combustion. Into such a mixture the sprayed oil is delivered. And although air may be admitted through the furnace door, and by induction with the injector, yet not enough can be made to pass in to supply more than a very slow rate of combustion, which cannot by any means known to me be increased. As a result an immense quantity of furnace would be required to burn a comparatively small weight of oil per hour. If more be thrown in than can be properly consumed, the remainder will pass off through the chimney accompanied by dense volumes of black smoke and stench of sulphur, due to decomposition of the oil by the furnace heat without air in proper condition for combustion.

"The pound of oil fuel will produce about two-thirds more available heat than the pound of good steam coal, both being burned in the same boiler in quantities per hour inversely as their economic efficiencies, but the slow combustion of the oil in comparison with that of the coal, both being consumed at their maximum rates, places it out of competition for the production of steam power, and particularly on board of steamers.

"I regard the use of oil fuel in any vessel whose machinery is required to develop its maximum power and produce high speed as hopeless."

A TALENTED AUTHOR'S VIEWS OF ITS POSSIBILITIES.

Marvin, in his "Region of Eternal Fire," writes so graphically of the possibilities of liquid fuel that the average reader is dazed by the brilliancy of his predictions. He believes that from Malta to Singapore the dusty piles of Cardiff coal are to vanish, for Baku will supply an inexhaustible amount of inexpensive petroleum refuse to take its place. From Singapore to Shanghai the cheaper grades of Australian, Chinese and Japanese fuels are to depart forever, for Rangoon will undertake the task of supplying a better and cheaper combustible to the district.

And his picture of the Russian firemen turning on the jet at Baku and then adjusting the flame, as the navigator takes his departure, is beautiful. From his view the man in this stokehold has no need to concern himself about anything until he reaches the mouth of the Volga, except the comfort of the passengers and his own mental improvement. His sole bit of trouble—that of burning a few handfuls of cotton waste or wood, to get up a little steam to start pulverizing the oil—is even abolished in some mythical arrangement of a furnace, where a small quantity of hydro-carbon gas is kept stored for this purpose.

This brilliant author is evidently better posted upon the industrial and political future of the trans-caucasian region than he is upon the value and future of their wells of petroleum fuel. From this prediction we turn to an English scientific authority for his opinion of the future.

A BRITISH EXPERT'S VIEW OF ITS CAPABILITIES.

The "Engineer," London, in one of its issues, says:

"We see, then, that the startling claims advanced by inventors of various systems of burning petroleum, have no real foundation in fact, and they tend to retard the use of oil fuel rather than promote it. The right spirit in which to approach the subject is, while not expecting too much in the way of evaporative efficiency, to bear in mind that it is unfair to compare its price with that of coal in England only, and to remember that it is a superbly convenient fuel, involving the least possible trouble in burning it. . . . . To utilize oil fuel, then, properly, it appears that marine boilers should be so constructed that they will, like Mr. Holden's locomotives, burn either fuel indiscriminately, so that as the cargo steamer moves from port to port she will always be able to provide herself with that form of fuel which can be had at the lowest price.

"Hundreds of patents have been secured for different methods of spraying and burning liquid fuel. The great secret of success seems to lie, in so arranging matters that the flame will not put itself out and prevent the oil from being properly consumed.

"As regards the spraying, that is usually effected by the use of steam; but the practice is very objectionable, because the quantity used is very considerable, and represents great waste of fresh water, which must be made up again for the sake of the boilers, at least in the case of sea-going steamers. The use of compresed air seems to be better, but it may be worth while to consider whether either air or steam are needed."

INSTALLATION OF THE SYSTEM AT THE CHICAGO EXPOSITION.

At the World's Fair at Chicago the boilers which furnished the steam for driving the machinery were all fed with crude oil. The conditions there were, of course, quite different from what would prevail aboard ship, but they were all in favor of a more successful burning of the liquid fuel. Lake Michigan with its supply of fresh water was near. There was no question of either weights or space occupied to be taken into consideration. The seven representative boiler firms which were pitted against each other sent excellent men to look out for their respective plants. The piping was arranged in the most efficient manner, it not being necessary to make extra bends or angles in order that it would clear a hatch or opening, as might occur on board ship. And yet an official report says, "The quantity of petroleum used for firing the main boiler plant at the World's Columbian Exposition amounted to upwards of 31,000 tons, and the work done is stated to have totalled 32,316,000 horse power hours. This makes the consumption of oil about 2.1 pounds per horse power hour." This report would tend to dispose of some of the claims of the thermal efficiency of liquid fuel. Is it possible that the commercial article is not so rich in hydrogen as that furnished for experimental purposes?

A SUCCESSFUL OCEAN VOYAGE MADE WITH THIS FUEL.

The steamer *Baku Standard*, an ocean tramp, in 1894 made a voyage from Shields to Philadelphia, burning only liquid fuel. It is said that this is the first instance on record of a steamship fitted to burn liquid fuel and making an ocean voyage. The passage to Philadelphia was made under difficulties. Instead of the usual crew of firemen and trimmers, only three water tenders were shipped. One met with an accident soon after the ship sailed, breaking a collar bone, and was laid up. The result was that the other two water tenders had to stand six hours watch and watch alternately on the rest of the voyage, which they could scarcely have managed if they had to work hard shoveling coal and cleaning fires. As a fact, however, the fires seemed to have needed little or no attention, even in the worst weather. On this trip the weight of the steam used in the pulverizers to spray the oil, exceeded the weight of the oil, and at least 10 per cent. of the steam was wasted in this way. If there had not been an evaporator aboard, the result to the boilers might have been serious, in pumping so much salt water to make up the deficiency.

It is said that the *Baku Standard* returned to Shields burning liquid fuel. So far as I can ascertain, she has not made any more long ocean voyages with liquid fuel, and the promoters of the scheme were evidently not overjoyed by the result. It proved, however, that ocean voyages could be made by vessels burning such a combustible.

Of the many articles written about liquid fuel, little else is told but the many advantages that will accrue from its successful use.

ITS DEVELOPMENT IN EUROPE FOR NAVAL PURPOSES.

We hear of the amazing progress that the Italians have made in their development of the burning of liquid fuel, and yet, only about two years ago, one of their highest officers practically said that if the use of petroleum in the torpedo boats of the Permanent Squadron proves to be a success, all their boats would be fitted with it.

It is exceedingly difficult to secure positive information in regard to the success of the Italians, but the following statement expresses nearly the extent of its installation on torpedo boats. Four have been fitted and four more altered.

From time to time we hear of the success attained by one of their cruisers on a short run with this fuel. A careful investigation invariably shows, that when oil was used in connection with coal, the speed over that of natural draft was increased. There is not one single instance on record where the burning of liquid fuel, either alone or in combination with coal, developed the speed or horse power that was secured with coal under forced draft.

For the past year, the Austrians have been experimenting with it. It is said that for every pound of residuum they were able to burn, seven-tenths of a pound of water in the form of steam was required to spray it. They have not yet been convinced of its merits for naval purposes, for not a single boat in the Austrian service has yet been fitted permanently with atomizers for burning this fuel.

A careful reading of the professional papers in regard to the success of the French with this combustible furnishes one with such information as the following: "The question is altogether in a state of tentative experiment, and the fuel will have to be tried in different boilers and under severe conditions before adoption in large vessels." Of another vessel it is written: "The results are said to be good, but not definite." Concerning three torpedo boats it is written: "The experiments have been more or less successful."

The latest experiments made by the French authorities were with the *Forbin* and *Milan*. "On board the *Forbin* the results proved fairly satisfactory, but on board the *Milan* they did not have such good results." This is, of course, very indefinite, but it is the best information obtainable.

COST NOT A FACTOR FOR NAVAL PURPOSES.

The question of cost should not be taken into consideration in determining its value for naval purposes. I am convinced that it will cost more than coal as a fuel to do the same work. The cost of details, whose successful operation may cause great results, cannot be inquired into. If it can be successfully burned in large quantities for any long period, then its installation on naval vessels will be secured, no matter how expensive it may be. And it is for this reason that the oil producers have incurred so much expense in trying to make it a success.

I believe that it should be fitted immediately to at least one of our small vessels. We can well afford to experiment with this fuel, but it must be well understood that the outlay may be very heavy before success can be assured.

The Engineer-in-Chief has recommended in several of his Annual Reports that Congress should make an appropriation to enable him to make experiments with this fuel. It might be possible for this College in some way to ask that this purpose be carried out.

In 1888, a Board of U. S. Naval Engineers reported, "We are of the opinion that the system could be advantageously put on board torpedo boats and coast defence vessels, if safety in stowage and handling can be clearly arranged, and think the device worthy of a trial, particularly as it can be applied without interfering with the coal burning arrangements." This is even farther than Italy has gone in this matter, for she has only four torpedo boats actually fitted for burning such fuel.

DISADVANTAGES AS A FUEL.

The disadvantages are:

1st. The erection of oil tanks and supply pipes in the place of existing coal stations, so as to insure the rapidity of taking oil on board alluded to above.

2d. The loud noise occasioned by sprinklers, which is exceedingly inconvenient in the case of passenger steamers. It would be downright fatal for torpedo boats.

3d. The combustibility of oil, which might occasion an explosion in the event of a shell hitting the tanks.

4th. The very small number of oils which can be used as a fuel. If estimated at a maximum, the annual output of all the natural oil of the world amounts to about six millions of tons of mineral oil, three quarters of a million tons of tar oil, and a quarter of a million tons of slate or shale oil, altogether seven million tons. Modern industry, which transforms these into liquid fuel, lubricating oils, benzole, paraffin, etc., cannot spare them; at most it can leave us about 20 per cent. of the original weight in residuals, which, however, would only represent a fifth part of the fuel required annually by the steam navigation of the world. On the other hand, the latter absorbs about a thirty-third of the annual output of four hundred millions ot tons of coal of the world, or twelve million tons.

5th. The enormous cost of liquid fuel at present is, however, the rock on which all attempts at introducing its use more widely in merchant vessels must founder. According to the present prices of coal and oil residuals, the latter, notwithstanding their higher power of evaporation, are about three times as dear as coal. The price of the oil will always be unstable.

6th. Difficulty in overcoming the objectionable odor. This objection was one of the reasons why the Southern Pacific Railway abandoned the use of petroleum fuel in the furnaces of their ferry boats.

The impossibility of overcoming the formation of gas and the consequent odor, and also the difficulty of examination of compartments in which this material has been carried, will retard somewhat its adoption on board ship, even if the other difficulties were removed.

7th. Destructive action upon the plates and rivets. One of the officials of the Standard Oil Company, in discussing the paper of Colonel Soliani, says: "We have four ships running out of New York carrying petroleum to foreign countries, and about every two years it is necessary to cut out and renew a large number of rivets in the plate edges, sometimes reaching up into the thousands, in order to overcome the deteriorating effect incident to the penetration of oils along the laps of the seams. It will affect water bottoms in the same way, and to fully as great an extent. There is a great difference between the carrying of refined oil or the raw product. In the latter, the generation of gas is the maximum, in the refined it is the minimum. A few years since, the Standard Oil Company, of New York, built a steam vessel for the carrying of refined oil, and she was reasonably successful and satisfactory. Later they attempted to carry crude petroleum in her, and within three months thereafter they had a very disastrous explosion on board, practically wrecking the vessel."

8th. Exceeding and intelligent care required to burn the fuel properly. Mr. P. A. Lennertz, who had charge of the building of eleven tank steamers for Nobel Brothers, in Russia, says: "I have seen boilers on board ships on the Caspian Sea, which have been left with open air holes in the fire doors after the burners had been shut off, and the result was cracked tube sheets, leaky tubes, seam and stay bolts."

9th. To my mind, it is a great mistake for those countries which possess no oil fields to experiment with this fuel for naval purposes. A late review says that Germany has taken this stand, and hereafter, except for purely scientific research, she will not experiment further with the residuum of petroleum as a combustible for the vessels of her navy.

With our great oil fields abundantly able to supply a manifold quantity of liquid fuel for naval purposes, it ought to be our policy to supplement the work that has already been done by a series of exhaustive experiments with this residuum as a combustible. The Engineer-in-Chief should be given a torpedo boat and a small gun boat to experiment with, and the investigation of the subject of liquid fuel should be carried on regardless of expense. The naval engineering expert, who would have supervisory charge of the work, would see that, despite the breadth and cost of the experiments, no money was wasted. Nor would he permit the work to be crippled by conducting the investigation after the plans of non-professionals who were incapable of finding out its merits.

Dissertations upon liquid fuel are a favorite theme of the novice, and some of the material is unintelligible to the naval engineer.

The solution of this engineering question, can only be delayed by having non-professionals interfere with a careful examination of its merits and defects. The engineer alone can realize the possibilities of this incomparable fuel, but he must have facts, and not hopes and promises, to justify him in adopting it as a combustible for naval purposes.

TRIALS OF THE LAKE STEAMSHIPS *ZENITH CITY* AND *VICTORY*.

By Passed Assistant Engineer B. C. Bryan, U. S. Navy.

These vessels were built for carrying freight on the Great Lakes. Their hulls were built by the Chicago Ship Building Company, and the machinery by the Cleveland Ship Building Company. The *Victory* has Scotch boilers built by the latter company, and the *Zenith City*, water tube boilers of the Babcock and Wilcox Company's marine type. The *Victory* went into service early in August, 1895, and the *Zenith City* in September, 1895, and since that time both boats have been running practically continuously.

The principal dimensions of hulls and machinery of both boats are given in the following table :

	Zenith City and *Victory*.
Length, keel, feet	380
over all, feet	400
Beam, moulded, feet	48
Depth, moulded, feet	28
Registered tonnage, *Zenith City*, tons	3,429
Victory, tons	3,340
Displacement at 16 feet draught, tons	6,617.9
Block coefficient at 16 feet draught	.813
Midship coefficient at 16 feet draught	.981
Water line coefficient at 16 feet draught	.896
Center of gravity of water line from stern to whole length	.507
buoyancy from stern to whole length	.498
above base to height of water line	.529
Metacenter above base line, feet	20.17
Tons per inch at 16 feet water line	37.61
Engines: Triple expansion, vertical, jet condensing:	
Cylinders, H.P., *Zenith City*, inches	22
Victory, inches	23
I.P., inches	38
L.P., inches	63

	Zenith City and *Victory*.
Stroke, inches	40
Valves, H.P. piston, diameter, inches	$10\frac{3}{4}$
length of port, inches	$2\frac{3}{4}$
I.P. slide	
steam ports, 2, inches	$1\frac{1}{2}$x36
exhaust port, 1, inches	$4\frac{3}{4}$x36
L.P. slide	
steam ports, 2, inches	$2\frac{1}{2}$x60
exhaust port, 1, inches	$6\frac{3}{4}$x60
Piston rods, diameter, *Zenith City*, inches	$5\frac{1}{8}$
Victory, inches	5
Air pump, single acting, lifting, diameter, inches	31
stroke, inches	$15\frac{3}{4}$

Boilers:	*Zenith City*.	*Victory*.
Type	Babcock & Wilcox.	Scotch
Number	2	2
Diameter, feet and inches	......	14–8
Length, feet and inches	8–$7\frac{3}{4}$	13–6
Breadth, feet and inches	12–2	......
Height, feet and inches	14–8	......
Number of furnaces in each	1	3
Grate surface, total, square feet	134	144
Heating surface, total, square feet	6,800	5,715
H.S. to G.S.	50.7 to 1	39.6 to 1
Diameter of tubes, inches	4 and 2	$3\frac{1}{2}$
Weight with water, etc., in steaming condition, pounds	173,876	335,787
Weight per square foot of heating surface, pounds.	25.57	58.7

Their hulls are precisely alike except that the water bottom of the *Victory* is 6 inches deeper than that of the *Zenith City*. They were built solely and entirely for the purpose of carrying freight, and everything in the design has been subordinated to that end. They have but one deck, the interior of the hull being strengthened by stringers and longitudinals and partial bulkheads. The framing is entirely of channel bars.

For ease in stowing and discharging cargo, the engines and boilers are placed at the extreme after end of the vessels. At the extreme forward end are the quarters for the crew, leaving all the rest of the hold free and unobstructed. There are 11 hatches, 8 by $33\frac{1}{2}$ feet, for the purpose of receiving and discharging cargo.

All the plates of the hulls are lapped and treble riveted along the ends and double riveted along the sides. Filling pieces or liners, triangular in section, are used where three sheets meet instead of drawing out the sheets themselves. The laps in all cases point aft.

The machinery of the two vessels is almost the same; in fact, the engines were built from the same patterns, the only difference being that in the *Zenith City* the high pressure cylinder was cored for a diameter of 22 inches instead of 23 to compensate for the higher steam pressure. The cylinders are not steam jacketed. The *Zenith City* also has an independent feed pump while that of the *Victory* is attached to the air pump beam.

In the construction of the machinery of these vessels economy was carried to the utmost, and there is no hand or machine work in any place where it can be avoided. The crank webs are steel castings bored out and shrunk on the pins and shafts. The main bearings have no brasses, being cored out for the reception of white metal, which is first run in and afterwards bored out. The crank pin ends of the connecting rods contain steel shells for the reception of white metal, and no brass is used in any portion of the engine where it can be avoided. The thrust bearing is an ordinary horse shoe thrust, 6 collars on the shaft working against 5 horse shoes. All the jaws on small connections are castings which are board out and tapped on the ends of the rods.

Trials of the machinery of these vessels were conducted by Chief Engineer J. H. Perry and Passed Assistant Engineer B. C. Bryan, U. S. Navy, in October last. The vessels were running on their regular trips at the time, only remaining in port a few hours to load or discharge cargo. The testing apparatus used was such as could be applied without delaying the vessels. The results of these trials are tabulated in tables A, B, C, D and E.

Each vessel was supplied with a 3-inch Worthington water meter fitted in the feed pipe between the pump and boiler, and the piping so arranged that the feed water could be passed through or around the meter at will. On the *Zenith City*, the meter was in constant use and frequent readings showed it to be running regularly and uniformly.

The exact number of pounds of water corresponding to one division on the index of a meter can only be determined by weighing the amount actually passed through in a given time, under pressure and at the rate at which the meter was run during the trial; and such a test can only be made when there are adequate means for weighing or measuring all the water passed for a period of several hours. It was intended that after the trial the meter from each vessel should be returned to the maker and subjected to such a test; but as the meter on the *Victory* was disabled on a previous trip the meter from the *Zenith City* was transferred and fitted in its place. For one day it ran satisfactorily but on the second day, just before the trial began, the casing burst, and the meter was rendered useless. This disabling of both meters rendered it impossible to measure the water evaporated in the boilers of the *Victory*.

The meter from the *Zenith City* will be repaired and tested, if possible, and a rate established, though it is evident from the results given in Tables A and B that its error is not very great.

Tests for entrained water in the steam were made with a Heisler throttling calorimeter, taking steam from the main steam pipe at the forward engine room bulkhead in each vessel, and at a distance of from 14 to 18 feet from the boilers; the steam being taken through a pipe tapped into the main steam pipe with perforations about 1 inch from the circumference of same. These tests were not entirely satisfactory, owing to defects in the arrangement of apparatus, but observation of the jets of steam issuing from the calorimeter showed that the steam from the boilers of the *Zenith City* was at all times drier than that from the boilers of the *Victory*. The tabulated results showed that the amount of moisture in the steam averaged about $\frac{8}{10}$ of 1 per cent. for the boilers of the *Zenith City* and about $2\frac{1}{4}$ per cent. for the boilers of the *Victory*.

It will be noticed from Tables C and E that the engine of the *Zenith City* made three revolutions more per minute, under practically the same conditions of wind and sea, than the *Victory*, while developing 284 I.H.P. less. As the propellers of the two vessels are of the same diameter and surface this can only be explained by supposing the blades of the *Zenith City's* propeller to have been set at a less pitch. This view is strengthened by noting the slip of the two wheels.

All the coal consumed on the various runs with both vessels was carefully weighed on platform scales and the ashes therefrom were weighed dry on the same scales.

Each of the two boilers of the *Victory* contains three furnaces, formed of Adamson rings, four feet in diameter and of sufficient length for Ætna grates of six feet. The furnaces debouch into a single combustion chamber 34 inches deep. The water space back of the combustion chamber is but 5 inches in width at the lower part; the connection sheet is stayed to the head by screw stays, riveted over, spaced 5½ inches horizontally and vertically. The tubes are 3½ inches diameter and are spaced 4½ inches center to center. Between the center and each side furnace one row of tubes is spaced 6 inches horizontally to improve the circulation of the water. The tubes are carried higher and further toward the side of the boiler than is usual in marine practice. Yet, when nearly 29 pounds of coal were burned per square foot of grate per hour, there was no serious priming, though the steam contained considerable moisture, as was shown by the dripping from all the valve stem stuffing boxes. The draft was remarkably good, considering the height of smoke pipe (about 50 feet above grate), being at times as high as $\frac{4}{10}$ inch of water, and the Ætna grates gave no trouble and were well spoken of by the engineer force of the vessel. The boilers are set entirely above the fire room floor making it difficult to fire the four side furnaces with the grate bars at such a height.

They are designed for a working pressure of 175 pounds per square inch by gauge. The performance of the boilers was remarkably good, as appears from Tables D and E.

The boilers of the *Victory* weigh, with water, in steaming condition but without smoke pipe, 335,787 pounds. This corresponds to a weight of 175.8 pounds per I.H.P. (at the I.H.P. in Table E), and 58.7 pounds per square foot of heating surface.

The two boilers of the *Zenith City* are of the Babcock and Wilcox Marine type. Each contains ninety 4-inch and three hundred and ninety-six 2-inch water tubes, each 8 feet in exposed length between headers; twenty 4-inch tubes, 4 feet 7½ inches long, for carrying the steam to the drum, and one hundred and thirty-two tubes, each 2 inches diameter and 4 feet in length forming the feed water heater in uptake. The sides of the boilers are formed of square tubes for the height of the furnace and round tubes above, all expanded into headers. Outside of these tubes the boilers were clothed with magnesia, and so perfect was the insulation that the boiler casing never became warm enough to burn the hand.

All the headers are made of lap welded tubing flattened and with ends closed by pieces welded in. All connection of headers with each other is by means of short expanded nipples.

Each Babcock and Wilcox boiler occupies a floor space of 12 feet 2 inches front, 8 feet 7⅝ inches deep and 14 feet 8 inches to top of heater. The front and back incline 2 feet 6 inches from the base owing to the inclination of the headers and tubes. The uptakes receding from the center of the fire room makes the latter remarkably cool and well ventilated as well as roomy.

The total weight of the two Babcock and Wilcox boilers, including water and all fittings, ready for steaming, is 173,876 pounds, or 106 pounds per I.H.P. (at the I.H.P. given in Table C), and 25.57 pounds per square foot of heating surface; the boilers are, however, capable of developing considerably more power.

There is a Westinghouse air compressor fitted in the engine room, which discharges into a supply tank bolted to the fire room bulkhead. From this tank, pipes run to the corners of each boiler and terminate in jets inside. To clean the tubes it is only necessary to open the valve in the air supply pipe, when the soot will be blown off the tubes and carried up the smoke pipe without dust or dirt in the fire room or interfering with the firemen tending their fires.

The grate surface in each Babcock and Wilcox boiler was originally 72 square feet but this was reduced by a 9-inch wall of fire brick, dividing the furnace in two parts, to 67 square feet. The heating surface is 2,800 square feet in the boiler proper and 600 square feet in the feed heater, or 3,400 square feet in all. All the tubes are expanded into the headers and the openings opposite the 4-inch tubes are closed by inner and outer plates and bolts, the joints being metal and metal; the openings opposite the 2-inch tubes are closed by screw plugs.

In service these boilers gave no trouble whatever. They carried their water steadily, and with only ordinarily good firing they will furnish all the steam at 200 pounds pressure that the engine can use. During the trial the safety valves lifted so frequently as to make the steam wasted a very appreciable quantity, and this loss is due entirely to irregular firing.

On both vessels the oiler was also the water tender, and it was not observed that the Babcock and Wilcox boilers required much more or closer attention than did the Scotch boilers to preserve a constant water level.

The coal used on each vessel was a good quality of free burning Pittsburg, or Western Pennsylvania, semi-bituminous, which gave off large quantities of very dark brown smoke and formed a moderate amount of clinker in the furnaces. It contained a large amount of lump, and required little or no working in the furnace after firing.

The power developed by the *Victory's* engine in the run from Devil's Island to Two Harbors, and given in Table E, may be taken as the very greatest it can develop, for the throttle was wide open, all the links were in full throw, and the steam was carried at the highest pressure allowed. The boilers of the *Zenith City* can easily be made to supply sufficient steam for this power, though for the reasons previously given, the corresponding revolutions per minute of the engine will be much greater.

The number of expansions in the *Zenith City's* engine during the run given in Table C was 24; the number in the *Victory's* engine during the run given in Table E was 16.

The drop from the boiler pressure to the initial pressure in the high pressure cylinders, as shown by the indicator cards of both vessels, was excessive, being in each case about 20 pounds at the highest powers developed by the engines. The openings for steam pipes were seven inches diameter, which would give a steam velocity per second, at 90 revolutions of the engines per minute, of about 100 feet for the *Zenith City* and about 110 feet for the *Victory*, which is not excessive. There may be some contraction in the passages through the throttle valve which may partly account for the drop.

It is probable, however, that this drop in the cards is largely caused by the location of the indicator openings. These openings on the high pressure cylinders are in the steam ports close to the valves, and their lead is such that the steam flows by them and away from the openings. With steam pipes as large in diameter and as short and with as straight leads as those on these vessels, a drop of more than five or six pounds between the boilers and cylinders would not be expected. This excessive drop shown by the indicators reduces the I.H.P. and consequently the performance shown by the engines.

The vacuum was remarkably poor for jet condensers, vertical lifting air pumps and cold injection water, in both vessels. This was slightly offset in the *Victory* by the higher temperature, about 20 degrees, of the discharge water, corresponding roughly to about 2 per cent. in evaporation. An increase in vacuum of 4 inches would increase the power of the engines about 100 I.H.P. at 90 revolutions, or decrease the expenditure of coal for the present power 2 tons a day.

The independent feed pump of the *Zenith City* was run continuously at a speed sufficient to deliver at least twice the water required for the boilers, the surplus being discharged through the relief valve; consequently the expenditure of steam for this purpose is much greater than in the *Victory*, where the feed pumps are worked from the main engine.

It is to be regretted that there were no means by which the coal used for auxiliary purposes, such as heating ship, running pumps, dynamos and steering engine could be determined even approximately, as the amount would appreciably affect the coal per I.H.P. given in the tables.

Each vessel is supplied with the following auxiliaries:

2 ballast pumps, duplex, inches	12 × 16 × 18
1 auxiliary pump, duplex, inches	8 × 4 × 10
1 steam steering gear, 2 cylinders, inches	7 × 7
2 dynamo engines, single cylinder, inches	6 × 6
1 capstan, forward, 2 cylinders, inches	9 × 8
1 capstan, aft, 2 cylinders, inches	6 × 8
1 blower, 40-inch fan	
In addition to the above the *Zenith City* has 1 feed pump, duplex, inches	10 × 5 × 12

In compliance with a very common custom on the Lakes, the boilers and coal bunkers of both vessels are supported on platforms raised 6½ feet on the *Victory*, and 8 feet on the *Zenith City*, above the inner bottom in order that the space underneath may be utilized for cargo. Raising the boilers is of advantage in giving a better ventilated fire room and a direct entrance from engine room to hold, but has disadvantages also.

All the main bearings and the thrust bearings on both ships are lubricated with solid lubricants forced in from the cups which were provided with a plug or piston for this purpose. The crank pins, crossheads and the smaller bearings were lubricated with mineral oil. A small dribble of water was run on the eccentrics and thrust bearings as a precaution, but there was no sign of heating in any bearing during the trip.

Tables A, B, C, D and E follow on next pages.

TABLE A.

ZENITH CITY.

9 A. M. October 20th to 9 A. M. October 25th.

Time, hours	24
Revolutions, total	126,010
per minute	87.5
I.H.P. of engine, average	1,540.19
per square foot grate	11.5
H.S. per I.H.P., square feet	41.4
Steam, engine, gauge, pounds	190.75
1st receiver, absolute, pounds	57.7
2d receiver, absolute, pounds	20.12
Links, from full throw, H.P., inches	$3\frac{3}{4}$
I.P., inch	1
L.P., inch	$\frac{5}{8}$
Throttle	10
Vacuum, inches	22.6
Temperature, fire room, degrees	66.1
injection, degrees	43.2
discharge, degrees	116.5
feed at boiler, degrees	188.7
Coal, total, pounds	83,420
per hour, pounds	3,475.83
per square foot grate, pounds	25.94
I.H.P., pounds	2.256
Ashes, total, pounds	7,341
per cent. of fuel	8.8
Draft in smoke pipe, water, inches	.293
Meter, total water, cubic feet	9,519
water per hour, cubic feet	396.625
total (temperature 116.5 degrees), pounds	588,179.01
per hour (temperature 116.5 degrees), pounds	24,507.46
pound coal, pounds	7.05
I.H.P. per hour, pounds	15.91
Calorimeter, gauge, pounds	183.3
thermometer, upper, degrees	380.5
lower, degrees	289.08

Strong head wind and light sea from 9 A. M. till 7 P. M. 20th, then moderating. Vessel very easy and engines racing but slightly.

From 6 till 9 A. M. 21st, light variable wind and smooth sea.

Dynamo running from 4·15 P. M. till end of run. Steam on heaters. Donkey pump running 2 hours 38 minutes to discharge ashes.

A number of the compartments were filled at start and were pumped out after weather moderated.

The coal and water per I.H.P. are the quotients derived from dividing the coal and water per hour by the I.H.P. and are, therefore, too great by the amounts used for auxiliary purposes and which could not be determined.

TABLE B.

ZENITH CITY.

Whitefish Point to Manitou Island.

Time, hours and minutes	9·56
Distance, nautical miles	113.5
Speed, knots	11.43
Slip of propeller (pitch, 16 feet), per cent	15.78
Revolutions, total	51,215
per minute	85.93
I.H.P. of engine, average	1,607.25
per square foot grate	12
H.S. per I.H.P., square feet	4.23
Steam, engine, gauge, pounds	195.2
1st receiver, absolute, pounds	59.9
2d receiver, absolute, pounds	20.9
Links, from full throw, H.P., inches	3¾
I.P., inch	1
L.P., inch	⅝
Throttle	10
Vacuum, inches	22.85
Temperature, fire room, degrees	62
injection, degrees	44.2
discharge, degrees	117.8
feed at boiler, degrees	182.5
Coal, total, pounds	35,388
per hour, pounds	3,562.55
per square foot grate, pounds	26.586
knot, pounds	311.79
I.H.P., pounds	2.216
Refuse from coal, per cent	8.8
Draft in smoke pipe, water, inch	.288
Meter, water, total, cubic feet	4,014.5
per hour, cubic feet	404.144
total (temperature 117.8 degrees), pounds	247,975.67
per hour (temperature 117.8 degrees), pounds	24,963.99
pound coal, pounds	7.007
I.H.P., pounds	15.54
Calorimeter, gauge, pounds	188.9
thermometer, upper, degrees	381.6
lower, degrees	290.3

Strong wind ahead, light sea; vessel easy; engines racing very slightly; a number of compartments filled.

The coal and water per I.H.P. are the quotients derived from dividing the coal and water per hour by the I.H.P. and are, therefore, too great by the amounts used for auxiliary purposes and which could not be determined.

TABLE C.

ZENITH CITY.

Time, hours	3
Revolutions, total	16,470
per minute	91.5
I.H.P. of engine, average	1,626.45
per square foot grate	12.14
H.S. per I.H.P., square feet	4.18
Steam, engine, gauge, pounds	191.66
1st receiver, absolute, pounds	55.7
2d receiver, absolute, pounds	20.5
Links, from full throw, H.P., inches	$3\frac{3}{4}$
I.P., inch	1
L.P., inch	$\frac{5}{8}$
Throttle	10
Vacuum	22.5
Temperature, fire room, degrees	70
injection, degrees	42
discharge, degrees	117.3
feed, degrees	195
Coal, total, pounds	10,670
per hour, pounds	3,556.7
per square foot grate, pounds	26.54
I.H.P., pounds	2.187
Ashes, per cent. of coal	8.8
Draft in smoke pipe, water, inch	.313
Meter, water, total, cubic feet	1,218
per hour, cubic feet	406
total, temperature (117.3 degrees), pounds	752,480.4
per hour, (temperature 117.3 degrees), pounds	250,826.8
per pound coal, pounds	7.052
per I.H.P., pounds	15.42
Calorimeter, gauge	......
Thermometer, upper, degrees	382 3
lower, degrees	288.67

Light breeze, smooth sea. Distance could not be obtained as vessel was in open lake where no ranges could be taken.

No water in compartments. Steam on heaters.

The coal and water per I.H.P. are the quotients derived from dividing the coal and water per hour by the I.H.P. and are too great by the amounts used for auxiliary purposes and which could not be determined.

TABLE D.

VICTORY.

2·45 P. M. to midnight, October 27, 1895.

Time, hours and minutes	9·15
Revolutions, total	47,725
per minute	85.99
I.H.P. of engine, average	1,438.8
per square foot grate	9 99
H.S. per I.H.P., square feet	3 97
Steam, engine, gauge, pounds	168.3
1st receiver, absolute, pounds	60 5
2d receiver, absolute, pounds	21.75
Links, from full throw, H.P., inches	$2\frac{5}{16}$
I.P. and L.P	Full.
Throttle	10
Vacuum, inches	21.65
Temperature, fire room, degrees	75.9
injection, degrees	44.9
discharge and feed, degrees	137.7
Coal, total, pounds	29,967
per hour, pounds	3,242.92
per square foot grate, pounds	22.52
I.H.P., pounds	2.24
Ashes, total, pounds	2,234
per cent. of coal	7.45
Draft in smoke pipe, water, inch	.364
Meter	Broken.

Run concluded at 12 midnight on account of inclemency of weather which obliged vessel to seek harbor.

At start, moderate wind ahead and light sea; wind and sea increasing till 6 P. M., when wind was strong from ahead with rough sea, and so continued till end of run.

From 6·30 till 7·15 engines raced badly and were regulated by throttle; from 7·15 the racing was moderate till 11·30, when it again became necessary to regulate speed by the throttle.

At start H.P. link in $1\frac{5}{8}$ inch, others full. At 7·15 H.P. link run in to 3 inches from full throw.

At 7 began filling double bottom compartments with water to steady ship; capacity of double bottom 2,500 tons.

Safety valves lifted at intervals during run. Water in gauge glasses $10\frac{3}{4}$ S., $7\frac{1}{2}$ P., at start, 6 inches in both at end.

Steam on heaters during entire time of run. Donkey pump running 30 minutes to discharge ashes. Dynamo running from 3·40 P. M.

The coal per I.H.P. is too great by the amount used for auxiliary purposes and which could not be determined.

The meter casing burst just as the trial commenced.

TABLE E.

VICTORY.

Devil's Island Light to Two Harbors.

Time, hours and minutes	3·1
Distance, nautical miles	38
Speed, knots	12.59
Slip of propeller (pitch 16 feet) per cent	10
Revolutions, total	16,000
per minute	88.4
I.H.P. of engine, average	1,910.8
per square foot grate	13.26
H. S. per I.H.P., square feet	2.99
Steam, engine, gauge, pounds	170
1st receiver, absolute, pounds	72.2
2d receiver, absolute, pounds	25.2
Links	Full.
Throttle	10
Vacuum, inches	22
Temperature, fire room, degrees	79.3
injection, degrees	43
discharge and feed, degrees	138
Coal, total, pounds	12,574.5
per hour, pounds	4,168.3
per square foot grate, pounds	28.94
knot, pounds	330.9
I.H.P. per hour, pounds	2.18
Refuse from coal, per cent	7.45
Draft in smoke pipe, water, inch	.33
Meter	Broken.
Calorimeter, gauge	
thermometer, upper, degrees	372.3
lower, degrees	238.3

Fresh breeze on bow; smooth sea; compartments filled, also water in hold.

Steam on heaters. Both compartment pumps running, taking water from hold.

The coal per I.H.P. is the quotient derived from dividing the coal per hour by the I.H.P. and is too great by the amount required for auxiliary purposes.

EXTRACT FROM ADDRESS OF THE PRESIDENT OF THE INSTITUTE OF MARINE ENGINEERS.

By Mr. A. J. Durston, C. B., Engineer-in-Chief, R. Navy.

. . . . 2. We are now possibly on the eve of important departures from present practice in marine engineering, and you are aware from the discussion of the subject in the House of Commons that several vessels in the Royal Navy have been, or are being, fitted with water tube boilers.

The general question of the use of higher steam pressures, which necessarily involve, in my opinion, the use of water tube boilers, will be of interest to all members, and if it be shown by experience that increased pressures can be obtained with water tube boilers with safety and efficiency, and that a considerable gain in economy results from the use of such high pressures, no doubt the mercantile marine will be forced by competition to their adoption, assuming, of course, that any practical difficulties are shown by experience to be overcome when proper appliances are fitted. One very important reason for the adoption of very high pressures exists in the Navy, however, to a much larger extent than in the mercantile marine, and follows from the fact that with naval machinery, although possessing the capability of exerting great power, the usual power exerted on service of the naval ship is but a small proportion of the full power. It is well known that such small powers cannot be developed in a large engine with economy, and one advantage of the provision of very high pressures for the maximum power lies in the reduced size of engine which results, and which will have a beneficial effect in making the engine more economical at those low cruising powers which the vessel exerts during most of her life.

Besides this special advantage which accrues in the Navy, there is, of course, the general advantage of lightness. There are certain types of war vessels where the development of the highest possible power for short spurts is of paramount importance, and this highest possible power is required on the lowest possible weight of machinery. . . . .

3. I imagine the members do not desire to be troubled with any information involving great technical detail, but there are a few other remarks I will make of a general character on subjects which all members of the Institution are interested in. These refer to practice in the Navy and Navy experience, and may be of use to members of the mercantile marine in dealing with their own problems. First, regarding the important question of leaky tubes in boilers, and experiments on the approximate temperature at which this occurrence takes place.

Some experiments were made at Devenport Dockyard in order to throw light on this, and also to ascertain the temperatures which were actually produced under practical conditions.

The results of a preliminary series of experiments were given in a paper read before the Institute of Naval Architects in March, 1893, and some of the leading points contained in that paper are shortly as follows:

First, tubes remained tight in a tube plate up to a temperature of about 750 degrees Fahr., but leakage must be expected when this temperature is much exceeded.

Secondly, as regards the temperatures which were attained under different conditions of working, it was found that when boiling water under atmospheric pressure in a plain vessel the temperature on hot side of plate was only 280 degrees with clean fresh water, but rose to above 550 degrees when the vessel was coated internally with a layer of grease $\frac{1}{16}$ inch thick.

The effect with boiling water under pressure was obtained by experimenting with a small boiler. This boiler, consisting of a cylindrical shell with tubes and a brickwork furnace at one end, was worked with a steam pressure of 145 pounds, air pressure 3 inches, the rate of evaporation being about 12 pounds of water per square foot of heating surface per hour. Two trials each of about five hours' duration showed a temperature on fire side of tube plate of about 750 degrees; at a third trial a small percentage of oil (.07 of feed) was introduced into the boiler, and the temperature rose to between 750 degrees and 1,060 degrees on the fire side; at the fourth trial a small additional percentage of oil (.05) was introduced, and this caused the tubes to leak; the temperature became about 1,060 degrees on the fire side, and between 680 degrees and 750 degrees at the center of the tube plates' thickness, representing the mean temperature.

The experiments were conclusive in showing the importance of keeping the water side of the heating surface free from greasy deposit, and the water free from grease, and only confirms what is now well established in practice. To attain this end as nearly as possible, feed water filters are now commonly adopted in Her Majesty's ships, and also every effort is made to reduce the quantity of oil used for lubricating internal parts of engines to a minimum. As a means of preventing an excessive tube plate temperature near the tube jointings, the cap ferrule was introduced, a fitting which was fully described in the paper above referred to; and it only remains to add that, up to the present, experience has shown that this fitting has been very beneficial in preventing leaky tubes, and that the ferrule deteriorates but slowly on service.

The Devonport experiments were continued after those described in the paper of March, 1893, with the object of obtaining fuller information on the distribution of temperature over the tube plates and tubes. The result of one of these trials may be given. The boiler was worked with the steam pressure at 145 pounds per square inch, and air pressure at 3 inches, and the resulting temperatures of the fire box tube plate were, on the water side, 400 degrees; middle of plate, 617 degrees; fire side of plate, 750 degrees to 1,060 degrees; the temperatures of the tubes themselves were, on the fire side, 680 degrees Fahr. at fire box end, 617 degrees middle of length, and below 480 degrees at smoke box end.

During the series of experiments which have been made at Devonport, several other points were investigated, and some conclusions indicated, among which the following may be worth noting:

Brass and copper tubes are more liable to leakage than those of iron or steel.

Tubes of Lowmoor iron are as liable to leak as steel tubes.

The loss of efficiency, arising from a thin coating of grease deposit, was a substantial amount, averaging 11 per cent.

4. An occurrence in one of the new torpedo boat destroyers may also be mentioned as confirming the view that when the temperature is raised beyond 750 degrees, *i. e.*, about the temperature of melting zinc, leakage of tubes will occur. The vessel in question is fitted with four boilers, arranged in two stokeholds, two boilers in each, one main feed pump and one auxiliary feed pump being provided for each pair of boilers.

During a full speed run, a defective tube burst in the forward boiler, but this fact was not immediately recognized by those in the stoke hold; the water disappeared from the gauge glass, and in the endeavors to maintain the usual water level in this damaged boiler, the water became so low in the other boiler that the tubes were seriously overheated. Some idea of the temperature reached can be obtained from the fact that the solder securing the ends of the wire on the main steam pipes, and a zinc slab in the steam collector of the boiler, were melted, so that the temperature of steam had been above 750 degrees Fahr.

When the accident was realized, the defective boiler was shut off, and water pumped into the overheated boiler; the tubes of this latter leaked considerably at the steam collector joints, and required subsequent rerolling throughout, but no other repair. This incident took place in a water tube boiler, where the generating tubes enter the top collecting chamber below the normal water line; but a still more recent case of shortness of water and consequent overheating has occurred in a boiler where the generating tubes all enter above the water line, and in this case also tube leakage resulted, so that in every case the same result may be expected to occur if the critical temperature is reached.

It is satisfactory to note that in the case of the tube bursting, the safety appliances, viz., automatic ash pit doors and automatic stop valves on the boiler where the tube burst, acted efficiently, and no injury of any kind occurred; indeed, those in the stokehold first ascertained what had taken place from inquiries made by those on deck.

5. Experiments have also been made with a view of ascertaining the steam pressure required to actually burst sound boiler tubes of small diameter, and the results obtained are of interest.

A copper tube, 1 inch in external diameter and 15 B.W.G. (.070 inch) in thickness was taken from a boiler of a torpedo boat destroyer that had been steamed under forced draft at the full power to a large extent, partly filled with water, and the ends closed. It was placed on a smith's forge, inclined at an angle of about 20 degrees to the horizontal, and a pressure gauge fitted at upper end. On being heated the pressure rose to 200 pounds, and the blast was applied. The pressure rapidly increased to about 1,500 pounds, then rose to about 2,000 pounds, the tube bursting 6½ minutes after pressure was first shown on gauge. The bursting pressure was not definitely noted, as the limit of the pressure gauge was exceeded, but as far as could be judged, only to a slight extent. The tube had apparently burst at the bottom next the fire; but the whole portion that was subjected to heat was split open and practically flattened.

Taking the bursting pressure at 2,000 pounds, this would correspond to a stress of about 14,700 pounds, or 6.55 tons per square inch.

By calculation, the temperature of the steam would probably be about 640 degrees Fahrenheit.

A similar experiment was made with a new steel tube intended for a torpedo boat destroyer boiler. This tube was 1¼ inches in external diameter, and 12 L.S.G. (.104 inch) thick, and had been coiled cold into a spiral of about 6 inches in diameter. This tube, which was half filled with water, burst at a pressure of 4,788 pounds per square inch, *i.e.*, 42¾ cwt., in which gauge was graduated; in this case, the tube separating and only flattening out locally. This pressure corresponds to a stress of about 28,800 pounds, or 12.85 tons per square inch. The temperature of steam in this instance would probably be about 800 degrees Fahrenheit.

Although it was endeavored to approach the circumstances of actual working, it must be borne in mind that in these experiments the tubes were partially filled with water and only slightly inclined to the horizontal, whereas in water tube boilers where such small tubes are used, the tubes are generally more nearly inclined to the vertical; and in all cases there is a stream of water, or water and steam, passing through the tubes when generating steam.

6. Coming now to another question, respecting which every member of this Institution will have some data obtained from his own experience,—I refer to the proportions of boilers for the powers to be developed,—there appears to be still a great deal of misapprehension in some quarters as to the proportions adopted in the Navy, and it may be desirable if I explain what this practice is.

For the ordinary tank boiler, the size of boiler fitted is such that one horse power is developed from each 2½ square feet of total heating surface on an eight hours' trial, termed the natural draft trial. For a shorter trial of four hours' duration, called the forced draft trial, this power is increased by 20 to 25 per cent., so that for this short period the heating surface is at least 2 square feet per indicated horse power.

On actual service, the minimum which it is insisted must be developed by the engines and boilers continuously for as long as the coal will last in the vessel, is 60 per cent. of the natural draft power, so that at this minimum power it will be seen that the heating surface is about 4 square feet per indicated horse power. This continuous power is clearly that which corresponds to the sea-going powers of the mercantile marine.

Although the Admiralty lay down this minimum power, there is no limitation of the amount obtained up to the full natural draft power, and on trials made expressly to ascertain the amount of power which can be continuously maintained, the minimum of 60 per cent. is generally considerably exceeded.

The table exhibited shows the results of a series of 14 trials and by inspecting the column No. 7, showing the heating surface for power actually developed, it will be seen that the Royal Navy and mercantile marine practice on this question is much the same.

7. No doubt members will have seen much discussion respect-

Trial at maximum continuous power.									
1.	2.	3.	4.	5.	6.	7.	8.	9.	
Ship.	Type.	Load on safety valve.	Duration of trial in hours.	Indicated horse power.	Heating surface.	Heating surface per indicated horse power.	Coal per indicated, horse power per hour.	Full natural draft power.	Type of boiler.
		Lb. p sq. in			*Sq. ft.*	*Sq. ft.*	*Lb.*		
Royal Sovereign..	Vertical triple..................	155	72	8,180	20,034	2.44	1.84	9,000	Cylindrical, single ended.
Royal Arthur.....	Vertical triple..................	155	72	8,821	24,828	2.81	1.85	10,000	Cylindrical, single ended.
Sans Pareil.......	Vertical triple........	135	50	7,051	19,980	2.83	2.23	7,500	Cylindrical, single ended.
Sirius.................	Vertical triple..................	155	64	4,555	15,918	3.19	2.03	7,000	Cylindrical, double and single ended.
Pallas..............	Vertical triple..................	155	73	3,620	11,109	3.06	...	4,500	Cylindrical, double ended.
Resolution	Vertical triple..................	155	48	8,085	21,178	2.61	2 1	9,000	Cylindrical, single ended.
Cossack..............	Horizontal compound.....	130	48	1,435	6,836	4.76	2.51	2,200	Cylindrical, straight away.
Mohawk	Horizontal compound	130	48	1,998	6,836	3.42	2 7	2,200	Cylindrical, straight away.
Fearless............	Horizontal compound.....	120	48	1,888	6,439	3.41	2.46	2,100	Cylindrical, straight away.
Spartan..............	Vertical triple..................	155	72	6,777	15,918	2 34	1.96	7,000	Cylindrical, double and single ended.
Bonaventure.......	Vertical triple..................	155	72	7,083	15,600	2.2	1.76	7,000	Cylindrical, single ended.
Partridge..........	Horizontal triple	145	48	719	2,087	2.9	2.1	700	Cylindrical, ——.
Vulcan.............	Vertical triple..................	155	48	7,236	15,868	2.19	1.86	7,200	Cylindrical, double ended.
Buzzard............	Horizontal triple	140	48	1,232	3,892	3.1	2.4	1,400	Cylindrical, straight away.

ing the merits and demerits of what is known as the induced draft system of increasing the rate of combustion in boilers.

Induced draft was first tried in the Navy afloat on H.M.S. *Vesuvius* in 1875; in her case, a 6-foot fan running 570 revolutions was used in connection with a boiler having 42 square feet of grate surface, producing about the same draft as an ordinary chimney; in this ship was also tried the effect of discharging the gases through a horizontal chimney with the outlet astern. Mr. Martin, who deserves credit for his persistent advocacy and has largely associated himself with this method of increasing the rate of combustion, made some further experiments with the system, and showed that a considerable draft could be obtained with it.

In 1889, it was decided by the Admiralty to make a comparative set of experiments with a boiler fitted with this system of draft, and subsequently with Navy forced draft, and a locomotive boiler at Portsmouth was selected for the purpose.

The results of these trials showed:

(*a*) That with fans used to produce the induced draft, there was no difficulty in obtaining high rates of combustion.

(*b*) That, as compared with forced draft, there was an appreciable gain in evaporative efficiency.

(*c*) Moreover, the open stokehold, if properly ventilated, has advantages in comparison with the closed stokehold.

It was, therefore, decided to proceed further with the system, and try it on board a ship, and for this purpose H.M.S. *Gossamer* was selected, one of her boiler rooms being fitted with induced draft, the other retaining the forced draft system.

An extensive series of trials was carried out in that ship, the net result of which was to show that while on other grounds there was little to choose between the two systems, the great convenience and comfort due to the conditions involved in working with an open stokehold, in lieu of a closed stokehold, were very valuable.

In view of these results further practical adaptations of the system have been made.

H.M.S. *Torch*, a gunboat, has been fitted on this plan, and still later H.M.S. *Magnificent*, a first-class battleship, and both these vessels have passed satisfactorily through their trials, and extended experience of the actual working of the arrangements at sea will soon now be obtained.

8. There is another subject, gentlemen, on which I may be permitted to offer a few remarks as illustrating the connection between the Royal and mercantile navies.

Many members of this Institute are Naval Reserve officers, and are, therefore, interested in the requirements of the Royal Navy.

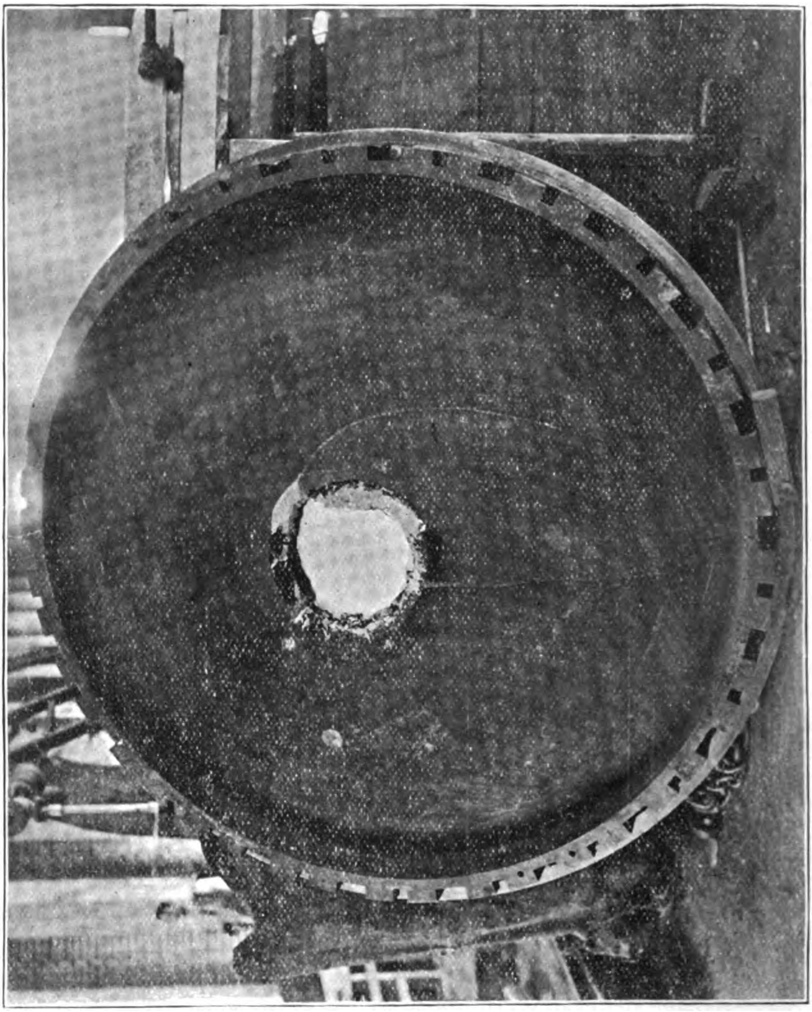
We have at present about 200 engineers of the mercantile marine enrolled as Royal Naval Reserve engineers, and the opinion has been often expressed that a certain proportion of these gentlemen should be given an opportunity of joining the Royal Navy for a limited period of training, in order to become familiar with the discipline of the engine department of a ship-of-war, and to acquire a knowledge of what may be termed extra-professional duties, such as those in connection with locomotive torpedoes and hydraulic gun machinery.

It has hitherto been held that engineers in the mercantile marine are employed on much the same duties as those they perform if called upon to serve in the Royal Navy, and that consequently no additional training is required, but this is a question that necessarily requires careful consideration. Although a naval training is not required to the same extent in the case of a Reserve engineer officer, as in the case of the Reserve executive officer, yet to enable the Reserve engineer to undertake the duties and responsibilities involved in the charge of the engineer's department of a warship, some previous service in the Royal Navy would be of the greatest possible advantage. If a certain proportion of the Reserve engineer officers were given the opportunity of serving for a period in the engine room of a man-of-war, and were afterwards paid the same retainer as in the case of executive Reserve officers of corresponding rank, it would, in my opinion, tend to promote a feeling of patriotism and content on the part of the Royal Naval Reserve engineer, and as it would also afford an opportunity of the naval engineer becoming acquainted with his [illegible] marine, it would also promote a very [illegible] feeling of good-fellowship.

I [illegible] official post I hold, discuss this matter [illegible] observed that some prominence has been [illegible] in a paper read before the [illegible] Service Institution on May 10, 1895, by Com- [illegible] I have ventured to express my [illegible] of affording engineer officers [illegible] Reserve an opportunity of becoming acquaint- [illegible] work and discipline of a man-of-war in time of peace, in order that they may be prepared to at once accept [illegible] if called upon to serve in the [illegible] in time of war or sudden emergency.

opportunity of the naval engineer becoming acquainted with his brother of the mercantile marine, it would also promote a very desirable feeling of good-fellowship.

I cannot, in view of the official post I hold, discuss this matter very freely, but having observed that some prominence has been given to it of late, and notably so in a paper read before the Royal United Service Institution on May 10, 1895, by Commander Caborne, R. N. R., I have ventured to express my personal opinion on the desirability of affording engineer officers of the Royal Naval Reserve an opportunity of becoming acquainted with the routine work and discipline of a man-of-war in time of peace, in order that they may be prepared to at once accept onerous and responsible duties if called upon to serve in the Royal Navy in time of war or sudden emergency.



NOTES.

FAILURE OF A CAST STEEL PISTON ON THE U. S. S. *CHARLESTON.*

The following description and photographs of the above failure were communicated by P. A. Engineer S. H. Leonard, Jr., U. S. N., now on that vessel:

The U. S. S. *Charleston* has horizontal compound engines, with cylinders 44 and 85 inches in diameter by 36 inches stroke. Last May, while the cylinders and pistons were undergoing the usual examination, what at first appeared to be a scratch showed on the fillet of the hub of the L.P. piston of the starboard engine. Careful cleaning and scraping, however, showed well defined hair cracks completely encircling the hub.

An inspection of the inboard side of the piston showed ten sand or blow holes within a radius of six inches of the piston rod, all in the upper half of the piston. Nearly all these were surface defects, yet one showed a depth of 2 inches, while into another a wire was worked to a depth of fully 4 inches, a crack running directly through this hole. Other circumferential cracks also showed on the inner face and relatively in the same position as those on the outer surface, though somewhat less pronounced than the latter.

The cracks showed most distinctly on the outboard lower side. In taking clearances, the piston was found canted correspondingly, the bottom having moved about $\frac{5}{16}$ of an inch towards the inner head of the cylinder, and the top the same amount towards the other head. The follower, its bolts, the ring and its springs, were all found secure and in good condition. The piston rod nut was also solid against the face of the hub, and the rod accurately parallel with the crosshead slide. As there was no record or knowledge of any undue strain having been brought on the piston, the only reason that could be ascribed for its condition was original and growing weakness, due to defective casting.

It was deemed that any further use of the piston would be dangerous, and it was accordingly removed. As a matter of interest to the Navy Department, as well as to the engineering profession at large, it was recommended that it be broken. This was accomplished at the Mitsu Bishi Works at Nagasaki, Japan, in the following manner:

The piston was supported at its rim, hub down, by four blocks placed 90 degrees apart; a steel collar 10 inches in diameter and 8 inches deep was placed directly on the center of the piston for the cast iron "dummy" to fall upon, the latter weighing 1,800 pounds and capable of being lifted 25 feet by the crane in the erecting shop. But four drops were necessary to knock the hub free from the disk, at the same time splitting the piston radially at two points—in one instance, clear through to the outer rim, and, in the second case, about three-fourths the distance. The results of the successive falls were as follows:

First. The cracks opened very perceptibly, especially on the under or hub side; several new circumferential cracks also developed.

Second. The cracks on the top side opened to fully ⅛ inch and on the bottom to ½ inch, scoria showing in the latter; the two radial cracks were also started and extended 12 inches in one case and 20 inches in the second.

Third. The cracks were still further opened, the shock throwing out fully a pint of scoria, fine coal, cinders and steel chips from the crack circumscribing the hub; the radial cracks extended about a foot towards the rim, one of the cracks assuming a spiral direction, while the other was straight. The sector enclosed by these cracks, at its inner end, was knocked fully 1 inch below the level of the surrounding disc, the fracture showing a fine close grain with no flaws.

Fourth. The boss or hub was knocked free, more scoria falling out. One of the radial cracks extended through the outer rim, the second extending to within 15 inches of the rim. The hub was found badly honeycombed, as is well shown in the photographs, the section having approximately but 35 to 40 per cent. of sound metal; in fact, had an additional ¼-inch cut been turned off the boss it would have entered the honey combing in several places.

The nature and extent of the defect show the correctness of the cause ascribed, faulty casting, and also of the decision regarding its dangerous condition.

In this connection it may be of interest to refer to page 88, volume iv, of the JOURNAL, where it is stated that four out of five defective cast steel pistons for cruiser No. 11 were rejected on account of deep sand and blow holes *at the center.*

EVAPORATIVE TRIALS OF BELLEVILLE BOILERS.

The Belleville boilers constructed by Messrs. Maudslay, Sons and Field, at their works at East Greenwich, for the new twin-screw steamer *Kherson*, built by Messrs. R. and W. Hawthorn, Leslie and Co. for the Russian Volunteer Fleet, were officially tried on November 1, 1895. They were arranged in series at the works (the backs and sides being built up with fire brick) exactly as they will be on shipboard. The atmospheric conditions were not altogether favorable. The working of the boilers was studied by several engineers. The contract required that the evaporation on a trial of 12 hours' duration should be 8 pounds of water per pound of coal consumed. There are twenty-four boilers in all on the *Kherson*, placed in three separate water tight compartments. It was decided that it would be sufficient to test two of the boilers, their total grate surface being 93 square feet, and the heating surface 2,946 square feet. Each boiler consists of eight elements, each element containing 20 wrought iron tubes, 4½ inches in outside diameter and about 8 feet 6 inches long. As it would have been expensive to erect a chimney as high as that for the steamer, about 100 feet from the grate, a temporary uptake and short smoke pipe were erected, and the draft assisted by a steam blast. There was a preliminary trial of 6 hours' duration on Tuesday, October 29th, the results of which are given in the following table:

RESULT OF PRELIMINARY STEAM TRIAL OF TWO BELLEVILLE BOILERS AT EAST GREENWICH, OCTOBER 29, 1895.

Time.	Net weight of— Welsh coal burned.	Net weight of— Water evaporated.	Evaporation per pound of coal.	Steam pressure. Boiler.	Pressure in blast pipe, in pounds per square inch.	Gas mixer. No. 17.	Gas mixer. No. 19.	Pounds of coal burned per square foot of grate.
	Pounds.	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*	*Pounds*	
11 to 12 M......	1,848	16,500	8.92	200	20	28	28	19.8
12 to 1 P. M...	1,747	16,500	9.44	200	23	28	30	18.7
1 to 2 P. M...	1,512	16,125	10.66	195	23	28	30	16 2
2 to 3 P. M...	1,747	16,500	9.44	195	23	28	30	18.7
3 to 4 P. M...	1,792	16,300	9.3	198	23	28	30	19.2
4 to 5 P. M...	1,568	17,000	10.84	198	23	28	30	16.8

The mean steam pressure was 197.6 pounds per square inch; mean evaporation per pound of coal, 9.76; average number of pounds of coal burned per square foot of grate, 18.23; mean blast pressure, 22.5; mean temperature of feed water, 64° F.

On the official trial also, Welsh steam coal of average quality was used. The fires were lighted at 5·40 A. M., the temperature of the atmosphere being 50 degrees Fahrenheit. By 6·20 A. M. the boiler pressure was 200 pounds, by the gauges, and ten minutes later a preliminary hour's trial was commenced, to allow the amount of coal and water used to be adjusted. From seven to eight, 18 cwt. of coal were burned, the evaporation being 8.8 pounds of water per pound of coal. The official trial commenced at 8 A. M., and continued for 12 hours, with the results given in the table on the following page.

During the first three hours the evaporation was equal to 9.2 pounds of water per pound of coal burned, and for the first six hours 9 pounds of water. At the end of the sixth and tenth hours the fires were cleaned, no allowance being made for this cleaning. The feed pump, of the special Belleville type, manufactured by Messrs. Maudslay, worked satisfactorily throughout, averaging about 11 double strokes per minute.

An accumulation test was next made to ascertain if the safety valves were capable of dealing with any quantity of steam likely to be produced. The valves were set at 245 pounds pressure, and the coal consumption was at the rate of 35 pounds to 40 pounds per square foot of grate surface per hour. This was continued for an hour, the maximum pressure recorded being 247 pounds.

EVAPORATIVE TRIAL, NOVEMBER 1, 1895.

Time. End of—	Coal burned.		Water evaporated.		Boiler pressure, pounds per square inch.
	Total, pounds.	Per square foot of grate, pounds.	Total, pounds.	Per pound of coal, pounds.	
1st hour......	2,016	21.36	17,700	8.78	200
2d hour......	4,032	21.36	36,000	8.93	200
3d hour......	6,048	21.36	55.700	9.20	200
4th hour	8,064	21.36	73.500	9.10	200
5th hour	10,080	21.36	90,000	8.92	200
6th hour.. ..	12,096	21.36	108,000	8 92	200
7th hour	14,112	21.36	126,000	8.92	200
8th hour	16.352	21.66	142,800	8.73	200
9th hour	18,368	21 62	160 500	8.73	200
10th hour	20.272	21.48	178,700	8 86	200
11th hour	22,400	21.58	196,700	8.73	200
12th hour	24,104	21.39	212,300	8.80	200

Temperature of feed 54 degrees, constant throughout trial.

The mean results of the above give 8.88 pounds of water evaporated per pound of coal, and 21.43 pounds of coal burned per square foot of grate surface. The mean temperature of the feed water was 54 degrees Fahrenheit, and the mean boiler pressure, 200 pounds per square inch.

No calorimetric tests of the steam were made.

FRENCH NAVAL REGULATION FOR SIZES OF EVAPORATORS.

The ministerial circular of December 12, 1892, required that a tank should be fitted in each ship to hold fresh water for the boilers, and that the tank should have a capacity of about 525 gallons for each 1,000 horse power at maximum power.

Inquiry of the three squadrons on the 28th of March, 1895, showed the necessity of increasing the above allowance, preferably by increasing the power or capacity of the evaporators.

The following rules have therefore been adopted (Aug. 31, 1895,) for ships building and hereafter to be built:

1. The capacity of the fresh water tanks will remain as before.

2. The power of the evaporators will be 1,070 gallons a day for each 1,000 I.H.P. of the engines at maximum power.

3. The evaporators used will be on the triple system, with a capacity, in addition to that given above for make-up feed, of four times the daily consumption, on the basis of four litres per man. That is, it will be about 1,070 gallons a day for each 1,000 I.H.P. and 4 gallons a day additional for each man on board ship. On large ships this power will be in two plants, and on small ships, in one, but in the latter the distillers must be in duplicate.

A recent circular (October 8, 1895,) makes the following rules for the power of evaporators on torpedo boats, under construction or hereafter to be built:

In addition to supplying about 4 gallons of potable water per day for each man on board, the evaporators must be able to supply for seagoing torpedo boats, first-class, about 800 gallons; for second-class boats, about 935 gallons; and for third-class boats, from 1,200 to 1,335 gallons per day per 1,000 I.H.P. of the maximum power.

All torpedo boats will receive a reserve supply of about 270 gallons of fresh water for each 1,000 I.H.P. of the maximum power.

FACTORS OF SAFETY FOR MARINE BOILERS AND ENGINES.

The following review of Mr. Key's paper is taken from "Engineering," London, October 4.

Mr. John Key, of Hull, read a useful and suggestive paper on "Uniform Factors of Safety for Boilers and Machinery of Steamships." The author pointed out that no uniform code of international regulations has yet been adopted by maritime countries for the safety of ship machinery. The following Table will prove useful, as showing the working pressures allowed by various authorities with steel boilers as stated:

Steel shells.	Percentage of joint.	Admiralty.	Board of Trade.	Lloyd's.	British Corporation.	Hamburg.	Bureau Veritas.
Diameter. Feet. × *Thickness. Inches.*		*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
5 × $\frac{3}{8}$	70	133.8	116.06	86.3	102.08	109.4	113.3
5 × $\frac{1}{2}$	70	178.4	154.7	129.4	142.9	146.3	152.8
12 × $\frac{3}{4}$	80	127.47	117 7	111.1	114.6	111.2	112 4
12 × 1	80	169.96	157 0	155 5	156.2	148.3	152.0
12 × $1\frac{1}{4}$	80	212.45	196.2	200.0	197.9	185.4	191.6
16 × $1\frac{1}{2}$	82	196.0	181.04	187.9	184.2	170 9	177 7

The water pressure test allowed by the British Admiralty provides that not four-ninths of the ultimate strength of the shell shall be exceeded, and the working pressure is fixed at 90 pounds below the test pressure, which is called the "constant margin" of safety for all pressures. The Board of Trade allow a factor of safety 4.5, with additions according to the circumstances of each case. Lloyd's Committee add $\frac{1}{8}$ inch, and the British corporation add $\frac{1}{16}$ inch to all thicknesses for wear, and their constants vary according to the form of riveted joint. Hamburg rules allow a factor of safety 5.0, reduced to 4.7 when the longitudinal seams are drilled and double riveted. Bureau Veritas allows a factor of safety of 4.4 after the plates have been corroded away by 0.04 inch. These authorities all differ in their respective rules for diameter of shafts, thickness of plates forming flat surfaces, stress on stays, thickness of plain or corrugated furnace tubes, steam pipes and area of safety valves. The author quoted as an example of how unnecessarily we are hampered by want of uniformity even in boiler fittings and connections in the case of water gauges, that the English Board of Trade insist on having cocks or valves next the shell of the boiler, whereas the German Board of Trade will not have such a fitting. The consequence is that ships running to Hamburg are fitted with two standpipes, one with cocks and one without. To this the English Board of Trade has to shut its eyes, as the German standpipe, from their point of view, is unsafe, and ought not to be allowed.

There is no doubt, that the anomalies to which Mr. Key here draws attention have caused for some time past considerable inconvenience, and there is no good reason why they should not be removed. It waits for some one to take action, and Great Britain, as the leading maritime State, might appropriately take the initiative. It is to be hoped Mr. Key's paper will bear fruit.

THE TORPEDO BOAT DESTROYERS.

The following is abridged from an editorial in "Engineering," London, of November 8:

There has been a good deal of misconception as to the speeds of these boats, it appearing to be a frequent custom of the daily press to look on each trial chronicled as the "record performance." It will be remembered that in introducing the Navy Estimates last year (financial year 1894–'5), the First Lord stated that forty-two vessels of this class had been ordered by contract; it being a condition in these contracts that the vessels should be completed in the coming financial year. At the end of the year, however, it was found that the conditions as to time could not be fulfilled by certain of the contractors. Some had been affected by labor difficulties; and "in all cases," we were told, "the novelty of the design and the very high speed demanded have involved the expenditure of considerably greater time in construction and in trials than had been anticipated." As a matter of fact, some of the contractors discovered that they had undertaken a task of greater difficulty than they had anticipated, and, if it had not been for a very liberal share of help and advice from the Admiralty, they might have found themselves in a very unpleasant position.

The list on the following page gives the trial speeds of all the torpedo boat destroyers, with water tube boilers, of which we have records. The speeds given are those obtained on the three hours' official trials, with the contract weight of 30 tons in the shape of coal, spare gear, &c., on board.

TORPEDO BOAT DESTROYERS WITH WATER TUBE BOILERS.

Name.	Builders.	Length of vessel.	Description of boilers.	Speed on three hours' official trial.
		Feet.		*Knots.*
Boxer	Thornycroft	201.5	Thornycroft	29.17
Surly	J. & G. Thomson	200	Normand	28.05
Ardent	Thornycroft	201.5	Thornycroft	27.97
Bruiser	Thornycroft	201.5	Thornycroft	27.97
Starfish	Naval Construction Company.	190	Blechynden	27.97
Janus	Palmers	200	Reed	27.80
Decoy	Thornycroft	185	Thornycroft	27.76
Daring	Thornycroft	185	Thornycroft	27.70
Hornet	Yarrow	180	Yarrow	27.63
Salmon	Earle's	200	Yarrow	27.60
Shark	J. & G. Thomson	200	Normand	27.59
Banshee	Laird	210	Normand	27.57
Ferret	Laird	195	Normand	27.51
Rocket	J. & G. Thomson	200	Normand	27.37
Contest	Laird	210	Normand	27.36
Sturgeon	Naval Construction Company.	190	Blechynden	27.16
Dragon	Laird	210	Normand	27.14
Skate	Naval Construction Company.	190	Blechynden	27.10
Handy	Fairfield	194	Thornycroft	27.04
Lynx	Laird	210	Normand	27.00

An inspection of this table brings out the notable fact that some of these vessels have obtained a better speed on the full three hours than was made during the six runs on the mile. This is to be accounted for by the load becoming lighter owing to the coal being burnt. That seems a natural result, but it did not occur in old times, speeds nearly always falling off towards the end of a long trial. The type of boiler used affords an explanation. With the multi-tubular boiler, either of locomarine or return tube type, the fouling of the tubes, "bird's nesting" on the tube plates, and other causes—perhaps not the least the flagging of stokers under the excessive and long continued strain—caused a fall of steam pressure during the last hour or so. With water tube boilers of properly designed form, the work is much easier for the men, the space for combustion is larger, tubes do not get choked, there is no surface for "birds' nests" to form upon, and the proportions of the boiler allow of easier blowing. The consequence is that an extended trial trip is no longer the trying ordeal it was formerly, and this is not the least of the advantages of the water tube boiler.

We believe the speeds given to be strictly accurate. In some instances our representative has been present, and in every instance we have obtained our information from a trustworthy source. In every case the guaranteed speed has been exceeded, in many cases very largely exceeded, in spite of the fact that there is no premium for extra speed. Vessels with the locomotive boiler are not included in our table, as such vessels are, it will be remembered, allowed a knot less than those having water tube boilers, that is to say, the contract three hours' speed is 27 knots for water tube boilers and 26 knots for craft with locomotive boilers.

The *Boxer*, which heads the list with a lead of over a knot, or a total superiority of 3½ nautical miles on the three hours' run, was up to a short time ago not only the fastest vessel in the British Navy, but also the fastest in the world. Within the last month, however, her speed has been exceeded by two vessels. The first, the *Sokol*, although constructed for a foreign power, has been built in England by Messrs. Yarrow & Co., made 29.76 knots on her three hours' trial. Her length is 190 feet. The other vessel, the *Forban*, was built by Messrs. Augustin Normand & Co., of Havre. Her length is 144 feet 4 inches. The load of armament, coal, crew, &c., was 16 tons. On an hour's run the mean speed was 31.029 knots.

There yet remain nineteen of the forty-two destroyers to complete their trials. Some of the above have locomotive boilers. If we add to the above the *Dasher*, *Charger* and *Havock*, the three boats by Yarrow & Co., with locomotive boilers, which have passed their trials, we have the total number of forty-two boats ordered.

The element of speed, although not the sole quality necessary for a successful destroyer, is one of the very foremost qualities, and, moreover, it is one upon which a definite conclusion can be arrived at. Speed is the final result of the combination which comprises the vessel—that is, her elements of design; and when boats of one group are built to Admiralty requirements, and under Admiralty supervision, the fastest boat may be said to be the most successful. In estimating the speeds of these vessels, the state of the weather is a disturbing cause which cannot be allowed for. Contractors, however, are not likely to run trials when the sea is very rough. The measured mile courses are always near the coast, and though the wind may be high it does not necessarily mean that the waves are big when there is a weather shore. Again, some measured miles are more favorable than others for getting speed in large craft, or with small craft traveling at high speed. Until all boats are tried on the same course at the same time, we must trust somewhat to good luck.

It is often said that speed in these boats is a mere question of "brute force"—of cramming bigger engines into the boats. That hardly describes the situation. It is true the problem is largely one for the engineer; although Mr. Yarrow has shown us lately how speed can be much increased by an intelligent application of a knowledge of materials in hull construction; the French second-class torpedo boat, built of aluminium, and the *Sokol* being both instances in point. Still, the question is chiefly one of machinery. Now to put simply bigger engines and boilers into a given hull is not generally possible, but if the engineer can so design his machinery that he can get greater power out of the same space and weight afforded to less powerful machinery, there has been achieved a triumph of which he may be justly proud; and he is entitled to every credit for the additional speed of vessel. The working of the boilers is an important matter in this respect. One design may give a higher duty per square foot of heating surface than another. We have heard it objected that the speed in certain cases was only obtained by blowing harder; but some types of boiler will not stand blowing harder. It is a point worth considering by those who design these vessels.

The new torpedo boat destroyers, which are to follow the forty-two above dealt with, were originally intended to be twenty in number. Their guaranteed speed is 3 knots faster than that of the first lot, namely, 30 knots. We believe, however, that up to the present only twelve of these vessels have been ordered. They are not all of the same dimensions, but some, at any rate, will not exceed in size the largest of the forty-two. The extra speed will, therefore, have to be obtained chiefly by an increase in power. No doubt advantage will be taken of recent experience to lighten the scantling of the hulls, but whatever the resources brought to bear, it will be anxious work to get the guaranteed speed.

The new boats are named as follows: Messrs. Thornycroft's vessels, *Desperate*, *Fame*, *Foam* and *Mallard*, 5,400 I.H.P., 272 tons displacement; Messrs. Laird's, *Quail*, *Sparrowhawk*, *Thrasher* and *Virago*, 6,000 I.H.P.; Messrs. J. and G. Thomson's, *Brazen*, *Electra*, *Recruit* and *Vulture*, 5,800 I.H.P. The last eight are to have a displacement of 300 tons and Normand water tube boilers.

The load, we understand, is to be 30 tons, as with the former craft, so that the larger vessels will have an advantage of a smaller proportionate deadweight.

SHIPS.

UNITED STATES.

Battleships Nos. 5 and *6*.—The battleships were partially described on page 581 of the last number. The following information has since then been received. The cost of each of these ships is not to exceed $4,000,000, exclusive of armament. One of them is to be named *Kearsarge*, according to the act of Congress authorizing the construction of these ships.

Length between perpendiculars, feet	355
on load water line, feet	368
over all, feet	371
Beam, moulded, feet	72
extreme, feet and inches	72–2½
Freeboard, forward, feet and inches	14–3
amidships, feet and inches	11–0
aft, feet and inches	12–3
Draught, mean, normal, with 410 tons coal, feet and inches	23–6
Displacement at this draught, tons	11,500
Speed, knots	16
Area of midship section, square feet	1,623
load water plane, square feet	19,833
Wetted surface, square feet	30,000
Tons per inch of immersion	47.30
Moment to alter trim 1 inch, foot tons	948.5
Draught, mean, 1,210 tons coal, all stores, &c., feet	25
Displacement at this draught, tons	12,350
Metacentric height (25 feet draught) feet	4.5
Range of stability at same (12,350 tons displacement) degrees	57½
Maximum righting arm, feet	2.08
moment, foot tons	25,688
arm, angle of, degrees	32

There will be five torpedo tubes.

The height of axis of forward 13-inch guns above the normal L.W.L. will be 20 feet 8 inches; of the after 13-inch guns, 19 feet; of the forward 8-inch guns, 29 feet 3 inches, and of the after 8-inch guns, 27 feet 8 inches.

All armor is to be of Harveyized nickel steel. The water line belt will be 15 inches thick at the top and 9½ inches at the bottom, amidships, and have a depth of 7 feet 6 inches, the top of this belt to be 3 feet 6 inches above normal L.W.L. This belt will be of the above thickness abreast of the engine and boiler spaces; forward of this it may taper gradually to 4 inches; it will extend at least from the stem to the after barbette.

Thickness of side armor above water line belt, 5 inches; of superstructure armor, 6 inches; of 13-inch turret armor, 17 and 15 inches; of 8-inch turret armor, 11 and 9 inches. The barbette armor will be 15 inches thick, and the conning tower, 10 inches. The protective deck will be from 2¾ to 5 inches thick.

The hull will be of steel, unsheathed. There will be two military masts with fighting tops.

The total coal bunker capacity will be not less than 1,210 tons, stowed without trimming by hand.

Bidders for these ships may, if they desire, adopt the plans for the machinery proposed by the Navy Department in whole or in part, but all designs of machinery must fulfill the general requirements of the specifications prepared by the Bureau of Steam Engineering.

The cylinders will be 33½, 51, and 78 inches in diameter with a piston stroke of 48 inches. The H.P. cylinder of each engine will be forward and the L.P. cylinder aft. Piston valves will be used, one on the H.P., two on the I.P., and four on the L.P. cylinder. The valve gear, Stephenson link motions, will be interchangeable. There will be two condensers with a total cooling surface of 14,000 square feet measured on the outside of the tubes.

The propellers will be right and left, of manganese bronze or approved equivalent metal. There will be an auxiliary condenser in each engine room, having not less than 800 square feet of cooling surface.

Each main air pump will be double, vertical, single acting, worked by two inverted steam cylinders. The main circulating pumps will be of the centrifugal type, worked independently, one for each condenser.

Each auxiliary condenser will have a combined air and circulating pump.

There will be five cylindrical steel boilers, three double-ended and two single-ended, in four compartments. The total grate surface will be about 685 square feet; and the total heating surface about 21,500 square feet, measured on the outside of the tubes.

Each of the double-ended boilers will have eight, and each single-ended boiler four corrugated furnace flues, 39 inches internal diameter.

The mean outside diameter of all boilers will be about 15 feet 6½ inches. The two forward double-ended boilers will be about 19 feet, the after double-ended boiler about 21 feet, and the single-ended boilers about 9 feet 11½ inches long.

There will be two main feed pumps, one in each engine room. Approved auxiliary feed pumps will be placed in the forward fire rooms of the after boilers, in the after fire room of the forward boilers, and in the fire room of the after single-ended boiler. In addition there will be approved auxiliary feed, bilge, water-service, fire and other pumps.

There will be two smoke pipes.

The forced draft system will consist of one blower for each fire room, the blowers discharging into air-tight fire rooms. Air-tight bulkheads will be fitted to reduce the space under pressure.

There will be steam reversing gear, ash hoists, turning engines, auxiliary pumps, engine for workshop machinery, hydraulic pumping plant for various purposes, gun table or turret turning engines, a distilling and evaporating apparatus, and other supplementary machinery.

The weight of the machinery is not to exceed 1,100 tons.

Other general requirements for these vessels are as follows:

1. The average speed to be maintained on trial for four consecutive hours, under conditions prescribed by the Secretary of the Navy, shall be not less than 16 knots.

2. If the average speed falls below 16 knots and exceeds 15 knots, the vessel will be accepted, but a reduction in the contract price will be made at the rate of $100,000 per knot.

3. Should the average speed fall below 15 knots the Secretary of the Navy may, in his discretion, reject or accept the vessel at a reduced price, to be mutually agreed upon. In case of rejection of the vessel the contractors must refund any money that may have been paid on account.

4. Three years from date of signing the contract are allowed for the construction of these vessels.

5. All designs of the vessel submitted by contractors, in case the Department's designs are not accepted as a whole, must be in sufficient detail and accompanied by such plans, specifications and calculations that the Department may readily determine the value of each design.

Brooklyn.—This armored cruiser, described on page 805 of Volume IV (see also Vol. V, page 201), was launched from the works of the William Cramp & Sons' Ship and Engine Building Company, Philadelphia, on the 3d of October.

Nashville.—Gunboat No. 7, described on pages 722–727 of Volume V, and page 176, Vol. VI, was launched by the Newport News Ship Building and Dry Dock Company on the 19th of October.

Wilmington.—Gunboat No. 8, described on pages 727–729 of Volume V, and page 176, Vol. VI, was launched on the same day as the *Nashville*, having been built on the same slip.

Katahdin.—This harbor defense ram, previously described on page 202 of Vol. V, had her official trial in Long Island Sound on October 31. The measured course was 34 nautical miles long—two runs of 17 miles being made. The average corrected speed was 16.1146 knots. A full description of the trial will be given in the next number of the JOURNAL.

Gunboats Nos. 10 to *15*.—Bids for the construction of these boats, of which a description was given on pages 581–583 of the last number of the JOURNAL, were opened at the Navy Department on October 1.

The proposals were for the construction of (1) four light draught composite gunboats, *Nos. 10–13*, of about 1,000 tons displacement each, having a single screw and full sail power; (2) two light draught composite gunboats, *Nos. 14* and *15*, of about 1,000 tons displacement each, having twin screws and carrying steadying sails only.

Bids were asked for under the usual classes:

Class I.—Hull and machinery according to the Department's plans and specifications.

Class II.—Hull and machinery according to the bidder's plans and specifications.

The following bids were received:

Names of bidders.	Class of bid.	Type of vessel.	Number bid for.	Price bid.	Deduct for omission of—			Increase for the addition of steam windlass.
					Steam windlass.	Steam steerer.	Electric plant.	
Lewis Nixon	II.	Nos. 10 to 13	One	$238,200	$3,200	$3,000	$10,500	......
Union Iron Works	I.	Nos. 10 to 13	One	246,000	3,000	3,200	10,000	......
Union Iron Works	I.	Nos. 10 to 13	Two*	240,000	3,000	3,200	10,000	......
Detroit Dry Dock Co.	I.	Nos. 10 to 13	One	215,750	2,250	1,000	2,500	......
Detroit Dry Dock Co.	I.	Nos. 10 to 13	Two	429,000	2,250*	1,000	2,500	......
Bath Iron Works	I.	Nos. 10 to 13	Two*	229,400	......	......	......	......
J. H. Dialogue & Son	I.	Nos. 10 to 13	Two	460,000	......	......	......	......
Union Iron Works	I.	Nos. 14 and 15	One	215,000	3,000	3,200	......	$10,000
Union Iron Works	I.	Nos. 14 and 15	Two*	209,000	3,000	3,200	......	10,000
Detroit Dry Dock Co.	I.	Nos. 14 and 15	One	213,750	2,250	1,000	......	2,500
Detroit Dry Dock Co.	I.	Nos. 14 and 15	Two	425,000	2,250*	1,000	......	*2,500
J. H. Dialogue & Son	I.	Nos. 14 and 15	Two	460,000	......	......	......	......

* Each.

The contracts were awarded in November for the two twin-screw gunboats, *Nos. 14* and *15*, to the Union Iron Works, San Francisco, Cal.; for two of the single-screw boats to the Bath Iron Works, Bath, Maine, and for one each to Messrs. J. H. Dialogue & Son, Camden, N. J., and the Crescent Ship Building Co., Lewis Nixon, Elizabethport, N. J.

It having been decided that the treaty agreement with Great Britain would not permit the building of a warship on the Lakes, the bid of the Detroit Dry Dock Company was rejected.

Torpedo Boats Nos. 6, *7* and *8*.—Bids for the construction of these boats, described on page 583 of the last number of the JOURNAL, were opened at the Navy Department on September 10.

The act authorizing the construction of these boats provided that one of them should be built on the Pacific Coast, one on the Mississippi River and one on the Gulf, unless it was found that they could not be built at these places.

Four bids were received on the Department's plans and specifications:

Union Iron Works, San Francisco, one for $175,000.

Union Iron Works, San Francisco, two for $173,000 each.

Union Iron Works, San Francisco, three for $172,000 each.

Wolff & Zwicker Iron Works, Portland, Oregon, one for $168,700.

Moran Brothers, Seattle, Washington, one for $163,350.

The Herreshoff Mfg. Co., of Bristol, R. I., bid on their own plans for one or all three boats at $144,000 each.

The contract for torpedo boats Nos. 6 and 7 was awarded to the Herreshoff Co. and for *No. 8* to Messrs. Moran Brothers.

The trial speed of the Herreshoff boats is to be 27½ knots for two hours with a dead load of 27.32 tons. If this speed is not reached, but is above 26½ knots, the boats will be accepted at a reduced price at the rate of $10,000 per knot below 27½.

The trial speed of torpedo boat *No. 8* is to be 26 knots for two hours with the same dead load, 27.32 tons. Similar penalties for a trial speed between 25 and 26 knots are provided.

ARGENTINE REPUBLIC.

Buenos Aires.—The following description is taken from "Engineering," London:

On Saturday, November 2, the trial was made in the North Sea off the Tyne of a cruiser Messrs. Armstrong, Mitchell & Co. have lately constructed for the Argentine Government. The trial resulted in a very remarkable performance, but before giving details of this it is well we should describe the vessel.

The *Buenos Aires* is a twin screw, steel built, sheathed cruiser. Her building was commenced on February 2, 1893, and she was launched on May 10, 1895. She is 396 feet long between perpendiculars and 424 feet long over all. Her extreme breadth is 47 feet 2 inches. Her mean draught on trial was 18 feet 3 inches, at which the displacement was 4,740 tons. The estimated power with forced draft was 17,000 indicated horse power. The full complement of coal is 1,000 tons. The vessel is flush decked, but has a bridge forward and aft, connected by a flying gangway.

There is a conning tower forward protected by 6-inch armor, and the protective deck is 1½ inches thick on the flat and 3 inches on the slopes, but 5 inches thick over the machinery space. There are two masts, having fighting tops about 15 feet above the deck. There are also light tops above with a rail; these serving for look-out purposes. The armament is exceptionally powerful. There are, firstly, two 8-inch quick firing guns placed forward and aft respectively on the center line of the ship. These are protected by armored shields, which revolve with the guns. These two guns are mounted forward and aft of athwartship screens, which rise above the upper deck, and above which are the bridges. The upper deck, between these two screens, carries the majority of the guns. At each corner of the central battery thus formed is a 6-inch quick firing gun; thus there are four 6-inch guns on the broadsides. In the central battery there are also on each broadside six 4.7-inch quick firing guns. The smaller guns consist of sixteen 3-pounder quick firing guns and eight 1-pounder guns. Two of the 3-pounders are mounted on each bridge. There are five torpedo discharging tubes, one being through the stem, and the other four, two on each broadside. All are above water.

The accommodation for officers is extensive and well arranged, consisting of a spacious wardroom amidships, and a large room aft for the captain, or admiral if the vessel is used as a flagship. The officers' cabins are arranged on each side on the main deck. Two long passages extend nearly the whole length of the ship on the main deck. The crew are berthed forward in the usual way. The whole arrangements give an impression of roominess and comfort, indicative of a thoughtful and well planned distribution of space.

The machinery has been supplied by Messrs. Humphrys, Tennant and Co., of Deptford, a firm which has been associated with Elswick in so many of their triumphs of warship construction. The engines are of the usual type, being three-stage compounds, and having four cylinders, respectively 40 inches, 60 inches, and two of 66 inches each, the latter, of course, being the low pressure cylinders. The stroke is 36 inches. The boilers are of the ordinary return tube type, four being double-ended, and four single-ended. The tubes are fitted with the screwed ferrule which Messrs. Humphrys have introduced, and which answered most satisfactorily on Saturday's trial.

As already stated, the ship is sheathed. She was not originally designed as a sheathed vessel, the teak and copper covering being added after some progress had been made in the construction. As the Argentine Government has not the command of graving docks, the sheathing is a necessity. Naturally it takes somewhat from the speed of the vessel, as the sheathing, with its fastenings, being approximately the same specific gravity as water, nothing is gained in carrying power, whilst the bulk of the vessel is considerably increased. There is no doubt, however, but that the sheathing will add to the average speed of the vessel when on her station; as the luxuriant growth of weeds that flourishes on the bottoms of unsheathed vessels in a warm country, takes greatly from speed. The stem and stern frames are of manganese bronze, which material is used in the construction of the rudder, and also in the two three-bladed propellers.

The now usual form of ram is adopted. It would appear, at first sight, to those unaccustomed to the consideration of problems in naval architecture, that this blunt spur must detract from the speed of the ship. It must be remembered, however, that the spur is several feet below the surface of the water, so deep that no appreciable wave making resistance is set up. The conditions of resistance, therefore, more nearly approach those of a fish, or, to use a more apposite simile, those of a fish torpedo. It will be remembered that the early Whitehead torpedoes were made pointed at the fore end, but it was found that a fuller head was actually conducive to speed. For the same reason the propeller shaft brackets are made pear shape in horizontal section, the blunt part being forward; for though the below water position of these parts prevents appreciable wave making, eddy making is not to be neglected, water being far from a perfect fluid. Our fathers would have been right in their "cod's head and mackerel-tail" theory of naval construction if they had had to do only with submerged bodies; but surface waves somewhat upset the principle when applied to vessels.

The stern is formed with deadwood cut away. The cutting up of the stern part results in giving the ship excellent manœuvring powers, as was well shown during the trials when the ship turned at the ends of the miles; although no official turning trials were made. The rudder is partially balanced. The weight is taken by the pintle and stern post in the usual way.

The *Buenos Aires* had been taken from Elswick to Jarrow previously, and on Saturday last the trial party left Newcastle at an early hour, but fog prevented the start. Shortly after mid-day a start was made, and the ship, attended by her two tugs, proceeded down the river and to the measured mile, which is just north of Tynemouth. There were on board the members of the Argentine Commission and Mr. Guillermo Lauder, who will be engineer-in-chief of the ship. Mr. P. Watts, chief of the Elswick shipyard; Mr. Perrett, of the constructive department, and Mr. Magnus Sandison, engineer, represented the contractors. Mr. R. Humphrys and Mr. T. Soper were in charge of the machinery, representing Messrs. Humphrys, Tennant and Co.

The time being short, it was determined only to run the six-hours' trial with natural draft. It was settled at once to make the mile runs, and thus get the data, by means of the revolutions, necessary to determine the ship's speed in the straight out-and-home run. We are not aware what was the contract speed, but in any case it was so far exceeded that it became a matter of small importance.

The following are the times for the six runs:

	Min.	Sec.	Speed.
First run, ...	2	47½	21.493
Second run, ...	2	34	23.377
Third run, ...	2	41	22.360
Fourth run, ...	2	33	23.529
Fifth run, ...	2	39	22.642
Sixth run, ...	2	37	22.930

It will be thus seen that the first two runs gave, as a result, a slower speed than the remaining four, their mean being 22.435 knots. This is accounted for by the fact that the engineers had not time to work up to full power before going on the mile. It would have been preferable to have thrown the first two runs out and have made two more, but the contractors saw they had plenty in hand, and time was pressing. As the trial progressed additional power was developed, the revolutions increasing, and the ultimate result was a speed for the whole six hours of 23.202 knots; a performance which puts the *Buenos Aires* at the head of the sea-going ships of the world for speed of steaming. The air pressure during the trial never exceeded $\frac{4}{10}$ inch, and for some time the stokeholds were open. There was no lack of steam, as was shown by the fact that the safety valves were blowing steam hard at one part of the trial, and indeed the dampers had to be put up for a time. The boiler pressure was 155 pounds to the square inch, and the vacuum between 28 inches and 29 inches. The mean revolutions for both engines averaged 151 per minute. The indicated horse power was approximately 14,000. At the end of the trial, which was not completed until after dark, the ship returned to her moorings off Jarrow. The engines ran perfectly throughout, and there was no trouble of any sort from the boilers. What the ship would do with forced draft one can only speculate upon. The engines were linked up during the trial, but if they were given full steam, and the boilers were pressed, another knot would be doubtless a moderate estimate to put on the speed.

By the trials of the *Buenos Aires*, an English built ship once more stands first in regard to speed, putting aside torpedo craft. The pride of place has for some time been held by the United States cruiser *Minneapolis*, a vessel which made 23.073 knots on a run of 88 nautical miles. The *Minneapolis*, however, ran with an inch air pressure, and, we believe, is not sheathed; the latter condition being, perhaps, a quarter of a knot in her favor. She is 411 feet 7 inches between perpendiculars, or 414 feet 10 inches over all, her width being 58 feet 2 inches, so that she has a ratio of length to beam of 7.08, whilst that of the *Buenos Aires* is 8.39. The *Minneapolis* has three screws, a fact looked on as advantageous to her by her designers. Her main engines developed 20,366 indicated horse power on trial, the mean revolutions being 132.4, the steam pressure 148 pounds.

It will be remembered that the *Yoshino*, also built at Elswick, and of which ship we heard a good deal lately, made 23.03 knots on four runs with forced draft, thus coming very near the speed of the *Minneapolis*. That her designers have been able to produce a ship to beat the latter vessel is a fact of which they may be justly proud.

AUSTRIA.

Buda-Pesth.—This vessel, the last one of the three coast defence vessels of the *Monarch* class to be laid down, and now building at Trieste, is to have Belleville water tube boilers. The *Monarch* (described on page 417 of this year's May number) and the *Wien* have cylindrical boilers. The Belleville boilers, ordered from Messrs. Maudsley Sons and Field, are to have 720 square feet of grate surface and 22,500 square feet of heating surface and to supply steam enough for the engines to indicate about 8,400 horse power under natural draft. The I.H.P. of the *Monarch* is 8,380 under forced draft.

Wien.—The second of the *Monarch* type of coast defence vessel was launched at Trieste, July 6. For data of this vessel see *Monarch*, page 417 of this year's May number.

CHINA.

Fei Ying.—This torpedo cruiser, of 850 tons displacement, was launched in July by the Vulcan Company, at Stettin, Germany. There are eight Yarrow water tube boilers with straight tubes. The engines were built by the Vulcan Company. During the full power trial in September, she made 22 knots for four hours with 4,500 I.H.P., the air pressure being ⅞ inch.

CHILI.

This Government has placed with Messrs. Laird Bros., of Birkenhead, an order for four 30-knot torpedo destroyers.

ENGLAND.

Magnificent.—This battleship, fully described on pages 161–167 of this year's February number, has completed her speed and coal consumption trials with the following results. It is to be noted that the mean draughts on trials were very much less than the draught, 27 feet 6 inches, with 900 tons of coal, which corresponds to a displacement of 14,900 tons. With full load, and 1,800 tons of coal in bunkers, the mean draught is probably about 29 feet.

Speed trials.	*Natural draft.*		*Induced draft.*	
Date of trial	Aug. 29, 1895.		Aug. 31, 1895.	
Duration, hours	8		4	
Mean draught, feet and inches	24–11½		24–8½	
Speed, knots, by patent log	16.5		17.5	
	Starboard.	*Port.*	*Starboard.*	*Port.*
Revolutions per minute	95.48	96.51	99.8	100.8
Vacuum, inches	26.3	26.8	26.0	26.6
I.H.P., each engine	5,026	5,275	6,002	6,155
both engines	10,301		12,157	

The designed powers were 10,000 and 12,000 respectively. The coal consumption trials were run under natural draft on September 3 and 4, 1895, for 30 consecutive hours, the I.H.P. being limited to 6,000. The average steam pressure was 133 pounds per square inch; revolutions, 82 per minute; I.H.P., 6,086; speed, 14.65 knots; and the coal burned, 1.69 pounds per I.H.P. per hour. The weather was very favorable.

From the time this ship was laid down on December 18, 1893, to the date of her steam trials is only 20⅛ months, a very noticeable feat in battleship construction.

Majestic.—This vessel, described on page 167 of this year's February number, has had her speed and coal consumption trials.

Speed trials.	*Natural draft.*		*Forced draft.*
Date of trial	Sept. 12, 1895.		Sept. 17, 1895.
Duration, hours	8		4
Mean draught, feet and inches	24–11¾		......
Speed, knots, by patent log	16.9		17.8
	Starboard.	*Port.*	
Revolutions per minute	100.7	100.3	106
Vacuum, inches	27	26	......
I.H.P., each engine	5,254	5,164	......
both engines	10,418		12,497
Air pressures, inches of water	......		0.9

Coal per I.H.P. per hour was 2.07 on the natural draft trial.

In going out for her coal consumption trial in the latter part of September, the ship ran on a sand bank. The condensers were filled with sand and the trial was abandoned. After overhauling, the 30 hours' coal consumption trial was concluded on October 20, the ship running about 440 miles. The I.H.P. developed was 6,075, with a coal consumption of 1.84 pounds per I.H.P. per hour.

Prince George.—This first-class battleship, a sister ship to the *Majestic*, was launched at the Portsmouth dockyard on August 22. The machinery is by Messrs. Humphrys, Tennant and Co.

Victorious.—Another sister ship of the *Majestic* was launched at the Chatham dockyard on October 19.

The following is given in the London *Times* as the distribution of weights: Steel in hull, 4,560 tons; wood in decks, &c., 570 tons; fittings, 820 tons; armor, with its teak backing, 3,025 tons; protective plating, 1,250 tons; machinery, 1,320 tons; armament, 1,550 tons; general equipment, 740 tons.

As the *Victorious* is the largest and heaviest ship that has been built in this dockyard on a slip—other big vessels of her class having been built in dock and floated out—additional precautions had been taken to insure her taking the water successfully. The launching weight, as stated, was 5,460 tons, and it was said that the weight per square foot on the ways was 2½ tons. The weight of the cradle was 300 tons, so that the total weight on the ways was 5,760 tons.

The machinery was built by Messrs. Hawthorn, Leslie and Co., Newcastle-on-Tyne. The coal capacity in bunkers is 1,890 tons, 826 tons in lower bunkers, 424 in wing bunkers, and 640 on the protective deck. The total grate surface is 821 square feet and the total heating surface, 25,826 square feet.

Andromeda.—This first-class cruiser has already been described generally on page 418 of this year's May number. The hull is building at the Pembroke Dockyard. The protective deck will be 4 inches thick, arching from 6 feet below normal water line at the ship's side to 3½ feet above it in the center; abreast of the engines it will be carried up to the level of the tops of the cylinders.

Two of the fifteen 6-inch guns will be mounted on the forecastle and one on the upper deck aft, and will be protected by shields. The remaining twelve 6-inch guns will be in armored casemates, six on a side, four of these guns having a direct ahead and four a direct astern fire. The forward mast will have two military tops, each with 3-pounder guns; the other or mainmast will have one military top with one 3-pounder gun.

The twin-screw engines, for which the contract has been awarded to Messrs. Hawthorn, Leslie & Co., Newcastle-on-Tyne, will be of the four-cylinder, triple-expansion type, each with one H.P., 34-inches, one I.P., 55½-inches, and two L.P. cylinders, 64 inches in diameter. The stroke will be 4 feet. The engines are to make 110 revolutions per minute, equal to a piston speed of 880 feet per minute. The I.H.P. will be 16,500, and 20,000 if the draft is forced.

There will be thirty water tube boilers of the Belleville type, which are also to be built and supplied by the Messrs. Hawthorn. The total grate surface will be 1,450, and the total heating surface about 46,000 square feet. They will generate steam of 300 pounds pressure, which will be reduced to 250 pounds per square inch at the engines.

The estimated weight of the machinery is said to be 1,540 tons.

Diadem.—Sister ship to *Andromeda.* To be built by the Fairfield Shipbuilding & Engineering Co., Govan.

Europa.—Sister ship to *Andromeda.* To be built by Messrs. J. & G. Thomson, Clydebank.

Niobe.—Sister ship to *Andromeda.* To be built by the Naval Construction & Armaments Co., Barrow-in-Furness.

Arrogant.—This second-class cruiser, of which a general description was given on page 419 of this year's May number, is building at Devonport Dockyard. The contract for the machinery has been awarded to the Earle Ship Building Co. There are to be 18 Belleville boilers, having 4½-inch tubes. The total grate surface is to be 867 square feet, and the total heating surface, 26,000 square feet. The steam pressure in boilers will be 300 pounds per square inch, which will be reduced to 250 pounds at the engines.

Furious.—This cruiser, a sister ship to the *Arrogant*, is building at the Portsmouth Dockyard. The machinery is to be built by the Earle Ship Building Co.

Venus.—This second-class cruiser of the *Talbot* class (a general description of which was given on page 427 of this year's May number), was launched by the Fairfield Shipbuilding and Engineering Company, Govan, on September 5. The vessel was put into the water 240 days from the date of the order being placed. She is constructed of Siemens-Martin steel and sheathed with teak. In order to steady her for sea, she is provided with bilge keels of considerable length. There is a protective steel deck with a thickness varying from 1½ to 3 inches. A Harveyized steel coaming protects the engines. The conning tower is of the same material. There are 3 torpedo tubes, two forward under water and one aft above water. A speed of 20 knots is expected. The high pressure cylinders have piston valves, and the others double-ported slide valves, and the cylinders are separate castings. Steam of 155 pounds pressure is supplied from eight single-ended boilers, each with three furnaces. They are placed in two separate compartments, and fitted to be worked under forced draft with closed stokeholds.

Minerva.—This second-class cruiser, the general particulars of which were given on page 516 of Vol. V, was floated out of dock at the Chatham Yard on September 23. The keel was laid on December 4, 1893.

Proserpine.—This third-class cruiser, some data of which were given on page 419 of this year's May number, is to have Thornycroft boilers. The machinery of this vessel is building at the Devonport Dockyard and the hull at the Sheerness Dockyard.

Hermione.—This is one of the sheathed cruisers built at the Devonport Dockyard, under the Naval Defence Act, and launched November 7, 1893. The machinery was built by Messrs. J. & G. Thomson, Clydebank. Recently the ship underwent a series of steam trials which, in comparison with the contract trials, are interesting. These trials were to be run from Plymouth to Falmouth and back, one at 7,000 I.H.P. under natural draft, and another at 9,000 I.H.P. under forced draft. The results of these runs are given in the columns headed "Service," and the contract results have been added for reference.

	Natural draft.		Forced draft.	
	Contract.	Service.	Contract.	Service.
Date of trial	May 10, 1894.	August, 1895.	May 12, 1894.	August, 1895.
Length of trial, hours	8	4	4	2
Pressure in boilers	140	140	144	152
Pressure at engines	......	134	......	147
Revolutions per minute	128.7	126.4	137.4	134.25
Vacuum, in inches	26.3	25.3	26.8	24.75
I.H.P	7,393	7,207	9,264	9,044
Speed by patent log	......	18.3	19.5	18.95
Air pressure, inches	0.45	0.42	0.94	1.1

On the above forced draft trial, the P.I.P. valve rod heated and the engines were slowed for a short time; but for this, the mean speed would have been greater than 18.95, as a speed of 19.3 was made during a part of the trial.

The displacement on these trials exceeded that on the contract trials, and the bottom was not clean.

In addition to these trials, a series of sixteen progressive runs, four at 10, four at 13, four at 16 and four at 18.5 knots were made. Besides, two runs were to be made at the slowest possible speed, and two at full power under forced draft.

Most of these progressive trials were satisfactory, but no results have been published. Just before starting on the forced draft runs, 9,000 I.H.P., one of the I.P. slide valve rods was found to be bent. Further examination showed that a new valve would have to be made and several other defects would have to be repaired.

After repairs, one forced draft run was made, but the results were not considered satisfactory. The steam pressure was 155 pounds in boilers and 148 at engines, the mean I.H.P. being 9,195 and the speed, by log, 19.75. This was nearly the same speed attained a few days previously with about 7,000 I.H.P.

In October the machinery was examined and the slide valves were found so unsatisfactory that the ship was paid off and laid up for repairs.

Salmon.—This torpedo boat destroyer, which is one of the two vessels built and engined by Earle's Shipbuilding and Engineering Company, of Hull, made her official trial at the mouth of the Thames on Monday, July 29. The following account is taken from "Engineering," London. The trial was made under the superintendence of Lord Charles Beresford, Captain of the Medway Dockyard Reserve, Mr. J. Pledge and Mr. J. Harding representing the Admiralty. Mr. Dixon conducted the trials on behalf of the contractors. The *Salmon* is one of the larger type of torpedo boat destroyers, being 200 feet long and 19 feet 6 inches wide. The displacement in sea-going trim is 253 tons. The twin-screw engines are of the usual three-stage compound type, having cylinders 19½ inches, 28½ inches and 43 inches in diameter, the stroke being 18 inches. The specified weight for all machinery, including water in boilers, condensers, fittings, &c., was 125 tons, but Mr. Seaton has, we believe, been able to keep within this limit. The boilers are of the Yarrow type, being similar in general design to those placed by Messrs. Yarrow & Co. in the *Hornet.* They are reported to have worked in a perfectly satisfactory manner throughout the trial. It will be seen by the accompanying details of the trial that for the first four runs on the mile the speed was about 28 knots, whilst the mean speed on the usual three hours' run was 27.608 knots. This is a very good performance considering the comparatively small power developed. The following are the details of the official trial:

Date of trial	July 29, 1895.
Nature of trial	3 hours, full power forced draft, contractors'.
Draught of water { forward, feet	5
Draught of water { aft, feet and inches	7-3
Mean speed of ship, knots	27.608
Steam pressure in boilers, pounds per square inch	177
Air pressure in stokeholds, inches of water	2.62

	Starboard.	*Port.*
Vacuum in condenser	23.5	24.3
Revolutions per minute	354 5	355.25

Mean indicated horse power:	*Starboard.*	*Port.*
High	553	491
Intermediate	586	653
Low	647	659
Total, each engine	1,786	1,803
Both engines	3.589	

Details of the trial:	*Revolutions.*	*Speed, knots.*
First mile	363.6	27.565
Second mile	363.3	28.125
Third mile	363.0	28.125
Fourth mile	360.7	27.907
Fifth mile	354.4	27.692
Sixth mile	351.7	26.946
Admiralty mean	......	27.88

Total revolutions for three hours:	*Starboard.*	*Port.*	*Mean starb.*	*Revs. port.*
First half hour	10,802	10,734	......	......
First hour	21,259	21,216	......	......
1½ hours	32,142	32,017	......	......
2 hours	42,857	42,771	354½	355¼
2½ hours	53,462	53,472	....	......
3 hours	63,817	63,943	......	......

Mean speed 3 hours, 27.608 knots.

Starfish.—This torpedo boat destroyer, built by the Naval Construction and Armaments Company, Barrow-in-Furness, ran her official speed and steering trials on the Clyde on October 7th. The vessel is 190 feet long, 19 feet beam, and at 5 feet 7 inches draught displaces 252 tons. The engines are triple expansion, with cylinders 18, 27 and 42 inches in diameter by 18 inches stroke. There are four Blechynden water tube boilers working with a pressure of 200 pounds to the square inch. The grate surface is 170 square feet. The weight of propelling machinery complete, with water and spare gear, is 104.75 tons. The contract stipulated that the vessel should maintain a speed of 27 knots on a trial of three hours' duration with a deadweight of 30 tons on board, the revolutions of the engines necessary to give the speed being determined by running the vessel six times over the measured mile. As a mean of these six runs, the *Starfish* obtained a speed of 27.87 knots, while the remaining and longer part of the trial was run at a speed of 28.05 knots, making the mean of the whole three hours 28 knots, or one knot in excess of the guarantee. The mean revolutions of the engines on the three hours' run were 407 per minute, and the I.H.P. 4,510. The amount of coal consumed on the three hours' run was 15 tons 2 cwt., a most creditably small consumption per horse power for forced draft and water tube boilers. If the speed had been kept down to the guaranteed speed of 27 knots, the consumption would have been reduced to between 12 and 13 tons, which is a most excellent result. This coal consumption is said to be less than for any of the other British destroyers. The speed on mile runs was as follows:

Run.		Mean of Means.	Revolutions.	
1.	27.692	27.87	405.2	406.24
2.	28.082		400.2	
3.	27.650		406.9	
4.	27.907		405.6	
5.	27.907		413.9	
6.	28.082		399.2	

During the whole trial the steam pressure was easily and constantly maintained, and there was no objectionable discharge of flame from the smoke pipes.

The 12 hours' coal consumption trial proved highly satisfactory, although the weather was somewhat boisterous, and there was a very confused sea. A speed trial was made on the measured mile at Wemyss Bay to ascertain the revolutions corresponding to 13 knots, the speed at which the coal consumption was to be determined; the result was: Speed, 13.278 knots; revolutions, 169.56. The vessel afterwards cruised down the coast of Arran and in the neighborhood. The coal was weighed at the bunker doors by the representatives of the Admiralty and the contractors. The conditions of the fires, and the levels of the water in the boilers and feed tanks, were noted at the commencement of the trial, and left in the same condition at the end. The revolutions of the engines were taken by the counters every hour, as also were diagrams from the engines. Steam was maintained at 180 pounds per square inch. The results of the twelve hours' trial were as follows: Speed, 13.03 knots; revolutions, 166.37 per minute; indicated horse power, 400.4; total coal consumed, 8,906 pounds; knots steamed per ton of coal, 39.32. Before commencing the trial a portion of the grate surface was covered with clinker. At the end of the fifth hour still more of the grate surface was covered. During the remaining seven hours of the trial, the results were much improved, being: Speed, 13.11 knots; revolutions, 167.245 per minute; indicated horse power, 402.3; coal consumed in seven hours, 4,599 pounds; knots steamed per ton of coal, 44.8; coal burnt per indicated horse power, 1.635 pounds per hour. The results for both the 12 and 7 hours are said to be better than any hitherto recorded in vessels of this class built for the British Navy, the highest previous record being about 38⅛ knots per ton of coal. As this vessel has a bunker capacity of 70 tons, she will have a radius of action at 13 knots speed of 2,800 miles at least, which will compare very favorably with many large vessels. The observations made while rolling broadside on the sea gave the time of complete oscillation as from 4.4 to 4.8 seconds.

It has been decided to replace the copper tubes in these boilers by steel tubes.

Quail.—One of four 30-knot torpedo boat destroyers building by the Messrs. Laird Bros., Birkenhead, was launched on September 24, 1895, eighty-eight days after the laying of the first plate. The displacement is 300 tons and the I.H.P. 6,000. The armament consists of one 12-pounder, five 6-pounders, and four 18-inch torpedoes. There will be two revolving torpedo tubes.

Sparrowhawk.—The second of the above Laird-built torpedo boat destroyers was launched on October 8, one hundred days after the laying of the first plate. The two remaining destroyers are to be named *Thrasher* and *Virago.*

30-Knot Torpedo Boat Destroyers.—Besides the four destroyers mentioned above, the *Desperate, Fame, Foam* and *Mallard*, are constructing by Messrs. Thornycroft & Co., Chiswick. Their displacement will be 272 tons, and the I.H.P., 5,400. Messrs. J. & G. Thomson, Clydebank, have the contract for the *Brazen, Electra, Recruit* and *Vulture.* Their displacement will be 300 tons and the I.H.P., 5,800. The armament is the same as that of the Laird destroyers.

Lynx.—After the accident by grounding (an account of which was given on page 170 of this year's February number), and the completion of the consequent repairs, a full power trial was undertaken in July. While the engines were developing about 3,500 I.H.P., a tube exploded in the forward water tube boiler (modified Normand type), happily without injuring any one, and the trial was stopped. Later, further defects were discovered. After repairs, a satisfactory trial was completed on August 7, the mean results of which are: Steam pressure at engines, 152 pounds per square inch; vacuum, 26 inches; revolutions, starboard engine, 309.3 and port engine, 303.4; I.H.P., starboard engine, 1,858, and port engine, 1,685; total I.H.P., 3,543; air pressure, 3.6 inches; speed by patent log, 22.2 knots.

She is now to be commissioned at Devonport Dockyard for the training of the engineer's force in the management of water tube boilers. Her complement of officers and men for this purpose will be forty-two.

Banshee and *Ferret.*—These torpedo boat destroyers (the former described on page 424 of the May number, and the latter on page 613 of Vol. VI), are to be commissioned for the same training purposes as the *Lynx*. The complement of officers and men of the *Banshee* will be fifty.

Spanker.—This torpedo gunboat has had her old boilers replaced by four water tube boilers of the DuTemple type. Each boiler has 736 tubes. These boilers were bought in France and put in the ship by the dockyard force. Before they left the makers' works, they were tested to 280 pounds per square inch by hydraulic pressure and 154 pounds per square inch steam pressure. Each boiler is to be tested separately for four hours for evaporative power, the contract requiring that each boiler shall supply, for the four hours, 8.8 tons of dry steam at 155 pounds pressure, with an air pressure not exceeding 4 inches of water.

The weight of the boilers without water is estimated at 12.3 tons, and including water, at 15.25 tons. About $30,223 was paid to the manufacturers for the boilers, and about $65,823 has been expended by the dockyard in fitting the boilers on board.

This vessel, built in 1890, at a total cost of about $262,658, has since cost for maintenance and repairs (including the new boilers) about $109,395, although she has never seen service beyond the naval manœuvres in home waters.

The new boilers were tested for evaporative efficiency and coal consumption with satisfactory results in August, but no data have been published.

A series of trials, similar to those with the *Sharpshooter*, are to be undertaken with this vessel.

Sharpshooter.—The four series of trials mentioned on page 601 of the last number, were satisfactorily completed in October. At the end of the eighth trial, a cracked L.P. cylinder head besides minor defects were discovered. Further trials are to be made, one of eight hours with the six after boilers, the engines indicating 2,300 H.P., and another of four hours, with the same boilers, at 2,800 I.H.P. Then trials in suddenly stopping and starting when running at full speed, and in starting and stopping at intervals. Also, to lie under banked fires for four hours and then go ahead at full speed and be manœuvred as if in action. These trials are all to take place sometime in November, in the channel off Plymouth, after docking and making good the various defects caused by the previous series of trials.

After these trials are completed, the *Sharpshooter* will be used as a training ship for the men of the engineer's force, more especially for those who are to serve on the *Powerful* and *Terrible*. It is hoped that in nine months a sufficient number of men can be trained in the use and care of Belleville boilers for this purpose.

Sturgeon.—This torpedo boat destroyer, the trials of which were noted on page 425 of this year's May number, and on page 602 of the August number of the JOURNAL, is to have the copper tubes in her boilers replaced by steel tubes.

Sunfish.—This torpedo boat destroyer, which has been designed, built and engined by Messrs. R. and W. Hawthorn, Leslie and Co., had a second preliminary trial on August 1 prior to leaving for Chatham. The mean speed attained, with full load on board, on six runs was 27.24 knots with an air pressure of 2½ inches, the revolutions being 340. The vibration was slight. The boilers are of the Yarrow type. Both engines and boilers worked splendidly.

Haughty.—This torpedo boat destroyer was launched from the shipbuilding yard of Messrs. Doxford and Sons, Sunderland, in the presence of several thousands of spectators. She is built on the most approved lines, is 196 feet in length, 19 feet broad, and 12 feet 6 inches deep. Her designed speed is 27 knots. She will carry a complement of about 50, a 12-pounder quick firing gun, and five six-pounders.

FRANCE.

Charlemagne.—This battleship, described on page 427 of Vol. VI, was launched at Brest on October 5.

Designed by M. Thibaudier, director of the arsenal at Rochefort, she was intended to be one of three battleships of a new type, her sisters being the *Saint Louis* and *Henry IV*; but the last named has been designed afresh upon a smaller displacement. The length of the *Charlemagne* (385 feet 6 inches) exceeds that of any other French battleship yet afloat, and she is built upon finer lines than her predecessors, her beam being 67.26 feet. The dimensions of the *Jauréguiberry* are 356 feet and 72 feet 8 inches. This new character, which permits greater possibilities of speed, is made possible by a redistribution of the armament. In recent French battleships the heavy guns have been placed singly in turrets or barbettes, two in the keel line of the ship, fore and aft, and one on each beam; but in the *Charlemagne* and her sister—as well as in the *Gaulois*, which is to be laid down on the slip which the first of these vacates—the English system of coupled guns has been adopted. Four 11.81-inch guns are thus to be mounted, in two closed turrets well above the water line, for the vessel has high freeboard, the type of the *navire à plage*—of which the *Hoche* is an example—being now definitely abandoned.

The rest of the armament and the armor protection and machinery have already been described.

Foudre.—This torpedo transport or depot ship, the construction of which was commenced in 1892, and a general description of which was given on page 126 of Vol. IV, was launched by the Chantiers de la Gironde, at Bordeaux, on October 20. As this vessel is to serve the same purpose as H. M. S. *Vulcan*, a comparison of the two will be interesting.

	Foudre.	*Vulcan.*
Length, feet and inches	370–9	350
Beam, feet and inches	52–6	58
Draught, aft, feet and inches	23–5½	23
Displacement, tons	5,876	6,630
I.H.P	11,244	12,000
Speed, knots	19	19
Coal carried, tons	850	1,000
Armament, all rapid fire guns	10, 3.9-in.; 4, 2 5-in.; and 4, 1.45-in.	8, 4.7-in; 12, 3-pounders.
Torpedo boats carried	10	9

The *Foudre* is furnished with powerful apparatus for hoisting in and out the ten vedette torpedo boats which she is to carry upon her deck, and which are all built of aluminum. Several of them are ready or in hand, and five more are to be built in 1896. The pattern boat was constructed by Messrs. Yarrow Co., and attained a mean spead of 20.56 knots at the mouth of the Thames in September, 1894. She displaced 14 tons, and was 62 feet 4 inches long, with a three-cylinder engine and Yarrow boilers, but was built of French materials. By the use of the lighter material a saving of 2 tons was effected on a total weight of 9½ tons, including machinery.

It will be noticed that the *Foudre* has very much finer lines than the *Vulcan*, although a slightly greater draught. Whether the lighter boats and consequent lighter hoisting apparatus will justify the greatly decreased beam of the *Foudre* and make the hoisting in and lowering of the torpedo boats safe in a moderate sea-way remains to be seen.

Chateaurenault and *Guichen*.—These are the new rapid cruisers, a general description of which was given on page 602 of the last number. There will be three screws, each driven by an engine of about 8,000 I.H.P., the estimated speed being 23 knots. There will be 36 water tube boilers in six compartments, forward and aft of the engines.

Jurien-de-la-Gravière.—This sheathed second-class cruiser is to be commenced at Cherbourg. She will be of the same type as the *Descartes*, have a displacement of about 4,000 tons and a speed of at least 19 knots.

Flibustier.—The following particulars of this sea-going torpedo boat, built by Normand, Havre, a mention of whose trial is made on page 430 of this year's May number, are from "La Marine de France":

Length on load water line, feet	137.80
Breadth, extreme, feet	14 76
Depth amidships, feet	9.84
Draught, aft (for screws), feet	7.87
of hull, at midship section, on trial, feet	4.53
Immersed midship section, square feet	47.79
Displacement on trial, tons	123.34
Speed on trial, knots	25.66
I.H.P., estimated	2,466
Coal carried on trial, tons	17

Her armament comprises one fixed tube in the stem, one swivel tube on deck just above the engines, and two 47-mm. rapid fire guns placed abaft the conning tower.

The engines are twin-screw and of the triple expansion type, and the boilers, two in number, of the DuTemple-Normand type, having a collective grate and heating surface of 66.7 and 3,078 square feet, respectively.

The weight of machinery, including water in boilers, is about 51 tons.

During the naval manœuvres last summer, she is said to have maintained a speed of 20 knots for eight hours.

Forban.—This sea-going torpedo boat, built by Messrs. A. Normand and Co., Havre, France, and designed for a speed of 30 knots, was briefly described on page 429 of Vol. VI. She was launched on July 24, 1895. Her dimensions are:

Length between perpendiculars, feet	144.36
Breadth at water line, feet	14.50
extreme, feet	15.29
Depth amidships, feet	9.96
Displacement on trial, tons	125
load, tons	136

Her armament consists of two 37-mm. rapid fire guns and two 14-inch torpedo tubes.

She is a twin-screw boat, with triple expansion engines, steam for which is supplied by two Normand boilers. The original design contemplated the use of aluminum for some of the working parts of the engine, but its use was soon abandoned. She is supplied with the Normand feed water heaters and filters; and one peculiarity of her machinery is that the condenser tubes are curved and expanded into the tube sheets.

The preliminary trial made on September 17, 1895, to determine the coal consumption at 14 knots, lasted eight hours, the resulting consumption, reduced to 14 knots, being 423.4 pounds per hour.

The official full speed trial of the *Forban* took place on the 26th of September, the load carried being 16 metric tons, or 15¾ long tons, and included torpedoes and their launching tubes, guns, coal, equipment, provisions, drinking water and electric plant. It was made as follows: At the beginning of the trial three runs were made over the measured base at Cherbourg, and the revolutions per knot noted; then a run in free route, lasting one hour, during which the revolutions of the engines were again noted; and, at the expiration of the hour, three more runs on the base, the revolutions per knot being again noted for each run. The speed in free route was then determined from the revolutions per knot on the base by taking the means of the means for each series separately, the middle run of each series entering twice in determining the mean for the series.

As thus determined, the mean speed for the one hour run in free route was 31.029 knots, the fastest speed yet made by any boat afloat.

The I.H.P. on trial was not stated, but the *Forban* was designed for 3,200. The coal consumption was 2,695 kilos, or 5,942.5 pounds per hour.

GERMANY.

Battleship, First-class—Ersatz *Preussen.*—The principal dimensions of this new triple-screw battleship, now building, are as follows:

Length, feet	377.3
Beam, feet	66.93
Draught, feet	25.7
Displacement, tons	11,000
I.H.P	13,000
Speed, knots	18

The armor belt will extend about four-fifths of the length of the ship, beginning at the bows. The three propellers will be specially protected by curved iron sheathing under water. The armament will consist of six 9.45-inch guns in barbettes having 12 inches of armor; eighteen 5.9-inch rapid fire guns; twenty-four other rapid firing guns; and six torpedo tubes. The central battery will be protected by 3 inches, and the conning tower by 9 inches of Harveyized steel armor.

The cost of the ship is estimated at 14,250,000 marks, exclusive of the armament, the cost of which will be about 5,000,000 marks. The time allowed for construction is four years.

Armored Cruiser, First-class—Ersatz *Leipzig.*—The principal dimensions of this sheathed steel cruiser, to be built at the dockyard in Kiel, are as follows:

Length, extreme, feet	410.1
between perpendiculars, feet	383.9
Beam, extreme, feet	66.93
Draught, feet	25.91
Displacement, tons	10,137
I.H.P., about	13,000

The thickness of the side armor will be 7.87 inches, and that of the armored deck, from 1.97 to 3.15 inches. The armament will consist of two 9.45-inch, 40-caliber guns; twelve 5.9 inch, and ten 3.46-inch rapid fire guns; eighteen machine guns and five torpedo tubes.

Water tube boilers will be used.

Three Protected Cruisers, Second-class.—K, L, and Ersatz *Freya.* —These steel, triple-screw cruisers, about to be commenced, will have the following principal dimensions:

Length, feet	344.4
Beam, feet	57.07
Draught, normal (500 tons of coal), feet	20.5
load (950 tons of coal), feet	21.68
Displacement at normal draught, tons, about	5,561
load draught, tons, about	6,004
I.H.P.	10,000
Speed, knots	21

The hull of one of these cruisers will be built at the Dockyard in Danzig, and the machinery by the Germania Co., of Kiel. The other two will be built entirely by contract, one by the Vulcan Co., of Stettin, and the other by the Weser Co., of Bremen.

The protective deck will vary in thickness from 2.3 to 3.9 inches, the lower end being 5 feet below, and the upper, horizontal and central part, 20 inches above the normal water line. On each side, for a length of 230 feet, there is a belt of cork, about 8½ feet high and 27½ inches thick.

The armament will consist of two 8.2-inch, 40-caliber guns in turrets; four 5.9-inch rapid fire guns in turrets and four in armored casemates; ten 3.46-inch rapid fire guns, protected by shields; ten 1.45-in rapid fire guns; four machine guns, and three submerged torpedo tubes, one in the bow and one on each broadside.

There will be two military masts, the forward one having two and the after one a single fighting top.

These ships will be propelled by triple screws, each engine being in a separate compartment, and have water tube boilers arranged in six separate compartments.

Komet.—The trials of this torpedo cruiser, which has been under construction for several years, were recently completed and a speed of 20.8 knots made for two hours with 214 revolutions of the engines. She was built at the Vulcan works, Stettin, and was designed for a speed of 22 knots, with 5,000 I.H.P.

Much conflicting data have been published respecting her dimensions, but the following, taken from the description accompanying her model at the World's Columbian Exposition, is believed to be correct: Length, 256 feet; breadth, 31½ feet; mean draught, 10.25 feet; displacement, 990 tons.

Her battery comprises four 3.5-inch and nine smaller rapid fire guns, and one torpedo tube.

HOLLAND.

Friesland, Holland, Zeeland.—These three steel, twin-screw, protected cruisers are now under construction. The first is to be built by the Netherlands Steamship Co., at Feijenoord; the second at the Dockyard in Amsterdam; and the third by the Schelde Co., at Vlissingen. These vessels are to be completed by the beginning of 1898. The following are the principal dimensions:

Length between perpendiculars, feet	294.3
Beam, extreme, feet	48.23
Draught, greatest, feet	17.71
Displacement, tons	3,838
I.H.P., about	9,124
Speed, knots	20

The protective deck will be made of two plates of a total thickness of 2 inches. The double bottom will extend over the greater part of the length of the vessels. The coal bunkers are abreast of the machinery, above the protective deck.

The conning tower will be of nickel steel 3.94 inches thick. Aft there will be a directing tower for the torpedoes, 2.95 inches thick.

The armament will consist of two 5.9-inch rapid fire guns, one on the forecastle and the other on the poop; six 4.7-inch and four 2.95-inch rapid fire guns on the upper deck; four 1.46-inch rapid fire guns on main deck, four on the two bridges, and four

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in the tops of the two military masts; and four torpedo tubes, one in bow, one in stern and one on each broadside.

There will be either two triple or two quadruple expansion engines, to work at 145 revolutions per minute. The cylinder diameters for triple expansion engines are to be 33, 49 and 74 inches, and for quadruple expansion engines, 28.94, 39, 53.5 and 72 inches, the stroke being 39 inches.

The I.H.P., 9,124, is to be maintained during a four hours' trial with a maximum air pressure of 2 inches of water.

There will be two cylindrical and eight Yarrow water tube boilers, the working pressure of all to be about 200 pounds per square inch.

The total grate and heating surfaces of the two cylindrical boilers will be 200 and 4,000 square feet, respectively; and for the eight Yarrow boilers, about 320 and 16,000 square feet, respectively.

There will be electric lighting throughout and electric signals for interior communication.

ITALY.

Vittor Pisani.—This armored cruiser, laid down on December 7, 1892, was launched on August 14 at Castellamare. The principal dimensions are as follows:

Length, greatest, feet	346 8
Length, between perpendiculars, feet	324.8
Beam, feet	59.16
Draught, forward, feet	22.31
aft, feet	23.62
mean, feet	22.96
Displacement, normal, tons	6,397
I.H.P.	12,822
Speed, knots	20

The water line belt is of nickel steel, 5.9 inches thick and extends along the whole length of the vessel, and is surmounted, for about two-thirds the length of the vessel, by an armored citadel, also 5.9 inches thick. In this central citadel are placed eight of the twelve 6-inch guns. The vital parts of the vessel are further protected by a curved steel deck the thickness of which varies from .87 to 1.46 inches. The conning tower is 5.9 inches thick.

The armament consists of twelve 6-inch guns; six 4.7-inch guns, four in broadside, one forward and one aft; two 2.95-inch; ten 2.24-inch; ten 1.46-inch, and several machine guns. There are five above-water torpedo tubes, one of which is in the bow.

The machinery was built by the Hawthorn-Guppy Co. of Castellamare, the twin-screw triple expansion engines being in two separate compartments. There are eight single-ended four-furnace boilers, in four compartments, forward and abaft of the engines. The working pressure in the boilers is 155 pounds per square inch.

The propellers are four bladed. The I.H.P. at natural draft is 8,482, and at forced draft, 12,822.

At normal load, the coal supply is 590 tons. The maximum amount of coal that can be carried is about 984 tons, besides liquid fuel.

The complement is 26 officers and 425 men.

Elba.—This sheathed steel cruiser, which was launched at Castellamare in 1894, has had her trials. The hull and machinery were built in Castellamare.

The following are the general particulars of the vessel and the results of her trials:

Length, feet	272.3
Beam, feet	39.37
Depth, feet	28.21
Displacement, feet	2,697
I.H.P., designed	6,411
Speed, designed, knots	18

The armament consists of seven 6-inch, six 4.7-inch, eight 2.24-inch, six 1.46-inch, two machine guns and two torpedo tubes.

The machinery was built by the Hawthorn-Guppy Co., of Castellamare.

The six hours' trial under natural draft was made off Naples on May 20, the ship's bottom being foul, with the following results:

Displacement, 2,660; mean draught, 15.35 feet; sea smooth; mean pitch of propellers, 15 feet; steam pressure in boilers, 128 pounds per square inch; average number of revolutions per minute, 135; vacuum, 26 inches; I.H.P., 4,860.8; mean speed, 15.9 knots. The temperature of the engine rooms was 123 degrees Fahrenheit, and that of fire rooms from 115 to 123 degrees Fahrenheit, with blowers running.

On May 22, a trial at very low speed and with jet condensation was made. It was found that the lowest number of revolutions at which the engines could be run was 16, while the maximum number obtainable with jet condensation and 90 pounds of steam at engines was 55, the vacuum being 24 inches.

On the 19th June a forced draft trial of 1½ hours' duration was made.

Mean draught of water, about 16 feet; sea, smooth; mean pitch of propellers, about 16 feet; steam pressure in boilers, 145 pounds per square inch; average number of revolutions per minute, 151; vacuum, 26 inches; air pressure, 2 inches; I.H.P., 7,369; mean speed, 17.9.

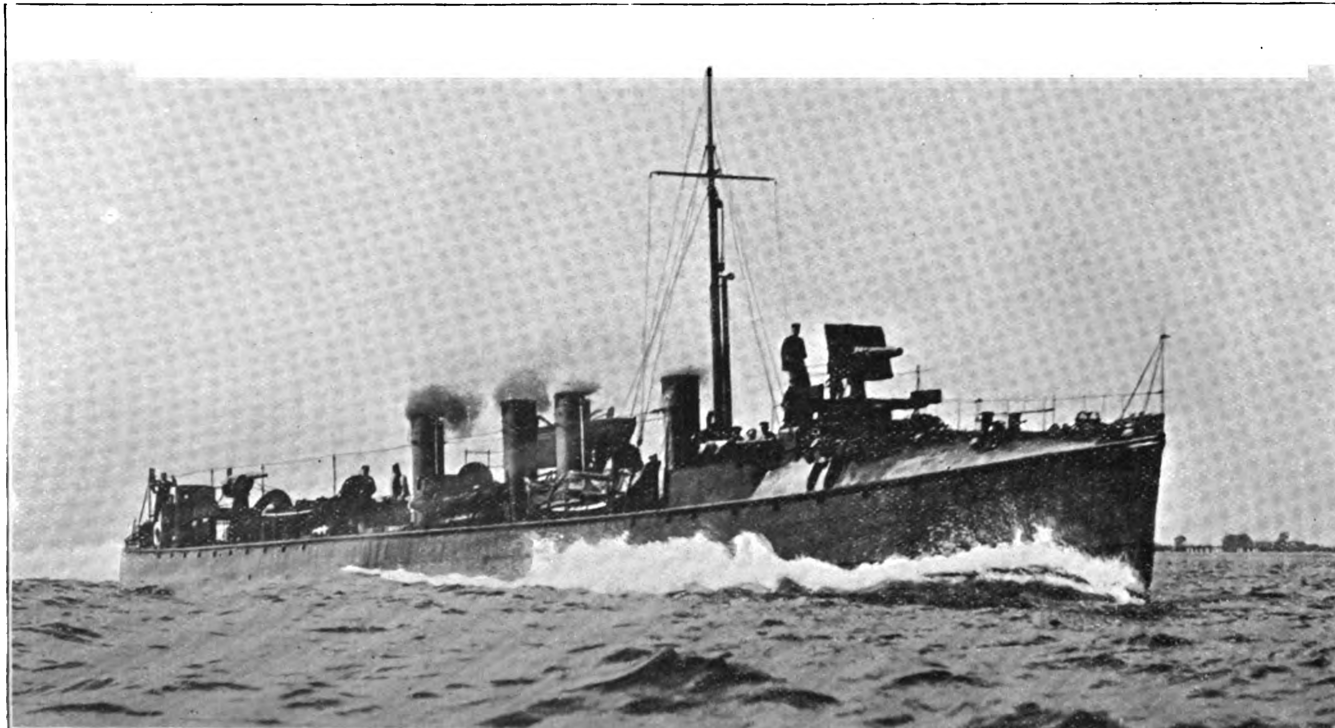
The temperature of the engine rooms ranged from 111 to 118 degrees Fahrenheit, and that of fire rooms from 122 to 136 degrees Fahrenheit.

Caprera.—This twin-screw torpedo cruiser, of which a general description was given on page 620, Vol. VI, had her trials recently.

Her designed displacement was 840 tons, and speed 20 knots, with 3,945 I.H.P., forced draft; the power with natural draft being 1,973.

On the natural draft trial, the I.H.P. developed was 2,146, the speed being 17.75 knots, and the coal consumption 1.72 pounds per I.H.P. per hour.

On the forced draft trial, the speed was not measured exactly. This trial was of 1½ hours' duration, the mean I.H.P. developed being 4,133. The steam pressure in the four locomotive boilers was 180 pounds per square inch; air pressure, 1.24 inches; the revolutions being limited to 290 per minute.



RUSSIAN TORPEDO BOAT DESTROYER "SOKOL."

BUILT BY YARROW & CO., POPLAR.

RUSSIA.

Sokol.—The following description of this fast torpedo boat destroyer is compiled from various sources. The photograph accompanying this description was kindly sent by the builders, Messrs. Yarrow & Co., Poplar.

On Thursday, August 22d, the new torpedo boat destroyer *Sokol* (Russian for Hawk) was launched from the works of Messrs. Yarrow & Co. This vessel has been built for the Imperial Russian government. She is 190 feet long, 18 feet 6 inches beam, draws 7 feet, has a displacement of 240 tons, and carries 60 tons of coal. The arrangement of the space forward, below the deck, is similar to that usually adopted in the British navy, that part of the vessel being appropriated to the crew, but in the after part abaft the engine room there is a distinct departure from British practice, the accommodation for the officers being a decided improvement on that of the *Havock* and *Hornet*, the alteration in this respect having been determined by the Russian naval authorities. She is the first torpedo boat destroyer in which nickel steel has been adopted as the material of construction. This class of steel, as is well known, has a strength exceeding that of ordinary mild steel to the extent of about 30 per cent. The engines are twin-screw, triple expansion, and indicate about 4,000 horse power. The speed guaranteed by the builders on a three hours' trial was 29 knots, carrying 30 tons. This speed was 2 knots in excess of any speed promised at the time the contract was made. Steam is supplied by eight of Yarrow's patent water tube boilers, with straight tubes. The armament is practically the same as that fitted in similar vessels in the British navy—two revolving torpedo tubes, placed on deck, for firing 16-inch torpedoes, one 12-pounder and three 6-pounder quick firing guns. As is customary at Messrs. Yarrow & Co.'s works, there was no ceremony at the time of launching the vessel. The Russian authorities, however, were represented by several officials.

She was launched with all machinery on board, and steam up in four of the boilers. After the launching, the main and auxiliary engines were at once tested under steam. The following day, Friday, the 23d, the first preliminary trial, which was progressive, as usual, took place on the measured mile at Maplin. The load carried was the contract weight of 30 tons The maximum speed, mean of the two last runs, with and against the tide, was over 30½ knots.

Steam pressure.			Vacuum.	Air pressure in stoke-hold.	Revolutions per minute.	Time.		Speed.	Mean speed.
Boilers.	First receiver.	Second receiver.							
Pounds.	*Pounds.*	*Pounds.*	*Inches.*	*Inches.*		*Min.*	*Sec.*	*Knots.*	*Knots.*
124	48	4	24½	$\frac{7}{16}$	334	2	39	22.641	
									25.778
130	54	7	24½	$\frac{9}{16}$	355	2	4½	28.915	
136	54	8	24	$\frac{7}{8}$	364	2	22	25.352	
									27 802
145	60	8¼	24	$\frac{3}{4}$	386	1	59	30.252	
154	64	10	23	$1\frac{3}{16}$	412½	2	10	27.692	
									29 363
162	67	10½	23	$\frac{7}{8}$	402	1	56	31.034	
164	71	11	22	1	410	2	6	28.571	
									30 285
165	72	11	22	$1\frac{1}{8}$	426	1	52½	32 000	

The Russian Government thus possesses the fastest vessel afloat. Besides the high speed, the low air pressure and the I.H.P., about 4,000, with which this speed was obtained are remarkable.

The engines are of the type ordinarily fitted by Messrs. Yarrow in vessels of this class, having cylinders 18 inches, 26 inches and 39½ inches in diameter by 18 inches stroke. There is one surface condenser having one centrifugal pump, in place of two as usual. The surface condenser is of copper; it was made by the Elmore process of electro-deposition, and has corrugations worked in the copper to stiffen it. The feed and air pumps are of the usual description. The ordinary auxiliary machinery, consisting of air compressors, an evaporator, electric light machinery for search light, is fitted. The steam steering gear is of a new design, which has been worked out specially by Messrs. Yarrow & Co., and made by them. The device for changing from steam to hand working has been much simplified, and is a very pretty arrangement. The boilers are eight in number, and the boiler arrangements are similar to those of the *Hornet*, the vessel built by this firm for the English government, but which was about 2¼ knots slower than the Russian vessel.

The official three hours' run was made on Friday, September 6th, in the presence of several Russian naval representatives.

The *Sokol* left the Poplar yard early in the morning, and took up the trial party at Gravesend about 11 o'clock. The programme was somewhat different to that usually followed by the English Admiralty. It was arranged that three consecutive runs should be made on the Maplin mile, down, up and down, after which a straight-away run out and back of 2½ hours should be made. At the end of this run the vessel would be on the mile again, when three more timed runs were made. The whole time occupied was exactly three hours, and during that time the usual regulations were observed, the trial being continuous. The mean speeds and revolutions of the two sets of three-mile runs were used as a basis to calculate the mean speed attained during the 2½ hours' run from the number of revolutions made by the engines in that time. The plan of splitting the measured mile runs up into two sections is not usual, though it has advantages, as it gives more approximately a mean displacement due to coal consumption, and avoids the necessity for allowance due to reduction of speed when making the turns. The following are the observed data on the first three runs:

	Mean pressure in steam pipe.	Air pressure.	Mean revolutions per minute.	Observed time.	Speed.	First means.	Second means.
	Pounds.	*Inches.*		*M. S.*	*Knots.*	*Knots.*	*Knots.*
First mile..........	153	1⅛	394.12	2 11	27.481		
						29.392	
Second mile........	154	1$\frac{5}{16}$	403.3	1 55	31.304		29.445
						29.498	
Third mile	152	1¼	394.8	2 10	27.692		

The 2½ hours' run followed, and for this the total number of revolutions was 54,674, or 405 per minute. The following are the figures for the second series of runs :

	Mean pressure in steam pipe.	Air pressure.	Mean revolutions per minute.	Observed time.	Speed.	First means.	Second means.
	Pounds.	*Inches.*		*M. S.*	*Knots.*	*Knots.*	*Knots.*
First mile..........	156	$1\frac{5}{8}$	411	1 $53\frac{1}{2}$	31 718		
						30.032	
Second mile........	159	$1\frac{3}{8}$	412.2	2 7	28 346		30.102
						30.173	
Third mile..........	162	$1\frac{3}{8}$	410 1	1 $52\frac{1}{2}$	32.000		

The mean speed on the six runs was therefore 29.773 knots. As the first mean of the revolutions per minute of the six mile runs was 405.15, the true mean speed of the vessel for the three hours was 29.762 knots; the coal burned during the three hours was 10 tons 7 cwt., with an average air pressure of 1.34 inches.

It will be seen, therefore, that the palm for the swiftest vessel in the world has once more reverted to the Poplar yard, and the British navy once more loses the supremacy in speed which it has held for some short time past. The maximum power exerted on Friday last did not reach 4,000, the mean during the trials being 3,700. Exactly what it was we are not aware, but taking a line through the spots obtained by progressive runs on the preliminary trial, it could not have exceeded 4,000. As a matter of fact, the highest speed is largely due to the precise attention paid to every detail, in order to insure lightness and efficiency.

A few examples may be given of the way in which the construction has been lightened. In the first place, nickel steel has been used for the hull. This in itself allowed a reduction in the scantling to be made, the material being stiffer and stronger than ordinary mild steel, and having high ductility. At the same time it is more expensive at first cost, and certainly more costly to work, so that it is not likely to be used for some time in vessels for the British navy. In the arrangement of the forced draft fan a saving in weight was effected by a very simple alteration. With the double stokehold necessary with water tube boilers the fan cannot, naturally, be mounted on the bulkhead, and it is therefore necessary to place it in the deck. In former destroyers, engine and fan were both attached to the deck, which had therefore to be greatly strengthened, thus entailing additional weight. In the *Sokol*, the engine is placed on the stokehold floor, and works the horizontal fan above by means of a vertical shaft. A canvas screen is provided to protect the engine from dust, and has proved quite effective. In the fittings and hull construction, again, aluminum has been extensively used in places where strength is not of first importance. Thus the side scuttles, bunker lids and rings, ejectors, cylinder casings, &c., are of that metal. It need hardly be said that this also adds to the cost of construction. The steam steering engine is of a new design, and has been made by the firm. The gear is of novel arrangement, and by its adoption, together with the improvement in the engine, a considerable saving in weight has been effected. In the main engines there are several points noticeable. The link motion has been altered, and the system of balancing has been modified from Mr. Yarrow's original design in some matters of detail, so as here again to secure additional lightness. Throughout the engines a considerable saving of weight has been effected by using the stronger and more costly bronzes, which have enabled less material to be worked in without sacrificing strength.

In this vessel the system of shutting off the boiler from the stokehold by means of a cross diaphragm plate in front of the boilers, which Messrs. Yarrow have adopted from the first, is introduced. With this arrangement, if the boilers are damaged in any way, say from the fire of machine guns during action, steam will not flow to the stokehold where the men are, but will pass up to the funnel. The arrangement, though not new, is worth noting here, as a very striking object lesson has been given during the recent war in South America. A number of men were killed during action by the escape of steam to the stokehold through damage done to the boilers. Had the arrangement adopted by Messrs. Yarrow been fitted to this vessel, although the boilers would equally have been put out of action, the men would not have been scalded to death or suffocated by steam.

An inspection of the boilers when the machinery was opened out indicated that they had been subjected to no excessive test. In the inner rows of tubes, which were quite easily examined, and which are subjected to the severest ordeal, there was no sign of leakage in any part, the tube ends, where they are expanded into the receiver above or the tube plates below, being perfectly tight and sound, and this may be said of the whole of the tubes, as there was no sign of leakage throughout. The tubes themselves did not present the symmetrical appearance of a new boiler, being bent a little out of straight. That, however, is the characteristic of all straight tube boilers of this description, and naturally in itself does not affect the steaming properties of the boiler. The large fire-grate area of these boilers leads to ease in working; indeed, the difference between running a trial with water tube boilers and with the old locomotive marine type, is only equaled by the difference in the appearance of the two types of boiler after the run.

In the case of the *Sokol*, although she had been steaming about 30 knots for three hours, the paint on the four chimneys was as fresh as when put on. The uniformity of the speed throughout the trial is worthy of attention. The run on the 2½ hours exactly corresponds in number of revolutions per minute to the mean of runs made before and after the 2½ hours. It is often assumed that it is impossible to work water tube boilers without considerable variations in steam pressure, owing to the small amount of water they contain. The regularity in the speed of revolutions could hardly have been obtained had not the pressure been constant. It is also satisfactory to notice the small increase of air pressure that occurred during the trial, as this indicates that there was no practical falling off in the efficiency of the boilers, owing to accumulation of cinders between the tubes or to the choking of the grates.

On Saturday, October 2, special trials at less than full power were made on the Maplin mile. Advantage was taken of the occasion to show the vessel to a number of foreign Government officials and others, but no representative of the British Admiralty was present. In addition to the crew, there were about 100 persons on board. The chief features of the trials were two half-hour runs. The first was made with open stokeholds. With 274 revolutions the indicated horse power was 1,050, and the speed 20.5 knots. The height of the top of the smoke pipe above the grate bars is 20 feet. On the second half-hour's run hatches were closed, and a plenum of ½ inch was maintained in the stokeholds. This is known in the British navy as "natural draft," while some people call it "assisted draft." The revolutions now went up to 359 per minute, the indicated horse power to 2,650, and the speed to 26.74 knots. It will be seen, therefore, that in the first case it required, roughly, 51 horse power to be developed for each knot steamed; and, in the second case, nearly 100 horse power; while at the full speed attained (taking it to be 30 knots with 4,000 indicated horse power) about 133 indicated horse power per knot were required.

Admiral Oushakoff.—This coast defence vessel has already been described on page 210 of Vol. VI, and on page 175 of this year's February number. The following particulars of her steam trial, on October 3, in the Baltic, are from "Engineering," London:

She is the first vessel of a class which is specially designed for coast defence, but which can also be utilized for foreign service under certain conditions. She has been constructed at the well-known Baltic works at St. Petersburg, where her keel was laid June 16, 1892, and the vessel launched October 27, 1893.

The conditions of the trials were to maintain at least 5,000 indicated horse power for twelve consecutive hours with natural draft and open stokeholds. The results obtained were highly satisfactory, the mean horse power for twelve hours being 5,764.8 and mean speed 15 knots. All machinery worked with the greatest possible smoothness, a steady steam pressure being easily maintained; the trial was remarkable for its uniformity.

The trial was made under the direction of Mr. John Sampson, of Messrs. Maudslay, Sons and Field, engineers and constructors of the machinery, and was witnessed by representatives of the Russian government.

General Admiral Apraxine.—This is another of the coast defence vessels, practically the same as the *Oushakoff*, mentioned above. The general dimensions are:

Length, feet	277.2
Beam, feet	52
Draught, mean, feet	17
Displacement, tons	4.061
I.H.P., forced draft, about	4,932
Speed, knots, natural draft	14
forced draft	16
Coal supply, normal, tons, about	210
greatest, tons, about	384

The side armor is 177 feet long, 6.56 feet high and tapering in thickness from 10 inches in the middle to 8.86 inches forward and 7.87 inches aft, the ends being connected by athwartship armored bulkheads, 7.87 inches thick forward and 5.9 inches thick aft. The armor for the two turrets, in each of which are two 9-inch guns, is 7.87 inches thick. The amored deck is 3 inches thick on the inclined sides and 2.64 inches on the flat part.

Besides the four 9-inch guns, there are four 5.9-inch Canet rapid fire guns in redoubts; six 1.85-inch and eight 1.46-inch rapid fire guns, and four 1.46-inch rapid fire guns in the fighting tops. There are four torpedo tubes, one forward, one aft and one on each broadside.

The engines are twin-screw, vertical, triple expansion, in separate compartments, and there are eight boilers.

Samoyede.—This armored transport, built and fitted for hydrographic service, has already been described on page 607 of the last number of the JOURNAL. The official trials took place on August 20, with the following results: The contract required a six hours' continuous run. Before starting on this, nine runs were made over the measured mile at the Maplins, the mean speed attained being 12.5 knots, about one knot in excess of the contract speed. The mean draught of vessel was 11 feet; revolutions of engines, 142 per minute; vacuum, 28 inches; steam pressure in boilers, 160 pounds per square inch; I.H.P., 1,495. The six hours' continuous running was then undertaken, part of the time being over the measured mile. The mean speed for the whole trial, which lasted nearly seven hours, was 12.6 knots.

SPAIN.

Almirante Oquendo.—The following description is from "Engineering," London:

The third of three cruisers built at the Astilleros del Nervion, at Bilbao, has completed her speed trials. The trials took place between Bilbao and San Sebastian on Monday, August 26, and were in every way satisfactory. Starting from Bilbao at 7 A. M., the cruiser was on the measured mile in two hours. Four runs were made, after which a six hours' run was completed, whereupon the vessel again ran the mile four times, the mean revolutions determining the speed on the six hours' run. This was under natural draft. The mean revolutions were 105, the power about 9,000 indicated horse power, and the speed 18.49 knots. Subsequently a run for slightly under an hour was made with forced draft to ascertain that everything worked well. This was regarded as sufficient in view of the fact that the machinery was identically the same as in the two preceding cruisers, *Infanta Maria Teresa* and *Vizcaya*, the former of which had been most exhaustively tried. (These trials and the complete description of the *Maria Teresa* were published on pages 621–631, and the results of the trials of the *Vizcaya* on page 810 of Vol. VI of the JOURNAL.) Everything worked well with the engines running at 117 revolutions. A single-screw trial was then undertaken for about half an hour. The number of revolutions was 85, and the speed 12¼ knots. In the construction of this vessel much Spanish skill and labor has been utilized under the direction of Mr. James McKechnie, the engineering manager of the works.

UNITED STATES OF COLOMBIA.

Gunboat.—The following particulars of the gunboat built by Mr. Hugh Ramsey, of Perth Amboy, N. J., are taken from the "Marine Record":

The contract calls for a side wheel gun boat, to be ready for transportation on January 1, 1896.

It is stipulated in the contract that the gunboat shall be completed in four months and shipped to the United States of Colombia in sections, the reconstruction and fitting out to be done by that government. Despatch and torpedo boats have been built in sections, both here and abroad, and shipped away, but these boats so constructed have been small, and the transportation in sections of the new gunboat, which is to be 140 feet long, will, according to Mr. Ramsey, be an unusual one. The gunboat will be put together at the yard with screw bolts, which will permit of breaking her up without injury to her frame or plates.

The new vessel will be a side wheel steel gunboat to be used for river service. She will have a speed of 15 knots and a draught of only 3 feet 3 inches. Her dimensions will be: Length over all, 140 feet; beam, over guards, 35 feet, at the water line, 19 feet; and depth of hold, 7 feet. She will have a military mast, on which will be mounted a machine gun and steel covered conning tower. On the latter will be a powerful search light.

The engine and boiler rooms will be protected with ¼-inch bullet proof nickel steel. The deck house will have instead of windows, steel sliding panels, from behind which the crew can fire without being exposed. The hull will be divided into ten water tight compartments, the saloon and staterooms being aft. She will have inclined triple expansion engines, with cylinders 12¾, 20½ and 31¾ inches in diameter, the stroke being 39 inches. The feathering paddle wheels will be 9 feet in diameter and 3 feet wide. Her armament will consist of three rapid firing machine guns, one mounted forward, one aft and one on the military mast. She will burn wood, her fuel capacity being small, as it is expected that she will always be able to obtain fuel all along the rivers.

When completed the gunboat will cost in the neighborhood of $125,000.

MERCHANT STEAMERS.

St. Louis.—The official trial, to determine whether this vessel fulfilled the requirements laid down in the Mail Subsidy Act for vessels of 20 knots' speed, took place in the English Channel on August 20. She ran 104 nautical miles, 52 with and 52 against the tide, the resulting mean speed being 22.3 knots.

Our attention has been called to an error in the description of the steering engine of the *St. Louis* on page 617, first paragraph, of the last number of the JOURNAL. The correction is as follows :

"The steering engine of the *St. Louis* is not of the Brown arrangement, but is of the same style as is used on the U. S. Naval cruisers and battleships. It is operated by the Brown telemotor.

"The steering engine of the *St. Paul* is of the Brown type throughout, and was constructed by the Messrs. Williamson Bros., of Philadelphia, from drawings furnished by the Messrs. Brown Bros."

St. Paul.—Sister ship to the American liner *St. Louis*, has also had her official trial of four hours' duration, under the terms of the Mail Subsidy Act. This trial took place on October 4, over a measured course of 41.96 nautical miles, between Cape Ann, Massachusetts, and Cape Porpoise, Maine. The vessel's bottom was foul. The mean speed attained was 20.5 knots.

On October 9, she left New York on her maiden voyage to Southampton, England, the run being made in 7 days 12 hours and 20 minutes, from the Sandy Hook Light Ship to the Needles. The greatest daily run was 439 miles.

Carinthia and *Sylvania.*—The following description of the vessels and the trials have been taken from "Engineering," London :

These new Cunard steamers have excited great interest by reason principally of the high efficiency of the boilers and engines, and were referred to, on this account, in the course of a debate in Parliament a month or two ago, when the question of the relative merits of the water tube and multitubular boilers was under consideration. They are the first of a new type added to the Cunard fleet. The company have hitherto been satisfied with their large share in the passenger traffic, and such freight as is carried by the mail steamers; but owing to the great advances in speed, the cargo capacity has steadily decreased, for the class of freight which can be profitably carried at 20 and 21½ knots speed is limited, and there is little need to add thus to the displacement of high speed vessels. Again, the live cattle traffic has been steadily increasing, and the company, in deciding to build cargo steamers of great deadweight carrying capacity, provided also for a large cargo of cattle on the main deck. Thus 6,500 tons of cargo may be carried, and 420 head of cattle; and judging from the experience of the first voyages of the steamer, there is every prospect of the new class being increased. The vessels again, are, the first constructed by the London and Glasgow Engineering and Iron Ship Building Company, Limited, for the Cunard Company, who had probably the greater confidence in placing the order in view of their experience with the general manager of the company, Mr. J. W. Shepherd, some time manager at Fairfield, where he had charge of the building of those very successful steamers, the *Umbria* and *Etruria*, and many large steamers for other companies. It was a small matter, therefore, that the London and Glasgow Company had not formerly undertaken the building of such large steamers. The dimensions of the steamers are as follows:

Length, feet	460
Breadth, feet	49
Depth to shelter deck, feet and inches	42–6
Cargo capacity, deadweight, tons	7,500
Draught, fully loaded, feet	27
Displacement, fully loaded, tons	12,160
Freeboard from upper deck, fully loaded, feet and inches	8–4
Gross tonnage, about, tons	5,600

The ventilation of the cattle spaces and holds is an important feature in the vessel, Utley's patent cowl and combination vents being provided throughout the ship. In addition to this, portions of the shelter deck can be hinged up in good weather and form uptakes.

There are six holds, with large hatches, and these are served by seven large steam winches, each having double derricks, specially constructed for loading cargo from barges alongside. These are supplied by Messrs. Clarke, Chapman and Co., as are also the steam windlass and capstan forward, and the steam warping capstan aft. Messrs. Harrison's steam steering gear is fitted in the after end of the engine casing, and in communication with the engine room, having a direct lead to the large circular head in the wheelhouse on the shelter deck aft, where a powerful screw gear, as well as an auxiliary gear, is fitted up for working the ship by hand if required.

The captain's and deck officers' and spare state rooms, as well as the saloon, are situated on the shelter deck at the fore end of the engine and boiler space, and each officer has a large and comfortable apartment for himself, heated by steam and lighted by electric light. The engineers have the same accommodation as the other officers, and their rooms are built round the engine casing, the entrances all being from the engine platform. There is one feature about the vessel which will commend itself to those who have the working of it, viz., there are no obstructions or ladder ways to get over in order to get from one end of the ship to the other, a free passage being left all fore-and-aft at the sides of the ship. There are four steel pole masts, fitted with fore-and-aft canvas for steadying purposes. The twin screw propelling engines are very compact, the cylinders being 22½ inches, 36½ inches and 60 inches in diameter, by 48 inches stroke.

Each cylinder is fitted with a separate liner and steam jacketed. The high pressure and intermediate pressure pistons are fitted with cast-iron Ramsbottom rings, the low pressure pistons having Lockwood's patent packing rings and springs. The piston rods are of mild ingot steel, 6 inches in diameter, with separate crossheads. The connecting rods, which are 5¾ inches in diameter, tapering to 7 inches, are of iron, with double gun metal bearings on the top ends, and brass bushes lined with white metal. Each set of engines has one air pump, diameter 22 inches, stroke 24 inches, fitted with Kinghorn's disc valves; two feed pumps, 3½ inches in diameter; two bilge pumps, 4 inches in diameter; and one sanitary pump—all single acting and worked by levers off the intermediate pressure engine. The feed pumps are arranged to discharge to the feed water heater, or direct to the boilers.

The condensers are short, the high pressure cylinder being supported at the back by a duplicate of the front column. The condensing surface in each is 2,750 square feet; the tubes are tinned outside and in, and packed with screwed ferrules and linen tape packing. The exhaust from the low pressure cylinder enters the condenser through the after column. The circulating pumps are two in number, one for each set of engines, made by Drysdale and Co., Glasgow. The diameter of suction and delivery pipes is 10 inches. The discharge of the centrifugal pumps is bolted direct on to the condenser end, and the pump and engine are supported on brackets attached to the condenser.

All the shafting was supplied by Vickers & Co., of Sheffield. The crankshaft is 12½ inches in diameter. The crankpins are 12¾ inches in diameter. The thrust blocks are of the ordinary horseshoe type, with water circulation through the shoes. There are eight collars on each shaft 2 inches thick. The length of thrust shaft is 11 feet 1 inch by 12½ inches in diameter, and 21¼ inches in diameter over thrust rings. The intermediate shafting is 12 inches in diameter, and the propeller lengths are 12½ inches in diameter. The propellers are 16 feet in diameter, each having three blades, with 60 square feet of surface, cast by the Manganese Bronze Company. The bosses are cast iron.

The outfit of auxiliary engines consists of one Cameron's quadruple-acting water ballast pump, capable of discharging 300 tons per hour; two of Carruther's duplex pumps, having brass water ends, for bilge and general service, and together with the ballast pump, arranged to discharge into water space of main condenser; one Carruther's duplex pump for supplying fresh water to cattle from four reserve tanks under engines; two of Quiggin's evaporators with steam feed pump, and one fresh water distiller, together having a capacity of 50 tons per 24 hours. The evaporators are also fitted to work as condensers for the winches and auxiliaries generally, all of which can also exhaust into the main condenser. The circulating water for the winch condenser is supplied by either of the water ballast pumps and either of the duplex service pumps.

The boilers are of special interest. They are worked under Howden's system of forced draft. The fan is 8 feet in diameter, and is driven by one of Chandler's engines. Two engines are provided, one for emergency duty. Two boilers were sufficient for the full power, 2,725 indicated horse power. These boilers are 20 feet 3 inches long and 15 feet in diameter. They have each six furnaces 3 feet 7½ inches in internal diameter, being fitted with Fox's flues. The following details of each of the two boilers will be of interest:

Number of plain tubes	542
stay tubes	274
Total number of tubes	816
Heating surface of tubes, square feet	4,204
furnaces, square feet	281
fire boxes, square feet	230
inner tube plate, square feet	90
Total heating surface, square feet	4,805
Steam space, cubic feet	800
Evaporating surface, square feet	260
Weight of water, tons	41.47
Grate surface on 5-foot bars, square feet	110
Ratio of grate to heating surface	1 to 43.6
Probable consumption of coal per square foot of grate per hour, pounds	28
Safety valves, three combined, diameter, each, inches	3¾
Limiting tensile strength of steel shell plate, Board of Trade, tons	28 to 32
Limiting tensile strength of steel shell plate, Lloyd's, tons	28 to 32

There is also a large auxiliary boiler for winches, electric light, &c. There is one of Weir's feed heaters with steam supply from each set of engines. Two pairs of Weir's feed pumps are fitted, having brass water ends and distribution chests, and arranged to draw from the sea, evaporator, tanks, condenser, hot well and feed heater, and discharge to the main and auxiliary boilers direct, and through or past Harris's feed water filter to the heater. Steam fire-extinguishing pipes are fitted to all the compartments of the holds and bunkers. Higginson's steam ash hoists are fitted in each stokehold.

The *Sylvania* was tried on the Firth of Clyde, running first six times over the mile and twice between the Cloch and Cumbrae. It was a coarse morning, but the speed exceeded the conditions, as the following results show:

RESULTS OF TRIALS OF S. S. *SYLVANIA*.

Draught, forward, feet and inches	15–9
aft, feet and inches	19–6
mean, feet and inches	17–7½
Displacement, tons	7,420

SIX RUNS ON THE MEASURED MILE.

	Boiler pressure.		Revolutions.		Power.		Total power.	Speed.
	Port.	Starboard.	Port.	Starboard.	Port.	Starboard.		
	Pounds.	*Pounds.*						*Knots.*
1st	175	172	91.4	93.4	2,269	2,257	4,527	15.32
2d.	175	180	93.8	95.0	2,741	2,749	5,490	15.25
3d.	175	180	93.9	95.0	2,798	2,740	5,539	15.65
4th	175	180	92.5	94.5	2,766	2,792	5,558	15.25
5th	175	180	94.2	95.0	2,777	2,778	5,556	15.45
6th	175	180	92.0	94.0	2,715	2,746	5,462	15.00

MEANS ON MEASURED MILE.

	Port.	*Starboard.*
High pressure cylinder	757.30	815.0
Intermediate pressure cylinder	840.18	957.7
Low pressure cylinder	1,080.87	904.6
Total	2,678.35	2,677.3
Total I.H.P., both engines	5,355.65	
Mean speed, knots	15.32	
Air pressure in fan discharge, inches	3½	
ashpit, inches	1⅝	
furnace, inch	1	

On the two runs between the lights the mean boiler pressure was 178 pounds, the vacuum, as in the six runs on the measured mile, being 28 inches. The revolutions were, for the port 93 and the starboard 95, and the mean powers were as follows:

	Port.	*Starboard.*
High pressure cylinder	772.3	815.1
Intermediate pressure cylinder	854.1	1,010.8
Low pressure cylinder	1,100.9	899.6
Total	2,727.3	2,725.5
Total indicated horse power, both engines	5,452.8	
Speed, knots	15.52	
Mean slip of port screw, per cent	8.69	
starboard, per cent	6.407	

As to the results on the measured mile, it should be stated that on the first run both engines were pulled up two or three times by Aspinall's governor, which had been left in gear. On the runs between the lights a more direct course was steered, which accounts in large measure for the difference in speed. The power developed between the lights was equal to 24.8 indicated horse power per square foot of grate surface, and 1 indicated horse power per 1.72 square feet of heating surface. As to coal consumption, no attempt was made to measure it, as there was no time, the vessel being required on her berth. It was estimated at 86 tons per 24 hours.

The *Carinthia* was not tried over the measured mile or between the lights, but was run a distance of fully 90 miles, viz., round Ailsa Craig and back to the Tail of the Bank. She did the distance in less than six hours, equal to 15½ knots. Both vessels have been on their station for some time, and are working satisfactorily.

The hull is entirely built of Siemens-Martin steel, the rivets being also of this metal. The shell plates are generally about 22 feet long, lap jointed and treble riveted. The orlop, lower, main and upper decks are of steel. The shelter deck is partially plated and then sheathed with pine.

As the vessels are propelled by twin screws, the framing of the after end is carried out to meet the stern tubes, and ends in a massive steel casting on each side, which is shaped into the form of the vessel. There are nine water tight bulkheads extending to the upper deck, and these are fitted with water tight doors on each side in 'tween decks only, to expedite the working of cattle and cargo. Besides the double bottom, which is fitted for water ballast, there are four large deep tanks for trimming purposes, one aft, one forward, and one at each end of the engine and boiler space, these being subdivided by fore-and-aft water tight bulkheads. There are in all twenty-four compartments for water ballast, and part of the double bottom under the engines may be utilized for carrying reserve fresh water for cattle or boiler use. The bulkheads are so arranged that any two compartments, and in some cases three, may be flooded, and still the vessel will keep afloat. Although built to Lloyd's highest class, 100 A 1 three-deck, the vessels have special extra strengthening at the bilge and topsides, and, in addition to the usual Board of Trade survey, are fitted to pass the American survey, having fusible plugs in the boilers, Downton fire pump, and steam pipes for extinguishing fire in every compartment.

All the holds, 'tween decks, engine and boiler spaces, cabins, and the vessel throughout are lighted with electricity on the double wire system, the current being generated by two compound wound self-regulating dynamos, situated in the engine room, and at each of the seven hatches there is a cluster of sixteen lamps of 16-candle power. This work has been carried out by Messrs. William Harvie and Co., Limited.

Accommodation is provided for 420 head of cattle on the upper deck.

Sumatra.—This single-screw steamer of the P. & O. Co. was partially described on page 626 of the last number of the JOURNAL. Since then, the following particulars of the machinery have become available.

The main condenser is cylindrical, built up of wrought-steel plates and has cast-iron ends, the cooling surface being 4,385 square feet. The air pump is worked from the L.P. engine, and is large enough to enable the condenser to be worked as a jet condenser in an emergency. A bilge pump and a sanitary pump are alongside of the air pump and worked by the same cross-head. The circulating pump is independent and centrifugal, 12½ inches in diameter.

The crank shaft is of Vicker's steel, its bearings being lined with Parson's white metal. All main pistons have Ramsbottom rings. The H.P. piston valve is fitted with MacLaine's patent rings. The reversing gear is designed by the builders, and reverses the engine, from full ahead to full astern, in ten seconds. There is a Morison evaporator, of 20 tons daily capacity, a Morison feed water heater, and a Caird & Rayner distilling apparatus capable of supplying 2,000 gallons of drinking water per day. There are two automatically controlled Weir feed pumps, one Weir duplex pump for general engine room service and a ballast pump which can pump out the whole water ballast, nearly 800 tons, in five hours.

The thrust bearing has a thrust surface of 1,750 square inches.

The propeller is four bladed, with manganese bronze blades on a cast iron boss. Zinc slabs are fitted to the forward side of the rudder post to prevent galvanic action.

There are two main double ended, cylindrical boilers, 13 feet 8 inches in diameter and 18 feet 6 inches long, working at 160 pounds pressure and fitted with Howden's forced draft system. The combined grate surface is 154 and the heating surface 6,720 square feet. Morison's suspension furnaces are used. There is a large donkey boiler which also has Morison's furnaces and works at 160 pounds pressure.

There are two independent sets of Siemens Bros'. dynamos, each set being capable of lighting the whole vessel.

Ventilating arrangements are provided, the engine and fire rooms being remarkably cool.

The trials of this vessel took place in the Firth, on August 20, but no data are published.

Pennsylvania.—This steamer of the Hamburg-American S. S. Co., now building by Messrs. Harland & Wolff, Belfast, Ireland, will be the largest steamer afloat. The contractors agreed to build the vessel in ten months, while two German bidders wanted fifteen months. The principal dimensions are as follows:

Length on load water line, feet	560
Beam, feet	62
Depth, feet	42
Deadweight carrying capacity, tons	13,000
Displacement, tons	20,000

The engines will be twin-screw triple expansion. There will be one smoke pipe and four pole masts. There will be accommodations for 200 cabin and 1,500 steerage passengers. Besides carrying "fast freight", arrangements have been made for cattle, and ample refrigerating apparatus provided for perishable freight.

North German Lloyd S. S. Co.—The new steamer of this company, for which the contract has been given to Mr. Schichau, Elbing, Germany, is guaranteed to make 22 knots on trial and 21 knots in regular service.

Kherson.—This auxiliary cruiser for the Russian Volunteer Fleet, a general description of which was given on page 618 of the last number, was launched from the yard of Messrs. Hawthorn, Leslie & Co., Hebburn-on-Tyne, on October 19.

She is arranged to carry about 1,500 soldiers or emigrants and about 100 other passengers. There are 24 Belleville boilers, particulars of which will be found in the article on the test of two of these boilers under the head of "Notes," page 791.

Scottish Hero.—This steamer was built by Messrs. William Doxford & Sons, Sunderland, England. She is one of the "turret" type of steamships described on page 620 of the last number of the JOURNAL, and has joggled plating throughout. The principal dimensions are: Length between perpendiculars, 297 feet; breadth, moulded, 40 feet; depth, moulded, 24 feet 1 inch. The gross register tonnage is 2,201 tons and the deadweight capacity, 3,800 tons.

The engines are of the quadruple expansion type, with cylinders 19½, 27½, 39 and 55 inches in diameter, the stroke being 42 inches. The three boilers are of the Babcock & Wilcox water tube type, the two main boilers containing 4,500 and the donkey boiler 990 square feet of heating surface. The main boilers are fifteen, the donkey boiler eight sections wide. The height and length are the same. The main boilers have 4-inch tubes in the bottom rows, the others being 1⅞-inches in diameter. The donkey boiler has 4-inch tubes entirely. On trial, the machinery easily developed 1,500 horse power, the resulting speed for four hours on the measured mile with the full deadweight on board being 10.2 knots. The engines and boilers worked satisfactorily.

Chesapeake.—This tank steamer, described on page 624 of the last number of the JOURNAL, had her trials in August. The mean speed attained on August 15 on the progressive trials was a little less than 12¼ knots, the displacement being 9,000 tons. On August 17, for the six hours' run and with the same displacement, the mean speed was 12 knots, or ½ knot over the contract requirement. The *Chesapeake* was the largest tank steamer afloat until the launch of the *Pectan*, described below.

Pectan.—This steel tank steamer, which had her trials in the latter part of September, was built for the bulk petroleum trade to the East through the Suez canal, by the Central Marine Engine Works of Messrs. William Gray & Co., West Hartlepool. She is the largest bulk oil steamer afloat, takes Lloyd's highest class, and her dimensions are: Length over all, 388 feet; breadth, extreme, 48 feet; depth, 31 feet 6 inches, with full poop, bridge and forecastle. The engine and boiler rooms are in the after part of the vessel, and underneath them there is a double bottom for water ballast. The forward and after peaks and deep tank in the fore hold are also fitted for water ballast for trimming purposes. Forward of the boiler room there are 11 strong transverse bulkheads, and also a very strong fore-and-aft bulkhead from the keel to the main deck. Altogether there are 15 separate oil tanks, separated from the boiler room and bunkers aft and from the cargo hold forward by large cofferdams, which are carried to the upper deck in each case. Expansion trunks are carried up from each oil compartment to allow the oil to rise and fall as the temperature varies. A complete installation of pumps, fans and electric light for the oil compartments has been fitted. Triple expansion engines have been fitted, the cylinders being 27½ inches, 43½ inches and 73 inches in diameter, with a 48-inch stroke. There is a Mudd's patent evaporator. There are three extra large single-ended boilers working at a pressure of 160 pounds per square inch, placed with their backs towards the cofferdam, removing the heat arising from the stokehold a considerable distance from the bulkheads. The speed on trial shown by the log was 11 knots.

Telena.—A sister ship to the *Pectan*, and built at the same works, was launched on October 19.

YACHTS.

Alcedo.—The following description is taken from the "American Shipbuilder," New York, September 5:

This flushed-deck steam yacht of composite construction, was built by George Lawley & Son, City Point, South Boston, Mass. The general dimensions are as follows; length, 124 feet over all, 102 feet at load water line; 16 feet 2 inches beam; 6 feet 6 inches draught. The hull is subdivided into five compartments by four steel water tight bulkheads. The scantlings conform in all particulars to the requirements of the U. S. Standard Steamship Owners', Builders' and Underwriters' Association. The hull is stiffened by a system of steel straps worked diagonally over the frames and deck frames. The planking of the hull is of Georgia pine 2⅝ inches thick, fastened to the frame with nut and screw bolts; all fastening to a height of 2 feet above the water line is of bronze. The deck is of clear white pine; the main rail is of teak; the deck house, skylights and hatches are of mahogany; over the engine and boiler space is a low steel house 10 inches high. The engines are forward of the boiler.

The cabin accommodations are extremely commodious and convenient. The dining room is forward in the deck house, finished in mahogany throughout. It is 18 feet long by 8 feet 6 inches wide, connected with the galley and pantry below by a dumb waiter. The entire deck house is used as a dining room and deck saloon, the steering gear being on the bridge deck overhead. Directly aft of the machinery space and separated from it by a steel water tight bulkhead, and protected from the heat of the boiler and the noise of the fire room by an across coal bunker, is the owner's stateroom. Aft of this is the main saloon, 13 feet 6 inches long. Aft of the main cabin is the hallway from which leads the companion way to the main deck. Leading from the hallway, there is on the port side a single stateroom, and on the starboard side, a toilet room. Aft of the hallway is a double stateroom.

Especial attention has been given to the sanitary arrangements of the yacht; the bath tub and set bowls in the cabin quarters are trapped and piped to a tight waste tank in the after hold and which is vented overboard. The waste tank is emptied by a steam syphon, located in the engine room. The ventilating arrangements are very ample, each room having a direct skylight ventilation. For the bilge ventilation there is an 8-inch exhaust ventilator located on deck and leading down into the after hold, which will continually draw air from the same. Forward of the machinery space and directly below the dining room comes the galley, 10 feet long, and the full width of the yacht. On the starboard side is the pantry from which leads the dumb waiter to the dining room above, with butler's sink and racks for dishes, etc. The galley and pantry are ventilated by a high skylight on either side of the deck house in addition to the port lights in the side of the hull. Forward of this are the quarters for officers and crew. Forward of the collision bulkhead are the chain lockers, also the engines to the steam capstan on deck. The triple expansion engine with cylinders of 9½, 15 and 24½ inches diameter and a stroke of 13 inches, was built by the Fore River Engine Co., of Weymouth, Mass. Steam is furnished by a double fire box, water tube boiler of the Almy type, licensed to carry a pressure of 250 pounds to the square inch. The circulating, air, feed and bilge pumps are all independent and are arranged to exhaust into either the low pressure receiver or the condenser.

The condenser is 6 feet long, 36 inches diameter, copper shell, brass heads and tubes, and contains 650 feet of cooling surface. The circulator is of the centrifugal type with direct connected engine, built on the condenser head, and runs at at average speed of 300 revolutions. The crank shaft is built up of open-hearth machinery steel; the bearings are lined with Fore River white metal. The crossheads are of bronze and the pistons of cast steel, with spring rings as lightly constructed as is consistent with strength. The piston valves, which are of cast iron, are actuated by a side crank shaft driven from the main shaft by steel and rawhide gears. The reversing is accomplished by a spiral sleeve, working on a spiral on side shaft. The spirals and sleeves are cut from the solid steel. The propeller is four-bladed, 5 feet in diameter and 7 feet pitch. The ordinary number of revolutions of engine, with a steam pressure of 200 pounds per square inch, is 320 per minute. The three main compartments of the yacht are piped independently to the bilge pump and syphon; the machinery compartment is also connected with the circulating pump. The coal bunkers have a capacity of 18 tons. The yacht is lighted throughout by electricity by a direct-connected multipolar dynamo, and there is a small auxiliary storage battery for use when the dynamo is not running. The yacht will carry three boats, a gig 18 feet long, a cutter 16 feet long, and a dinghey 15 feet long. The davits for the gig have been made extra heavy to carry a naphtha launch, should it be desired to do so.

Arcturus.—This auxiliary steam yacht was launched on October 18 from the works of the builders, Messrs. Ramage & Ferguson, Leith, Scotland. Her tonnage is 473, yacht measurement.

She was built for Mr. R. Stuyvesant, of New York. The yacht has three masts and a large spread of canvas, as the owner intends to use her for long foreign cruises, and the propeller is of the Bevis feathering type. The principal dimensions are: Length on load water line, 135 feet: length over all, 169 feet; breadth, 27 feet; depth, moulded, 17 feet 5 inches. There are two large deck houses, the one forward containing pilot and chart house, also smoking room, and the after one forming a handsome dining room. The machinery consists of a set of triple expansion engines made by the builders, having cylinders 13, 21 and 34 inches in diameter by 24 inches stroke. Steam is supplied by two Almy water tube boilers, made at Providence, R. I., this being the first British built yacht fitted with these American boilers. Steam steering gear, winches and windlass are fitted. The yacht has a powerful search light and electric lighting throughout.

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