REPORT

OF THE

"HOHENSTEIN BOILER" AND "LIQUID FUEL" BOARDS,

SHOWING

RELATIVE EVAPORATIVE EFFICIENCIES OF COAL AND LIQUID FUEL UNDER FORCED AND NATURAL DRAFT CONDITIONS

AS DETERMINED BY

AN EXTENDED SERIES OF TESTS

MADE BY DIRECTION OF

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1902.

EXTRACT FROM REPORT OF THE CHIEF OF BUREAU OF STEAM ENGINEERING, RELATING TO COMPARATIVE TESTS OF COAL AND OIL MADE UNDER A WATER-TUBE BOILER OF THE HOHENSTEIN DESIGN, ALSO OFFICIAL REPORT OF THE STEAMSHIP "MARIPOSA" BURNING LIQUID FUEL.

THE PROBLEM OF THE WATER-TUBE BOILER—THE HOHENSTEIN BOILER TRIALS.

The present problem of the modern battle ship is not that of the gun and its mount, but the boiler and its installation. The gun is mounted in the most favorable position for care, operation, and inspection, and practically everything on board ship is subordinated to its efficient working. Since a large factor of safety is given to every part of the weapon that is subjected to shock, the gun can only be impaired by incompetence, neglect, or by chemical action of the explosive. Before it is placed in a turret or redoubt it is fully tested, but it is never put on board ship if there is a suspicion that it has been subject to undue strain.

The boiler, on the other hand, is placed beneath the protective deck just above the bilges and near the bunkers. It is installed in compartments that are avoided rather than sought by other than engineer officers While a careful test is made of the structure before being placed in the vessel, it must necessarily be subjected, even before installation, to conditions that often impair its strength. In its construction many of the plates are subjected to the severest kind of flanging, and its efficient inspection is much more difficult than that of the gun. As there has been a progressive demand for increased steam pressures, the factors of safety used in designing a marine boiler are progressively becoming smaller. The conditions under which the boiler is operated necessarily cause some of the parts to be subjected to rapid corrosion, and only incessant care and attention can prevent the disablement or rupture of the structure.

The experience of the United States Navy with the boilers of the torpedo boats and torpedo-boat destroyers ought to afford some startling evidence as to the manner in which incompetent or untrained men can impair or destroy the efficiency of these steam generators. The agitation in Great Britain over the navy-boiler question ought also to convince naval administrators that the boiler problem is the naval problem of the hour.

In view of the British experience with the Belleville boiler, it is not surprising that the general public of that Empire regard the boiler commission, now in session, as the most important board appointed by the Admiralty during the past ten years. The membership of this board comprises distinguished experts within and without the naval service. This board has been in session nearly two years investigating the question as to which type of marine boiler is most suitable for use in the navy as the one of approved design. The Admiralty regard the solution of this problem as of vital importance to the efficiency of the British fleet, for it has been discovered, after installing over a million and a quarter of horsepower of boilers of particular design, that a doubt has arisen as to whether or not this particular form of boiler should have been settled upon as the approved type for the naval service. A series of evaporative and endurance tests have been made, and the more carefully the question is investigated the more important does it appear in relation to the operation of a modern navy.

The work of the British boiler commission will have a very important influence upon naval construction, since it will cause thoughtful experts to give more attention to the design, construction, installation, and operation of the boiler. One must have experience in the operation of a modern marine boiler to appreciate the intelligence, skill, and care that must be devoted in keeping it in a state of efficiency. The boilers are the lungs of a vessel, although this fact is not generally understood. It was not many years ago when a naval officer of high rank spoke of the boilers as "the steam tanks in the bottom of the ship," it being probably his impression that these tanks could be tapped like a gasometer, and it was the fault of the fireman if the boiler output was not sufficient at all times.

While the war ship may be nothing more than a gun platform, it requires considerable power to move a platform of 14,500 tons at a high speed in a heavy sea. This platform is not only expected to be maneuvered rapidly, but to steam uninterruptedly for a distance of one-fourth the way around the world. The battle ship that can not make the enemy's coast the first line of defense is limited in the field of its usefulness, and when operating at such distance the value of the boiler factor comes only second to the value of the factor of the gun.

The efficiency of the war ship of the several naval powers is simply proportionate to the efficiency of their boilers and the character of their personnel. Neither in armor, armament, or machinery is there any vital difference between the battle ship of the several nations. In these respects, the last ship, wherever designed, is the best, for as regards draft, tonnage, thickness and extent of armor, character and distribution of guns, and design of machinery, every nation has settled upon a type of vessel that meets its particular requirements, and each navy has therefore secured the best for its particular purpose.

The boiler problem, however, has been unsolved. Without taking into consideration the question of personnel, the value of the war ships of the different naval powers can be measured by the efficiency and endurance of the steam generator installed in the vessel. This fact may not be appreciated in its fullness at the present time, but the experience of the coming five years with the ships nearing completion will conclusively show that in coming naval conflicts the question of victory may be quite as much dependent upon the battle of the boilers as the contest between the guns.

With a deep appreciation of the necessity of soon settling upon an approved type of marine boiler for the battle ships and armored cruisers of the United States Navy, the Bureau has invited competition among designers. It believes, however, that, if possible, a boiler of American design should be adopted, and that this marine boiler should be a development of one in general use on shore. By seeking a design that is familiar to thousands of firemen on shore, an important military advantage would be secured, since in time of emergency there could thus be recruited for the naval service water tenders and firemen who had operated almost similar steam generators, and who would therefore require but little training to familiarize themselves with the duty on board ship. While the Navy can and ought to do some efficient work in training firemen, it would be very advantageous to the service if the enlisted force in the stokeholes could have considerable preliminary training with boilers of nearly like design to the one in most extensive use as the approved type for the Navy.

There is now being built, for the battle ships in course of construction, water-tube boilers of three distinct types. Practically four-sevenths of this boiler power will be of the Babcock & Wilcox design, two-sevenths of the Niclausse, and one-seventh of the Thornycroft. These types include the best of representative groups of water-tube boilers, and a sufficient installation of each kind will be secured to test the efficiency and endurance of the several designs.

About two years ago the Bureau was informed that another American boiler firm, with considerable financial backing, desired to enter the field of marine-boiler construction. In keeping with the Bureau's policy of inviting competition, encouragement was therefore given the Oil City Boiler Works to design and build a marine boiler and turn it over to the Bureau for test as to its evaporative efficiency and endurance.

The question of entering upon the field of marine-boiler construction had been carefully considered by the Oil City Boiler Works. As the officials of that establishment believed that the time was not far distant when there would be a large demand for marine water-tube boilers, they volunteered to equip an experimental plant at the company's expense. The boiler was of sufficient size to thoroughly test its adaptability for naval purposes. There was therefore constructed a steam generator whose limitations as to weight, height, and floor space were similar to the conditions prescribed for the cruiser *Denver*, and these conditions are in many respects the most severe that have been exacted by the Department. Eighteen months ago the experimental plant was completed, and there was placed at the disposal of the Bureau a boiler of the Hohenstein design.

The boiler was installed in an air-tight steel house, this structure likewise approximating to one of the fire rooms of the cruiser *Denver*. All the limitations and difficulties that were met with in the installation of the boilers of the cruiser *Denver* were therefore designedly encountered in the installation of the experimental plant.

It was well understood before the Bureau undertook to experiment with this boiler that the character and extent of the data to be collected were to be entirely determined by officials of the Government. In justice to the Oil City Boiler Works it should be stated that every suggestion of the Department was carried out, and that it was the evident purpose of the company to accurately ascertain the requirements of the Bureau, and to discover the greatest difficulties that were likely to be experienced in meeting naval demands. Stated in a business way, the company was willing to expend from fifty to one hundred thousand dollars to ascertain whether or not it would be advisable to extend their plant to enter the field of marine-boiler construction.

In many respects the experimental plant was one of the most complete that have ever been established. The series of tests conducted will command attention in the engineering world, for absolute information has been obtained as to the evaporative efficiency and endurance of the boiler. Information has also been secured in regard to the best means of baffling the gases, thus increasing the evaporative efficiency as well as permitting the boiler to be forced for emergency purposes. Particular care has also been given by the Board to the investigation of the circulation of the water, for probably the key to the boiler problem is the question of circulation.

While only seventeen official tests were made with coal as fuel, there were a great many unofficial experiments. Between the several official tests the experts of the Oil City Boiler Works conferred with the Bureau, and therefore each test represents the result of study and experiment. An examination of the data will conclusively show that in many respects the completeness and character of the tests have never been surpassed.

The first six tests were run by a picked crew of firemen who had experience in torpedo-boat work. It was believed that these men by training and experience were particularly well fitted to operate the boiler when under severe forced-draft conditions. An experience of a few weeks with this force showed that new methods in firing had to be employed in efficiently operating water-tube boilers, and that the best means of securing efficient work was to have skill and intelligence from those in charge of the fire room and implicit obedience upon the part of the subordinates. The remaining eleven tests were thus made by firemen living in the city, not one of whom had ever before worked a boiler under forced-draft conditions. The second set of firemen implicitly obeyed orders, and it was therefore possible for the board to have its instructions carried out. A uniform pressure of steam was maintained, as well as a regularity in firing that was productive of good results.

The data secured can be regarded as reliable, for checks and counterchecks were used so that the Bureau could be placed in possession of information that could be relied upon as to completeness and accuracy. As this same boiler is being used to carry on the extended series of tests to determine the value of liquid fuel for naval purposes, it is proposed to duplicate every one of the coal tests with oil as a combustible. The comparative information thus obtained ought to afford valuable data as to the relative value of the two combustibles.

In view of the present condition of this experimental boiler after eighteen months of use with both coal and oil as a combustible, considering the results secured, and by reason of the following report submitted by the board which conducted the series of tests, the Bureau has no hesitation in regarding the boiler as the equal in efficiency and endurance of any used in a foreign battle ship.

REPORT OF BOARD ON HOHENSTEIN BOILER TRIALS.

NAVY DEPARTMENT,
BUREAU OF STEAM ENGINEERING,
July 1, 1902.

SIR: The board appointed to conduct an extended series of tests to determine the efficiency and adaptability of the Hohenstein marine boiler for naval purposes submits the following report:

The boiler was built by the Oil City Boiler Works, of Oil City, Pa., in conformity with the Bureau specifications for the cruiser *Denver* and class. The limitations as to weight, height, and floor space in

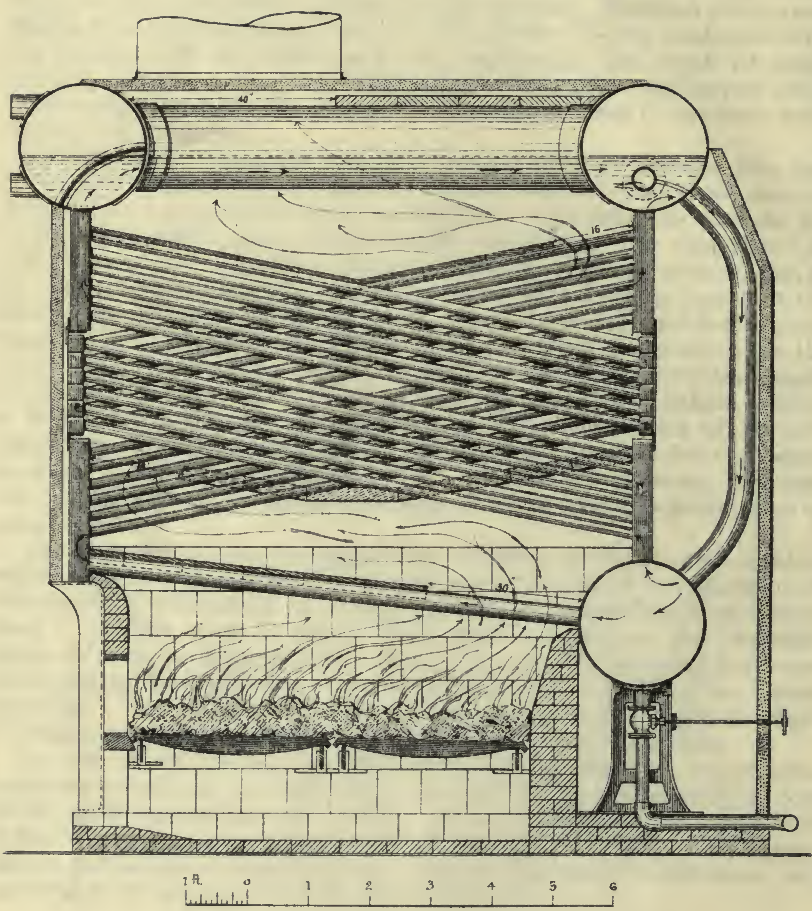


FIG. 1.—THE HOHENSTEIN EXPERIMENTAL BOILER.

regard to the *Denver's* steam generators were therefore taken into account in the construction of this boiler. The installation was effected in an air-tight steel house, the dimensions of this house approximating to one of the fire rooms of the *Denver*. It may be incidentally stated that the specifications for the boilers of the *Denver* are probably as severe as those for any American war ship. The headers of the boiler are made of wrought steel, a special requirement of the Bureau. While only seventeen official tests were made with coal as fuel, there was considerable experimentation between these tests, so that the series of tests represent much more observation and experimentation than is apparent. A most noteworthy feature of the boiler is the arrangement of the tubes in pairs in such a way that each tube is free to expand independently of other tubes, thus effectually preventing longitudinal stresses in them. Figure 1 shows a longitudinal section of the boiler. Attention is called to the fact that the entire down flow takes place within tubes which are located in a comparatively cool place, while, on the other hand, there is invariably an upward trend to the current in all tubes and headers exposed to the hot gases. It is therefore highly probable that there are no reverse currents at any part of the water circuit, and the cross-section areas of tubes and headers are equitably apportioned with a corresponding degree of certainty. The feed water is introduced at the top of the down-take tubes, which is obviously the best possible place as regards influence on the circulation; at the same time the head due the velocity of the feed water is conserved by means of injector nozzles pointing in the direction of flow.

The following are the more important dimensions:

BOILER DATA.

Drums at water-surface level: One front drum, 24 inches diameter (inside); one rear drum, 24 inches diameter; four connecting drums, 16 inches diameter.

One lower rear mud drum, 24 inches diameter.

Tube-heating surface: Three hundred and eighty-four 2-inch tubes 9 feet long; sixteen 4-inch tubes 7 feet long.

Fifteen down-take tubes 5 inches diameter.

Floor space occupied, 9 feet wide, 10 feet 11¼ inches deep.

Height above floor line, 12 feet ¾ inch.

Height over all, 12 feet 6¾ inches.

Heating surface: 2,174 square feet for tests No. 1 to No. 6, inclusive; 2,130 square feet for tests No. 7 to No. 17, inclusive. Per cent water-heating surface, 100.

Grate surface: 50.14 square feet, 6 feet 4 inches long, 7 feet 11 inches wide.

Ratio of heating surface to grate surface: 43.4 to 1 for tests No. 1 to No. 6, inclusive; 42.5 to 1 for tests No. 7 to No. 17, inclusive.

Volume of water at steaming level, 142 cubic feet.

Volume of steam space, 50 cubic feet.

Area of steam liberating surface, 75 square feet.

Weight of water at steaming level and 275 pounds pressure, 7,559 pounds.

Weight of boiler and fittings, excluding uptake and smoke pipe: Without water 46,568 pounds; with water, 54,127 pounds. Without water per square foot of heating surface, 21.4 pounds for tests No. 1 to No. 6, inclusive; 21.8 pounds for tests No. 7 to No. 17, inclusive. With water per square foot of heating surface, 24.9 pounds for tests No. 1 to No. 6, inclusive; 25.4 pounds for tests No. 7 to No. 17, inclusive. With water per square foot of grate surface, 1,080 pounds.

Height of furnace, 2 feet 5 inches.

Volume of furnace above bars, 121.14 cubic feet.

Width of air spaces between grate bars: Five-eighths inch for tests No. 1 to No. 11, inclusive; three-fourths inch for tests No. 12 to No. 17, inclusive.

Ratio of grate area to area of air space: $1\frac{1}{8}:\frac{5}{8}=1:0.555$ for tests No. 1 to No. 11, inclusive; $1\frac{1}{4}:\frac{3}{4}=1:0.60$ for tests No. 12 to No. 17, inclusive.

Height of smoke pipe above grate, 70 feet.

Area of smoke pipe, 8.73 square feet.

Ratio of smoke-pipe area to grate area, 1:5.75.

Number of fire doors, 3.

The boiler was erected in a steel structure built especially for these tests and having the following dimensions: Floor space, 16 feet by 24 feet; height, 14 feet. The structure was air-tight, had an air lock for entrance and exit during forced-draft trials, and seven windows that could be opened during natural-draft trials. Fig. 2 is a halftone view of the plant and fig. 3 shows the ground plan. The auxiliary machinery, together with facilities for making observations, were, so far as possible, placed in an adjoining lean-to wooden structure. The auxiliaries consisted of a Davidson suction pump, two weighing tanks, one feed tank, a Snow high-pressure feed pump, a small upright boiler with independent feed pump, and a direct-connected blowing engine and fan. The fan had an impeller 72 inches in diameter and a discharge duct 20 inches by 42 inches, which led to the fire room and terminated in a box placed so as to direct the air current toward the ceiling. The pipe connections were such that steam for the auxiliaries could be taken either from the small upright boiler or from the main boiler. The bottom blow valve was blanked, but in plain sight, so that leakage from that source would be particularly observed.

The feed water was weighed in two tanks, each of 1,000 pounds capacity, and resting on 1,500-pound Howe scales. These scales had been tested by the city's sealer of weights and measures. The scales and weighing tanks were on a platform above the feed tank. The weight of each tank was taken when filled, and the water was then allowed to flow into the feed tank as needed. As soon as the weighing tank was emptied the weight was again taken and the time noted. The feed tank was provided with a graduated water-level gauge. The height of water by this gauge was noted at the moment of beginning the test, and at the end of each hour it was again brought to the same level. The feed tank had a steam coil for heating the water, wide variations in the temperature of which were easily avoided by keeping the water level fairly constant. In most of the forced-draft trials the weighing tanks had to be filled, weighed, and emptied with such rapidity, owing to their insufficient size, that the above method of catching the weight at the end of each hour could not be used. The weighing tanks were accordingly each fitted with a water-level gauge graduated to 5 pounds, by the aid of which the weight within 5 pounds could be caught at any moment without interfering with the rapid manipulation of the tanks. The temperature of the feed water was taken at an elbow of the feed pipe between the pump and the boiler.

The several air-pressure gauges and two steam gauges were placed near each other on the wall of the steel structure, on the opposite or fire-room side of which the necessary pipe connections were made.

The steam gauges were 3 feet lower than the water level in the boiler. A deduction of 1½ pounds from the observed steam pressures was therefore made in working up the results. The steam was blown off into the atmosphere, the pressure being controlled by a hand-operated stop valve.

The coal was weighed in sheet-metal cans or bags, the method being to adjust each can or bag to a uniform weight of 220 pounds, or 130 pounds while on the scales, and then keep tally of the number passed into the fire room. Beginning with the seventh test, the coal account was balanced at the end of each hour by estimating and deducting the weight of coal lying at the moment on the fire-room floor.

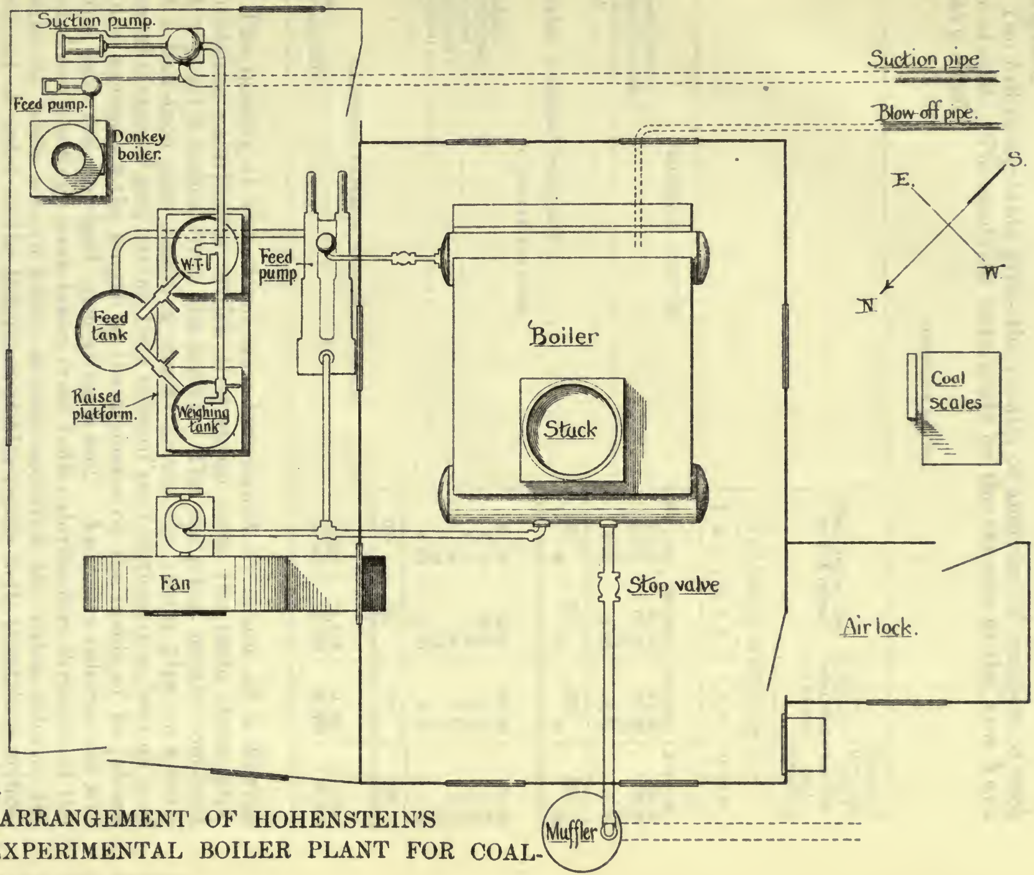


FIG. 3.—ARRANGEMENT OF HOHENSTEIN'S EXPERIMENTAL BOILER PLANT FOR COAL-BURNING TESTS.

The ashes and refuse were weighed in sheet-metal cans as they accumulated, and the weight of sweepings from tubes and baffles was ascertained for each test on the day following the test.

A sample of coal for analysis and for the determination of moisture by weighing and drying was taken from a box which had been gradually filled during the test by specimens taken from each can or bag as weighed.

The following table gives the results of analyses of samples of each lot of coal. The analyses were made by the chemist at the New York Navy-Yard.

Analyses of fuel.

	Pocahontas coal, run of mine.		New River coal, run of mine.	Pocahontas coal, hand picked and screened.
	Fuel burned in boiler test No.—			
	1, 2, 3.	4, 5, 6.	7, 8, 9.	10 to 17.
PROXIMATE ANALYSIS.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	73.30	75.78	72.99	76.81
Volatile matter	17.61	19.53	21.79	19.62
Moisture	.49	.79	.49	.73
Ash	8.60	3.90	4.73	2.84
	100	100	100	100
Sulphur, separately determined	.48	.71	.46	.82
ULTIMATE ANALYSIS.				
Carbon	82.26	84.96	83.60	85.94
Hydrogen	3.89	4.07	4.85	4.45
Oxygen	4.12	5.46	4.87	4.50
Nitrogen	.64	.90	1.41	1.14
Sulphur	.49	.71	.46	.82
Ash	8.60	3.90	4.81	3.15
	100	100	100	100
CALORIFIC VALUE (B. T. U.'S PER POUND).				
Coal	14,067	14,534	14,841	14,992
Combustible	15,391	15,124	15,684	15,475

The quality of the steam was determined by means of a Barrus throttling calorimeter, which drew steam from the main steam pipe at a point 8 inches from the boiler. The sampling nozzle consisted of a half-inch pipe reaching nearly across the steam pipe on a horizontal diameter and having four rows of perforations (top, bottom, and sides) extending the length of the diameter of the inside of the steam pipe, save for one-half inch at each end. An extra calorimeter was fitted and readings were taken from both calorimeters throughout the series of trials, except when, as once occurred, the extra calorimeter got out of order by the lodgment of black scale in its throttling orifice.

The temperatures at the base of the stack and the samples of flue gas were taken above the roof at a point about 5 feet from the nearest heating surface of the boiler, measured along the path of flow of the gases. In the natural draft trials the temperatures were taken with a mercury-nitrogen pyrometer, and attempts were made to do the same in the forced-draft trials. Momentary flaming in the stack, however, caused so many breakages of glass bulbs that reliance had finally to be placed on a Brown quick-reading pyrometer, the readings of which were, however, checked as well as could be by the melting points of zinc, aluminum, and copper.

The samples of flue gas were drawn by means of an aspirator improvised from two half-gallon bottles. The sampling tube was one-half inch diameter and extended to the center of the stack, the inner end being nearly closed and the sides being perforated with one-eighth-inch holes spaced 4 inches apart.

The aspirator, charged with gas, was carried to a neighboring building, where the sample was analyzed by the aid of an Orsat apparatus.

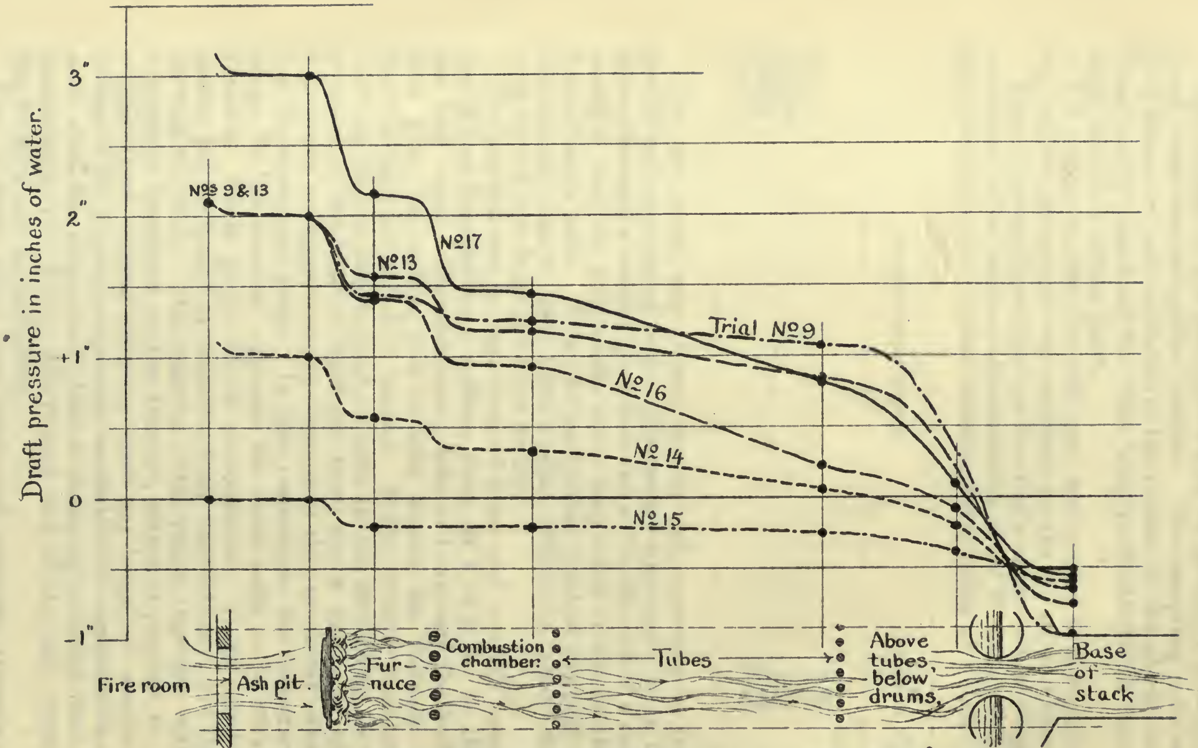
The following determination was made of the actual weight of water contained in the boiler at a temperature of 56° F. and at different gauge-glass readings, the correct steaming level being at 1 inch.

Height of water in gauge.	Total weight of water.	Difference.	Area of water level.
	Pounds.	*Pounds.*	*Sq. ft.*
0	8,588		
		281	52.2
1 inch	8,869		
		366	70.5
2 inches	9,235		
		413	79.6
3 inches	9,648		
		385	74.2
4 inches	10,033		
		372	71.7
5 inches	10,405		

The feed water was always muddy and especially so for the fourteenth and subsequent tests. The water was drawn from the Potomac River through a suction pipe that ran out to the end of a dock. When about to start the fourteenth test a long reach of the suction pipe was found frozen solid. To avoid postponing the test the pipe was quickly rearranged so as to draw from a point farther in, where the water was only 3 or 4 feet deep and very muddy.

The last test was to have been of three and one-half hours duration, but it was brought to a sudden close at 1.02 p. m. by the failure of the feed water. The outflowing tide had exposed the end of the suction pipe, but before this became known the furnace doors were thrown open and the fires hauled. It was several minutes before the blowing engine was stopped, so that, in the meantime, the tubes were exposed to the blast of cold air from the 4 inches of air pressure. There was no appearance of leakage at this or at any other time during the seventeen trials. In this connection the construction of the plugs in the headers opposite the tube ends is worthy of special remark. These plugs are of composition. There are two sizes, 2⅜ inches and 4½ inches in diameter with, respectively, 11½ threads and 8 threads per inch. The material of the plugs, together with the use of a graphite lubricant on the threads, makes it possible to remove and replace them without difficulty after any length of service. Also, by virtue of the greater expansion coefficient of composition as compared with steel, the plugs are tighter at steaming pressure than at ordinary temperature (70° F.) by 0.0026 inch and 0.0049 inch, respectively, for the 2⅜-inch and 4½-inch sizes.

Part of these plugs were made with tapering threads such as are inserted in the ordinary screwed pipe joints and depend for tightness on the threads alone. The joints thus formed were tight, but the plugs could be removed only with great difficulty. The others had parallel



Abscissas are roughly proportional to measurements along the path of gases.

FIG. 4.—CURVES SHOWING VARIATION OF AIR PRESSURE WITHIN THE BOILER DURING CERTAIN COAL-BURNING TRIALS. *SPOTS* INDICATE POINTS WHERE MEASUREMENTS WERE MADE.

threads and a narrow flange at the end. A "McKim" gasket, consisting of a copper ring fitted with suitable packing material, was used under the flange to make a tight joint. The plugs thus fitted were tight and could be easily removed or replaced when desired. The same gasket could be used for an indefinite time. A good graphite lubricant was used on all the threads of all the plugs.

By varying the connections of the draft gauges during the early trials it was found that the draft was seriously interfered with by the resistance of the uptake.

The uptake was accordingly increased in size for the later trials, with the result that the boiler showed a greater capacity, the fireroom temperature was much lower, and there was no further trouble, as there had been previously, with the burning of grate bars. The variation of draft pressure within the boiler, together with the improvement that resulted from the change just alluded to, is shown diagrammatically in fig. 4.

In the accompanying tables of the individual trials the "pounds of air per pound of carbon" is calculated by the approximate formula:

$$\frac{11.55\ (CO_2+0+\frac{1}{2}\ CO)}{CO_2+CO}$$

which takes no account of the air consumed in burning hydrogen. In the table of summaries the weight of dry gas per pound of carbon is calculated by the accurate formula as there given.

The amount of smoke is designated in a rather crude manner by a scale in which 0 stands for no smoke and 5 stands for very thick smoke.

The first 6 tests were run by a crew of firemen experienced in torpedo-boat work, but the remaining 11 tests were made by firemen picked up around the wharves, not one of whom had ever before fired a boiler under forced draft conditions.

Careful examination of the boiler after each of the tests showed no distortion of the tubes, nor any damage to the boiler.

The notes that are recorded in connection with the several tests will show the severe work to which the boiler has been exposed. Under these several trials the boiler shows no indication of injury whatever. Not a leak has developed and not a tube has been bent. The tubes have frequently been examined, and they are clear of mud, showing that a good circulation has been maintained.

The casing of the boiler has not proved satisfactory, the lining not being able to stand the effect of strong forced draft. This has been probably due to the use of improper nonconducting material. This defect is one which can be easily remedied by a more liberal use of fire tile or fire brick.

The front drum is only 24 inches in diameter. Although this boiler is so baffled that it has given reasonably dry steam, and the design of the boiler is such that there is a much greater water surface in the drums, and at least an equal weight of water to that used in other water-tube boilers, yet the board considers that for marine work, where the ship will roll and pitch, and thus cause the water level to vary, the front drum should be increased to about 42 inches in diameter.

With an improved casing and a larger front drum for the boiler, the series of experiments conducted indicate that this boiler is a satisfactory steam generator for the naval service. The board therefore recommends that the Hohenstein boiler be given a place on the very limited list of straight-tube water-tube boilers of American design that have been found suitable for naval purposes.

The board believes that the important question of selecting an approved water-tube boiler for naval purposes will be finally settled by a process of selection from types installed on board ship, and subjected for several years to the stress of service conditions. In order, therefore, to assist in discovering an approved type that will meet the requirements of the Navy, the board recommends the use of the Hohenstein boiler on an American war ship, preferably one requiring a large installation.

Very respectfully,

JOHN R. EDWARDS,
Lieutenant-Commander, U. S. Navy.
WYTHE M. PARKS,
Lieutenant-Commander, U. S. Navy.
FRANK H. BAILEY,
Lieutenant-Commander, U. S. Navy.

Rear-Admiral GEORGE W. MELVILLE, U. S. Navy,
Chief of Bureau of Steam Engineering.

No. 1.—*Test of Hohenstein water-*

[Eight hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.
			Higher temperature.	Lower temperature.	Quality of steam.	
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*
9.30 a. m	245	130	......	......	......	......
9.45 a. m	270	180	410	330	0.996	......
10 a. m	270	170	408	320	.991	4
10.15 a. m	270	170	406	310	.985	4
10.30 a. m	270	155	406	310	.985	4
10.45 a. m	270	170	406	314	.988	3½
11 a. m	270	160	406	316	.989	3
11.15 a. m	272	150	404	308	.984	3
11.30 a. m	270	170	404	310	.986	4
11.45 a. m	270	150	404	262	.957	4
12 m	270	150	404	310	.986	4
12.15 p. m	270	130	404	309	.986	3
12.30 p. m	270	140	406	308	.986	4
12.45 p. m	268	120	404	309	.986	4
1 p. m	268	130	406	309	.986	3
1.15 p. m	265	160	409	310	.984	4
1.30 p. m	265	160	404	300	.980	4
1.45 p. m	265	150	404	308	.986	4
2 p. m	265	125	404	316	.984	3½
2.15 p. m	260	120	404	310	.986	4
2.30 p. m	260	135	404	310	.986	4
2.45 p. m	260	125	404	318	.986	4½
3.00 p. m	260	150	404	310	.986	4½
3.15 p. m	265	150	404	310	.986	5
3.30 p. m	265	110	404	302	.981	5
3.45 p. m	260	130	404	268	.961	5
4.00 p. m	265	140	404	224	.936	4½
4.15 p. m	260	130	404	310	.986	4
4.30 p. m	265	135	404	264	.959	5
4.45 p. m	265	130	404	252	.952	4
5.00 p. m	260	135	404	309	.986	4
5.15 p. m	265	140	404	308	.986	4
5.30 p. m	265	160	404	304	.984	4
Average	265.4	144	......	......	.980	......

State of weather, clear.
Barometer at noon, 30.02 inches.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 2,400 pounds.
Coal burned during test, 9,720 pounds.
Ashes before beginning test, 260 pounds.
Ashes during test, 377 pounds.

tube marine boiler, April 23, 1901.

with natural draft.]

Temperature.			Air pressures in inches of water.		Flue gases.				Water.	
Outside air.	Air in fire room.	Gases at base of stack.	Ash pit.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
Deg. F.	*Deg. F.*	*Deg. F.*			%	%	%	*Lbs.*	*Lbs.*	*Lbs.*
52	....	485	....	−0.30	....	....	....	....	....	....
....	87	570	−0.05	− .30	....	....	....	....	....	....
50	87	602	− .05	− .40	....	....	....	....	....	....
....	87	720	− .05	− .40	....	....	....	....	....	....
55	89	(a)	− .05	− .40	10.4	6.1	2.3	16.1	9,511	9,511
....	93	(a)	− .05	− .50	....	....	....	....	....	....
53	93	(a)	− .05	− .55	....	....	....	....	....	....
....	91	(a)	− .05	− .60	....	....	....	....	....	....
54	89	(a)	− .05	− .55	9.4	7.1	2.2	17.5	9,218	18,729
....	90	(a)	− .05	− .50	....	....	....	....	....	....
55	88	(a)	− .05	− .50	....	....	....	....	....	....
....	88	(a)	− .05	− .55	....	....	....	....	....	....
55	89	(a)	− .05	− .55	10.3	7.2	.8	18.6	9,867	28,596
....	94	(a)	− .05	− .50	....	....	....	....	....	....
56	94	(a)	− .05	− .55	....	....	....	....	....	....
....	94	(a)	− .05	− .55	....	....	....	....	....	....
62	94	(a)	− .05	− .55	9	8.4	1	20.6	9,100	37,696
....	97	(a)	− .05	− .55	....	....	....	....	....	....
61	97	(a)	− .05	− .55	....	....	....	....	....	....
....	96	(a)	− .05	− .55	....	....	....	....	....	....
59	96	(a)	− .05	− .55	9.6	5.8	1.6	16.9	9,671	47,367
....	97	(a)	− .05	− .55	....	....	....	....	....	....
62	100	(a)	− .05	− .50	....	....	....	....	....	....
....	101	(a)	− .05	− .55	....	....	....	....	....	....
61	101	(a)	− .05	− .55	11	5.5	2.1	15.5	9,832	57,199
....	101	(a)	− .05	− .55	....	....	....	....	....	....
61	102	(a)	− .05	− .55	....	....	....	....	....	....
....	101	(a)	− .05	− .55	....	....	....	....	....	....
60	100	(a)	− .05	− .55	9.3	7.9	1.7	18.9	9,501	66,700
....	86	(a)	− .05	− .55	....	....	....	....	....	....
59	87	(a)	− .05	− .55	....	....	....	....	....	....
....	92	(a)	− .05	− .55	....	....	....	....	....	....
59	100	(a)	− .05	− .55	....	....	....	....	9,279	75,979
57.3	93.8	594	− .05	− .515	9.85	6.85	1.67	17.7	9,497	....

[a] Pyrometer out of order.

Refuse, including sweepings from tubes and baffles, 640 pounds.

Per cent of moisture in coal by weighing and drying sample, 0.5.

Firing very poor and irregular. Average interval between firings, 13 minutes. Average interval between rakings, 12 minutes. Average thickness of fire, 12 inches. At 2.30 p. m. only about two-thirds of the grate was in actual use on account of irregular thickness of fire. Average smoke by Ringelmann charts, 2¾. Water drawn from mud drum on following day, when allowed to settle in a bottle, left five-eighths inch of sediment in 8 inches depth of water.

No. 2.—*Test of Hohenstein water-*

[Six hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.
			Higher temperature.	Lower temperature.	Quality of steam.	
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*
10.35 a. m	275	120	407	260	0.956	2½
10.45 a. m	260	140	396	290	.978	2
11 a. m	275	138	393	300	.985	2½
11.15 a. m	275	138	398	299	.977	2
11.30 a. m	275	140	398	278	.970	1½
11.45 a. m	275	160	398	272	.967	2
12 m	275	120	399	288	.976	2½
12.15 p. m	275	140	398	303	.984	3
12.30 p. m	275	150	399	212	.930	3
12.45 p. m	275	160	399	304	.983	3½
1 p. m	275	130	399	292	.977	2½
1.15 p. m	275	130	399	270	.965	2½
1.30 p. m	275	130	398	280	.971	2½
1.45 p. m	275	130	399	270	.965	2½
2 p. m	275	138	398	216	.934	2½
2.15 p. m	275	170	400	270	.965	2½
2.30 p. m	275	145	400	264	.961	3½
2.45 p. m	275	165	400	250	.953	3½
3 p. m	275	145	400	307	.986	2
3.15 p. m	275	140	400	305	.985	3
3.30 p. m	275	160	400	290	.976	3
3.45 p. m	275	150	400	284	.973	2½
4 p. m	275	160	399	276	.968	3¾
4.15 p. m	275	165	400	290	.976	2½
4.35 p. m	275	170	401	218	.934	3
Average	274.4	145.36			.968	

State of weather, dull and overcast.
Barometer at noon, 30.12 inches.
Revolutions of blower, 250 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 300 pounds.
Coal burned in starting fires, 2,000 pounds.
Coal burned during test, 10,445 pounds.

No. 3.—*Test of Hohenstein water-*

[Four hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.
			Higher temperature.	Lower temperature.	Quality of steam.	
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*
12 m	275		398	300	0.982	
12.15 p. m	275	155	396	309	.988	+ ½
12.30 p. m	275	150	398	324	.996	+ ½
12.45 p. m	275	140	400	324	.996	− ½
1 p. m	275	142	398	322	.995	0
1.15 p. m	275	150	397	314	.991	0
1.30 p. m	275	138	399	314	.991	+ ½
1.45 p. m	275	130	399	314	.991	+ ½
2 p. m	275	142	399	314	.991	− ½
2.15 p. m	275	150	399	312	.989	+ ¾
2.30 p. m	275	150	400	312	.989	+1½
2.45 p. m	275	152	398	305	.985	+ ½
3 p. m	275	144	299	314	.991	0
3.15 p. m	278	152	400	312	.989	0
3.30 p. m	276	150	401	310	.988	0
3.45 p. m	285	140	400	309	.987	+2
4 p. m	280	148	400	310	.988	0
Average	276.1	145.8			.989	

State of weather, dull and overcast.
Barometer at noon, 29.86 inches.
Revolutions of blower, 335 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 390 pounds.
Coal burned in starting fires, 2,500 pounds.
Coal burned during test, 10,569 pounds.

tube marine boiler, April 26, 1901.

with forced draft.]

Temperature.			Air pressures in inches of water.			Flue gases.				Water.	
Outside air.	Air in fire room.	Gases at base of stack.	Fire room.	Ash pit.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
Deg. F.	Deg. F.	Deg. F.				%	%	%	Lbs.	Lbs.	Lbs.
72	102	640	......	1.7	−0.80	7.6	6.4	2.3	17.6	....	....
....	....	....	......	1.1	− .60	....	....	....	....	....	....
....	98	605	1	.95	− .60	8	5.8	2.2	16.8	....	....
....	....	....	1	.95	− .60	....	....	....	....	....	....
68	113	690	1.1	1	− .70	11.2	5.2	1.5	15.6	14,038	14,038
....	....	....	1	.95	− .65	....	....	....	....	....	....
....	116	710	1.1	1	− .65	8.7	5.3	3.6	14.8	....	....
....	....	....	1.1	1	− .65	....	....	....	....	....	....
70	119	750	1.1	1	− .65	8.8	6	2.4	16.5	15,572	29,610
....	....	....	.9	.85	− .60	....	....	....	....	....	....
....	120	700	1.1	.95	− .65	10.5	5.8	1.7	16.2	....	....
....	....	....	1.2	1.1	− .70	....	....	....	....	....	....
70	120	980	1.1	1	− .70	10.3	6.9	1.6	17.5	15,540	45,150
....	....	....	1.1	1	− .70	....	....	....	....	....	....
....	120	725	1.1	1	− .65	7.6	7.9	2.4	19.2	....	....
....	....	....	1.1	1	− .60	....	....	....	....	....	....
70	122	1025	1.1	1	− .65	11.4	6	1	16.6	13,328	58,478
....	....	....	1.1	1	− .65	....	....	....	....	....	....
....	126	805	1.1	1	− .65	10.4	7.5	1.6	18	....	....
....	....	....	1.1	1	− .65	....	....	....	....	....	....
72	127	720	1.1	1	− .65	9.8	6.8	2.2	17	14,278	72,756
....	....	....	1.1	1	− .65	....	....	....	....	....	....
....	126	805	1.1	1	− .65	9.2	7.4	1.2	19.1	....	....
....	....	....	1.1	1	− .65	....	....	....	....	....	....
....	123	575	1.1	1	− .65	9.5	7.5	1.8	18.3	14,074	86,830
70.3	117.8	748.4	1.08	1.02	− .654	9.46	6.5	1.96	17.2	14,471	....

Ashes before beginning test, 160 pounds.
Ashes during test, 575 pounds.
Refuse, including sweepings from tubes and baffles, 550 pounds.
Per cent of moisture in coal by weighing and drying sample, 0.5.
Firing very irregular, with average interval of 11 minutes. Average interval between rakings, 9 minutes, varying from 4 minutes to 13 minutes. Average thickness of fire, 12 inches. Average smoke by Ringelmann charts, 2¾. Slicing doors kept closed after 11 o'clock.

tube marine boiler, May, 8 1901.

with forced draft.]

Temperature.			Air pressures in inches of water.			Flue gases.				Water.	
Outside air.	Air in fire room.	Gases at base of stack.	Fire room.	Ash pit.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
Deg. F.	Deg. F.	Deg. F.				%	%	%	Lbs.	Lbs.	Lbs.
....	108	730	....	....	....	10.1	5.7	1.8	16.2	....	....
74	112	....	2.05	2	−0.75	....	....	....	....	....	....
....	119	1340	2.05	2	− .85	16	2.1	.0	13.1	....	....
....	124	....	2.20	2.10	− .90	....	....	....	....	....	....
76	127	1240	2.05	2	− .85	15.2	3	.0	13.8	19,108	19,108
....	126	....	2.05	2	− .85	....	....	....	....	....	....
....	127	1175	2.05	2	− .85	10	6.4	1.6	17.1	....	....
....	128	....	2.05	2	− .85	....	....	....	....	....	....
72	129	955	2.05	2	− .85	13.3	5.2	.7	15.5	19,916	39,024
....	127	....	2.05	2	− .85	....	....	....	....	....	....
....	125	920	2.10	2.05	− .85	12.5	5	.9	15.5	....	....
....	115	....	2.05	2	− .85	....	....	....	....	....	....
72	121	825	2	1.95	− .80	12.6	5	1.1	15.3	20,286	59,310
....	123	....	2.05	2	− .85	....	....	....	....	....	....
....	120	875	2.10	2	− .85	10	6.9	1.6	17.6	....	....
....	119	....	2	1.95	− .80	....	....	....	....	....	....
70	120	955	2.05	2	− .80	12.1	4.4	1.3	14.8	20,483	79,794
72.8	121.7	1001.6	2.059	2	− .838	12.42	4.85	1	15.4	19,948	....

Ashes before beginning of test, 195 pounds.
Ashes during test, 459 pounds.
Refuse, including sweepings from tubes and baffles, 815 pounds.
Per cent of moisture in coal by weighing and drying sample, 0.5.
Fired and raked alternately at intervals averaging 9 minutes for each. Average interval between slicings, 14 minutes, varying from 3 minutes to 31 minutes. Frequent flames in stack, especially during first two hours. Average smoke by Ringelmann charts, 2¼.

No. 4.—*Test of Hohenstein water-*

[Eight hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9 a. m	272	140	399	300	0.982	0	60	93	....
9.15 a. m	272	135	402	310	.987	0	....	95	....
9.30 a. m	275	145	404	313	.988	0	....	102	610
9.45 a. m	275	135	402	315	.990	0	....	104	....
10 a. m	275	135	403	316	.990	0	60	104	605
10.15 a. m	275	140	404	316	.990	0	....	107	....
10.30 a. m	275	130	406	316	.989	0	....	108	610
10.45 a. m	275	135	406	316	.989	+⅛	....	111	....
11 a. m	272	130	403	316	.990	0	60	111	610
11.15 a. m	275	135	404	316	.990	0	....	109	....
11.30 a. m	273	135	402	316	.990	0	....	111	660
11.45 a. m	275	130	403	316	.990	0	....	100	....
12 m	270	135	403	317	.990	0	64	114	660
12.15 p. m	272	135	404	318	.990	+⅛	....	115	....
12.30 p. m	272	138	403	317	.990	+⅛	....	113	665
12.45 p. m	272	135	404	317	.990	0	....	112	....
1 p. m	272	140	404	317	.990	0	66	113	655
1.15 p. m	272	135	404	317	.990	0	....	112	....
1.30 p. m	272	135	403	317	.990	0	....	112	670
1.45 p. m	274	135	403	317	.990	0	....	111	....
2 p. m	270	135	402	317	.991	0	66	113	735
2.15 p. m	270	140	403	317	.990	0	....	117	....
2.30 p. m	270	145	404	317	.990	+⅛	....	122	665
2.45 p. m	272	142	404	317	.990	0	....	124	....
3 p. m	272	140	404	316	.990	0	70	125	650
3.15 p. m	275	140	406	318	.990	0	....	126	....
3.30 p. m	273	150	404	317	.990	0	....	127	665
3.45 p. m	272	150	404	321	.993	0	....	129	....
4 p. m	274	130	404	324	.995	+⅛	66	126	845
4.15 p. m	272	135	403	324	.995	0	....	125	....
4.30 p. m	272	135	403	326	.996	0	....	124	850
4.45 p. m	274	135	404	330	.998	0	....	124	....
5 p. m	274	130	403	324	.995	0	68	125	640
Average	272.8	137	....	....	.990	....	64.4	114	675

State of weather, squally.
Barometer at noon, 29.70 inches.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 340 pounds.
Coal burned in starting fires, 2,000 pounds.
Coal burned during test, 8,633 pounds.
Ashes before beginning of test, 175 pounds.
Ashes during test, 226 pounds.

tube marine boiler, May 29, 1901.

with natural draft.]

Air pressures in inches of water.					Flue gases.				Water.	
Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*
0.0	−0.20	−0.20	−0.20	−0.20						
.0	−.20	−.20	−.20	−.22						
.0	−.18	−.20	−.20	−.22	13	4	1.5	14.1		
.0	−.16	−.20	−.20	−.22						
.0	−.18	−.20	−.20	−.20	11.2	5.1	1.7	15.4	10,570	10,570
.0	−.18	−.20	−.20	−.20						
.0	−.16	−.20	−.20	−.20	12.3	4.7	1.6	14.8		
.0	−.18	−.20	−.20	−.20						
.0	−.16	−.20	−.20	.20	11.5	6	1.4	16.3	10,252	20,822
.0	−.16	−.20	−.20	−.22						
.0	−.16	−.20	−.20	−.22	11.2	5.1	1.4	15.6		
.0	−.18	−.20	−.20	−.22						
.0	−.18	−.20	−.20	−.26	9.5	5.2	2.8	14.9	10,320	31,142
.0	−.16	−.20	−.20	−.28						
.0	−.16	−.20	−.20	−.28	11.4	3.7	2.6	13.5		
.0	−.16	−.20	−.20	−.26						
.0	−.16	−.20	−.20	−.26	10.1	7.4	1.2	18.5	9,994	41,136
−.05	−.16	−.20	−.20	−.26						
−.05	−.18	−.20	−.20	−.28	10.9	4.5	2.8	14.1		
−.05	−.18	−.20	−.20	−.28						
−.05	−.20	−.22	−.22	−.28	9.4	5.3	2.5	15.5	9,653	50,789
.0	−.18	−.20	−.20	−.26						
.0	−.18	−.20	−.20	−.28	10.4	4	3.1	13.7		
.0	−.18	−.20	−.20	−.26						
.0	−.18	−.20	−.20	−.28	11.6	4.9	2	14.9	9,122	59,911
.0	−.16	−.20	−.20	−.26						
.0	−.16	−.20	−.20	−.24	10.7	3.7	3.3	13.2		
.0	−.18	−.20	−.20	−.24						
.0	−.18	−.20	−.20	−.26	11.4	4.4	2	14.5	8 846	68,757
.0	−.20	−.22	−.22	−.28						
−.02	−.20	−.22	−.22	−.30	11.7	3.5	3	13.1		
−.02	−.22	−.25	−.25	−.30						
−.02	−.20	−.25	−.25	−.28					9,192	77,949
−.0008	−.177	−.20	−.20	−.24	11.08	4.75	2.19	14.8	9,744	

Refuse, including sweepings from tubes and baffles, 549 pounds.

Per cent of moisture in coal by chemical analysis, 0.79.

Average interval between firings, 6½ minutes. Average interval between rakings, eight minutes. Average thickness of fire, 6 inches. The draft was checked by means of a damper in the smoke pipe, so as to keep the rate of combustion at about 1,100 pounds of coal per hour. Average smoke by Ringelmann charts, 2.2. At 1.40 o'clock two bricks came down from combustion-chamber baffle.

No. 5.—*Test of Hohenstein water-*

[Six hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9.30 a. m	275	130	400	304	0.984	0	80	118	....
9.45 a. m	270	125	401	304	.984	+1	....	125	....
10 a. m	275	125	402	307	.985	0	....	130	730
10.15 a. m	275	130	402	309	.987	0	....	133	....
10.30 a. m	275	130	402	308	.986	0	82	135	660
10.45 a. m	275	136	402	309	.987	0	....	137	....
11 a. m	275	132	400	309	.986	+1	....	138	690
11.15 a. m	272	128	401	310	.987	0	....	139	....
11.30 a. m	273	130	402	310	.988	0	84	139	675
11.45 a. m	273	120	402	310	.988	0	....	139	....
12 m	273	130	402	312	.989	0	....	143	675
12.15 p. m	275	130	402	311	.988	+ ½	....	141	....
12.30 p. m	275	130	401	312	.988	+ ½	85	140	740
12.45 p. m	275	128	402	313	.989	0	....	142	....
1 p. m	275	130	401	314	.990	+ ½	....	141	700
1.15 p. m	275	132	402	314	.990	0	....	141	....
1.30 p. m	275	128	402	313	.989	+1	86	143	700
1.45 p. m	275	134	402	316	.981	+1	....	142	....
2 p. m	275	130	401	317	.992	+ ½	....	144	670
2.15 p. m	275	130	401	317	.992	+ ½	....	147	....
2.30 p. m	273	132	401	311	.987	0	86	146	670
2.45 p. m	273	126	402	314	.990	0	....	145	....
3 p. m	275	128	403	316	.990	0	....	146	745
3.15 p. m	272	126	404	317	.990	0	....	146	....
3.30 p. m	272	132	401	318	.992	0	86	148	528
Average	274	126.6	....	....	.988	....	84.1	139.5	681

State of weather, bright and sunshiny.
Barometer at noon, 30.08 inches.
Revolutions of blower, 243 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Wood burned in starting fires, 360 pounds.
Coal burned in starting fires, 2,200 pounds.
Coal burned during test, 10,695 pounds.

No. 6.—*Test of Hohenstein water-*

[Three and one-half hours'

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9.30 a. m	275	112	398	296	0.980	0	70	106	....
9.45 a. m	273	118	398	310	.988	0	....	116	....
10 a. m	270	118	398	311	.989	0	....	120	840
10.15 a. m	272	112	399	309	.988	0	....	120	....
10.30 a. m	272	110	399	310	.988	0	76	124	930
10.45 a. m	270	112	399	309	.988	0	....	124	....
11 a. m	270	110	399	306	.985	0	....	124	800
11.15 a. m	272	108	400	306	.986	0	....	128	....
11.30 a. m	270	110	399	321	.995	0	76	131	1,450
11.45 a. m	272	112	400	324	.996	0	....	132	....
12 m	275	120	400	319	.993	+ ½	....	133	1,240
12.15 p. m	273	130	400	317	.992	0	....	134	....
12.30 p. m	272	130	400	324	.996	0	77	137	1,060
12.45 p. m	272	130	401	329	.999	0	....	140	....
1 p. m	....	....	399	328	.998	0	....	141	1,560
Average	272	116.5	....	....	.990	....	74.75	127.3	1,125.7

State of weather, bright and sunshiny.
Barometer at noon, 29.95 inches.
Revolutions of blower, 375 per minute.
Kind of fuel, Pocahontas coal, run of mine.
Coal burned during test, 8,736−275=8,461 pounds.
Ashes during test, 591 pounds.

tube marine boiler, June 5, 1901.

with forced draft.]

Air pressures in inches of water.					Flue gases.				Water.	
Fire room.	Ash pit.	Furnace.	Combustion chamber.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*
1	0.95	0.80	0.60	−0.4	....	....	....	....	....	....
1	1	.85	.60	− .4	....	....	....	....	....	....
1.05	1	.85	.60	− .45	12.2	4.4	1.6	14.5	....	....
1.10	1.05	.85	.60	− .45	....	....	....	....	....	....
1.05	1	.85	.60	− .4	10	5.7	2	16.1	15,200	15,200
1	.95	.85	.60	− .4	....	....	....	....	....	....
1	.95	.80	.60	− .4	11.1	4.3	2.1	14.4	....	....
1	.95	.70	.55	− .4	....	....	....	....	....	....
1	.95	.75	.60	− .4	9.7	5.2	2.3	15.4	15,041	30,241
1	.95	.75	.60	− .4	....	....	....	....	....	....
1.10	1.05	.70	.60	− .4	11	4.3	2	14.5	....	....
1.10	1.05	.75	.60	− .4	....	....	....	....	....	....
1.10	1.05	.85	.65	− .4	12.2	4.8	1.4	15	16,505	46,746
1.10	1.05	.80	.65	− .4	....	....	....	....	....	....
1.10	1.05	.85	.65	− .4	10.7	4.8	2.2	14.9	....	....
1.10	1.05	.85	.65	− .4	....	....	....	....	....	....
1.10	1.05	.80	.65	− .4	10	6.6	1.8	17.1	14,914	61,660
1.10	1.05	.80	.65	− .4	....	....	....	....	....	....
1.10	1.05	.85	.70	− .4	9.8	4.9	2.7	14.8	....	....
1.10	1.05	.80	.65	− .4	....	....	....	....	....	....
1.10	1.05	.75	.65	− .4	9.4	5.7	2.3	16	15,270	76,930
1.10	1.05	.80	.65	− .4	....	....	....	....	....	....
1.10	1.05	.80	.65	− .4	11.2	4.3	2.1	14.4	....	....
1.10	1.05	.80	.65	− .4	....	....	....	....	....	....
1	.95	.75	.60	− .4	6.9	5.4	3.9	15.2	15,534	92,464
1.064	1.016	.80	.624	− .404	10.35	5.03	2.2	15.2	15,411	....

Ashes before beginning test, 200 pounds.
Ashes during test, 1,038 pounds.
Refuse, including sweepings from tubes and baffles, 539 pounds.
Per cent of moisture in coal, by chemical analysis, 0.79.
Fired and raked alternately at intervals averaging 8 minutes for each. Average smoke by Ringelmann charts, 2.2.

tube marine boiler, June 8, 1901.

duration with forced draft.]

Air pressures in inches of water.					Flue gases.				Water.	
Fire room.	Ash pit.	Furnace.	Combustion chamber.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fed per hour.	Total weight fed.
					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*
2	1.95	1.50	1.35	−0.30	....	....	....	....	....	....
2	1.90	1.50	1.35	− .30	....	....	....	....	....	....
2	1.95	1.55	1.40	− .30	13	....	2.2	....	....	....
2	1.90	1.55	1.40	− .25	....	....	....	....	....	....
2	1.95	1.60	1.45	− .20	10.5	3.9	1.9	14.3	17,641	17,641
2	1.95	1.60	1.45	− .20	....	....	....	....	....	....
2.1	2	1.65	1.45	− .25	11.8	4.9	1.3	15.3	....	....
2.1	2	1.70	1.50	− .15	....	....	....	....	....	....
2.2	2.15	1.70	1.50	− .10	17.8	.7	.1	12	17,521	35,162
2	2.05	1.60	1.40	− .15	....	....	....	....	....	....
1.95	1.90	1.45	1.30	− .20	16.7	1.7	.2	12.6	....	....
2	1.95	1.50	1.40	− .30	....	....	....	....	....	....
2	1.95	1.45	1.40	− .30	16.6	2.4	.1	13.2	16,648	51,810
2	1.95	1.50	1.45	− .30	....	....	....	....	....	....
....	....	....	....	....	10	8.8	.7	20.6	8,729	60,539
2.025	1.968	1.56	1.41	− .235	13.77	3.73	.928	14.66	17,297	....

Refuse, including sweepings from tubes and baffles, 626 pounds.
Per cent of moisture in coal by chemical analysis, 0.79.
Fired and raked alternately at intervals averaging 6 minutes for each. Average smoke by Ringelmann charts, 3.4. Almost continual flaming in stack. Base of stack occasionally red hot. Test stopped prematurely at 1 o'clock on account of roof taking fire. The fires were about 2 inches thicket at end of trial than at beginning, corresponding to a difference of about 275 pounds of coal.

No. 7.—*Test of Hohenstein water-tube*

[Eight hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
8.30 a. m	....	....	404	306	0.984	2½	....	110	....
8.45 a. m	275	126	404	307	.985	2½	60	117	540
9 a. m	275	124	404	307	.985	2½	....	117	....
9.15 a. m	275	124	404	309	.986	2	....	121	555
9.30 a. m	275	128	404	309	.986	2	....	126	....
9.45 a. m	275	124	404	309	.986	2	66	130	535
10 a. m	275	126	404	309	.986	2	....	137	....
10.15 a. m	275	128	404	309	.986	2½	....	137	570
10.30 a. m	275	130	404	310	.986	2	....	138	....
10.45 a. m	275	128	404	310	.986	2¼	68	140	575
11 a. m	275	128	404	310	.986	2	....	143	....
11.15 a. m	275	126	404	310	.986	2	....	141	560
11.30 a. m	275	126	404	310	.986	2½	....	144	....
11.45 a. m	275	134	404	310	.986	2	72	148	581
12 m	275	134	404	310	.986	2	....	143	....
12.15 p. m	275	128	403	310	.987	2½	....	148	560
12.30 p. m	275	130	404	310	.986	2½	....	148	....
12.45 p. m	275	130	404	310	.986	2½	74	147	584
1 p. m	275	130	404	312	.987	2¾	....	144	....
1.15 p. m	275	132	404	311	.987	2½	....	148	550
1.30 p. m	275	134	404	312	.987	2¾	....	144	....
1.45 p. m	275	132	404	311	.987	2¾	76	150	560
2 p. m	275	130	404	310	.986	2¾	....	143	....
2.15 p. m	275	134	402	311	.988	2½	....	150	560
2.30 p. m	275	134	404	311	.987	2½	....	158	....
2.45 p. m	275	136	404	310	.986	2¾	76	162	570
3 p. m	275	138	404	310	.986	2¾	....	164	....
3.15 p. m	275	140	404	310	.986	2¾	....	160	565
3.30 p. m	275	140	404	310	.986	2½	....	159	....
3.45 p. m	275	140	404	311	.987	2½	78	162	570
4 p. m	275	142	404	311	.987	2½	....	160	....
4.15 p. m	275	140	404	312	.988	3	....	156	565
4.30 p. m	275	142	404	312	.988	3	....	155	....
Average	275	131.8	....	....	.986	....	71¼	144	562½

State of weather, clear.
Barometer at noon, 30.34 inches.
Kind of fuel, New River coal, run of mine.
Wood burned in starting fires, 360 pounds.
Coal burned in starting fires, 2,000 pounds.
Ashes before beginning test, 198 pounds.
Ashes during test, 485 pounds.

marine boiler, October 21, 1901.

with natural draft.]

Air pressures in inches of water.					Flue gases.				Coal.		Water.	
Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
					%	*%*	*%*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
−0.05	−0.10	−0.07	−0.15	−0.50	9.7	6.2	1.1	17.5	......	......	......	......
− .05	− .10	− .06	− .20	− .50	......	......	......	......	......	......	......	......
− .05	− .10	− .06	− .20	− .50	10	5.8	1.1	17	......	......	......	......
− .05	− .10	− .06	− .20	− .50	......	......	......	......	1,300	1,300	9,534	9,534
− .05	− .10	− .06	− .20	− .50	10.1	5.6	2	15.9	......	......	......	......
− .05	− .10	− .06	− .20	− .50	......	......	......	......	......	......	......	......
− .05	− .12	− .08	− .22	− .50	9.5	5.7	2.1	16.2	......	......	......	......
− .05	− .14	− .08	− .22	− .50	......	......	......	......	1,175	2,475	9,554	19,088
− .05	− .16	− .10	− .24	− .50	10	6.5	1.1	17.7	......	......	......	......
− .05	− .16	− .10	− .24	− .50	......	......	......	......	......	......	......	......
− .05	− .16	− .10	− .24	− .50	10	5.7	1.8	16.2	......	......	......	......
− .05	− .16	− .08	− .22	− .50	......	......	......	......	1,125	3,600	9,693	28,781
− .05	− .16	− .12	− .24	− .50	10.2	6.2	1.6	16.8	......	......	......	......
− .05	− .18	− .12	− .22	− .50	......	......	......	......	......	......	......	......
− .05	− .18	− .12	− .22	− .50	9.2	7.4	1.2	19.1	......	......	......	......
− .05	− .18	− .14	− .22	− .50	......	......	......	......	1,100	4,700	9,058	37,839
− .05	− .18	− .14	− .22	− .50	9.2	6.8	1.7	17.8	......	......	......	......
− .05	− .18	− .14	− .22	− .50	......	......	......	......	......	......	......	......
− .05	− .20	− .14	− .22	− .50	9.2	6.8	1.8	17.7	......	......	......	......
− .05	− .20	− .14	− .22	− .50	......	......	......	......	1,100	5,800	8,660	46,499
− .05	− .18	− .14	− .22	− .50	9.1	7.7	1	19.7	......	......	......	......
− .05	− .20	− .14	− .22	− .50	......	......	......	......	......	......	......	......
− .05	− .18	− .14	− .22	− .50	8.7	6.8	2.3	17.5	......	......	......	......
− .05	− .18	− .15	− .22	− .50	......	......	......	......	1,000	6,800	8,381	54,880
− .05	− .18	− .15	− .22	− .50	8.5	6.1	1.6	17.6	......	......	......	......
− .05	− .16	− .15	− .22	− .50	......	......	......	......	......	......	......	......
− .05	− .16	− .15	− .22	− .50	8	6.4	1.8	18	......	......	......	......
− .05	− .16	− .15	− .22	− .50	......	......	......	......	650	7,450	7,217	62,097
− .05	− .16	− .15	− .22	− .50	8.8	6.7	1.2	18.5	......	......	......	......
− .05	− .16	− .15	− .22	− .50	......	......	......	......	......	......	......	......
− .05	− .14	− .14	− .20	− .50	8	7.3	.9	20.4	......	......	......	......
− .05	− .14	− .14	− .20	− .50	......	......	......	......	605	8,055	6,475	68,572
− .05	− .155	− .116	− .216	− .50	9.26	6.48	1.52	17.7	1,007	......	8,558	......

Refuse, including sweepings from tubes and baffles, 561 pounds.

Per cent of moisture in coal by weighing and drying sample, 3.14.

Average interval between firings, 6 minutes. Raked and sliced alternately between firings. Thickness of fire during first four hours, 6 inches; for next two hours, 9 inches; then allowed to burn down to original thickness. Average smoke by Ringelmann charts, 2.

No. 8.—*Test of Hohenstein water-tube*

[Six hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9 a. m	....	....	....	....	....	2½	....	106	....
9.15 a. m	275	128	403	292	0.976	2½	70	111	630
9.30 a. m	275	130	402	292	.977	2½	....	114	....
9.45 a. m	275	120	402	295	.979	2¾	....	116	637
10 a. m	275	120	402	292	.977	2½	....	118	....
10.15 a. m	275	118	402	292	.977	2½	72	118	670
10.30 a. m	275	119	402	293	.977	2½	....	123	....
10.45 a. m	275	124	402	292	.977	2½	....	120	630
11 a. m	275	120	402	293	.977	2½	....	123	....
11.15 a. m	275	129	402	296	.979	3	76	128	680
11.30 a. m	275	122	402	292	.977	2¾	....	124	....
11.45 a. m	275	126	402	290	.976	2½	....	124	678
12 m	275	128	402	290	.976	2¾	....	128	....
12.15 p. m	275	126	402	292	.977	3	76	125	667
12.30 p. m	275	122	402	292	.977	3	....	127	....
12.45 p. m	275	128	402	291	.976	3	....	128	660
1 p. m	275	126	401	289	.976	2½	....	130	....
1.15 p. m	275	124	402	290	.976	2¾	76	129	660
1.30 p. m	275	122	402	289	.975	3	....	128	....
1.45 p. m	275	126	402	289	.975	4	....	128	680
2 p. m	275	132	402	291	.976	3	....	124	....
2.15 p. m	275	136	402	288	.975	2½	76	127	635
2.30 p. m	275	132	402	288	.975	2½	....	131	....
2.45 p. m	275	130	402	288	.975	2½	....	131	620
3 p. m	275	138	402	288	.975	2½	....	126	....
Average	275	126.1	....	....	.976	....	74.34	123.5	654

State of weather, cloudy.
Barometer at noon. 29.95 inches.
Kind of fuel, New River coal, run of mine.
Wood burned in starting fires, 250 pounds.
Coal burned in starting fires, 1,910 pounds.

marine boiler, October 23, 1901.

with forced draft.]

Air pressures in inches of water.						Flue gases.				Coal.		Water.	
Fire room.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O,	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
						%	%	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	0.95	0.80	0.70	0.45	−0.50	8.6	7.3	1.5	19	......	......	......	......
1.05	.95	.78	.70	.50	− .47	......	......	......	......	......	......	......	......
1.05	1	.70	.65	.45	− .45	8.9	7	2.1	17.8	......	......	......	......
1.05	1	.75	.70	.48	− .42	......	......	......	......	2,000	2,000	13,996	13,996
1.05	1	.75	.70	.45	− .45	9	6.5	1.5	17.8	......	......	......	......
1.05	1	.75	.68	.45	− .43	......	......	......	......	......	......	......	......
1.05	1	.80	.70	.50	− .45	7.7	7	2.9	17.6	......	......	......	......
1.08	1	.75	.70	.50	− .45	......	......	......	......	1,800	3,800	14,508	28,504
1.08	1	.80	.70	.50	− .43	9	6.3	1.9	17.2	......	......	......	......
1.08	1	.80	.70	.50	− .45	......	......	......	......	......	......	......	......
1.05	1	.80	.70	.50	− .45	8.6	7.2	1.1	19.5	......	......	......	......
1.08	1	.82	.75	.55	− .42	......	......	......	......	1,800	5,600	14,344	42,848
1.10	1	.85	.72	.55	− .45	9.5	6.7	1.6	17.7	......	......	......	......
1.10	1	.85	.72	.55	− .48	......	......	......	......	......	......	......	......
1.10	1	.85	.76	.58	− .45	9.5	6.6	1.3	17.9	......	......	......	......
1.10	1	.85	.75	.55	− .50	......	......	......	......	1,600	7,200	14,194	57.042
1.08	1	.85	.75	.55	− .50	10	6.6	1.1	17.8	......	......	......	......
1.08	1	.85	.75	.55	− .50	......	......	......	......	......	......	......	......
1.08	1	.85	.75	.55	− .48	9	7.2	1.6	18.5	......	......	......	......
1.05	1	.85	.75	.55	− .48	......	......	......	......	1,400	8,600	13,459	70,501
1.08	1	.85	.75	.55	− .48	9.1	8.3	.6	21	......	......	......	......
1.08	1	.85	.75	.55	− .48	......	......	......	......	......	......	......	......
1.10	1.05	.85	.75	.50	− .48	7.5	6.6	1.9	18.5	......	......	......	......
1.10	1.05	.85	.75	.50	− .48	......	......	......	......	1,098	9,698	10,246	80,747
1.07	1	.813	.722	.515	− .464	8.87	6.94	1.59	18.4	1,616	......	13,458	......

Ashes before beginning test, 161 pounds.
Ashes during test, 365 pounds.
Refuse, including sweepings from tubes and baffles, 528 pounds.
Per cent of moisture in coal by weighing and drying sample, 3.14.
Average interval between firings, 6 minutes. Raked and sliced alternately between firings. Occasional flames in stack. Average smoke by Ringelmann charts, 2.

No. 9.—*Test of Hohenstein water-tube*

[Four hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
12.45 p. m	275	....	396	290	0.978	2½	....	102	....
1 p. m	275	112	397	292	.979	2	....	102	685
1.15 p. m	275	110	397	294	.980	2	....	102	....
1.30 p. m	275	110	397	292	.979	4	....	104	713
1.45 p. m	275	112	397	297	.982	2¾	68	104	....
2 p. m	275	112	397	294	.980	2¼	....	105	750
2.15 p. m	275	116	397	296	.981	2	....	108	....
2.30 p. m	275	112	397	294	.980	2½	....	110	650
2.45 p. m	275	112	397	296	.981	3	68	108	....
3 p. m	275	112	397	293	.979	2¾	....	110	732
3.15 p. m	275	112	397	292	.979	2¾	....	108	....
3.30 p. m	275	112	397	294	.980	2¾	....	109	605
3.45 p. m	275	110	397	293	,979	2¾	68	109	....
4 p. m	275	110	397	292	.979	3	....	108	725
4.15 p. m	275	112	397	292	.978	3¾	....	108	....
4.30 p. m	275	112	397	291	.978	2½	....	107	640
4.45 p. m	275	112	397	294	.980	2½	68	106	....
Average	275	111.75	....	....	.980	....	68	106.5	687.5

State of weather, smoky.
Barometer at noon, 30.25 inches.
Kind of fuel, New River coal—run of mine.
Wood burned in starting fires, 361 pounds.
Coal burned in starting fires, 2,200 pounds.

marine boiler, October 26, 1901.

with forced draft.]

Air pressures in inches of water.						Flue gases.				Coal.		Water.	
Fire room.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
						%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
2.10	2	1.40	1.25	1.05	−0.90	7.5	6.3	2.4	17.1	......	......	......	......
2.10	2	1.45	1.25	1.05	− .95	......	......	......	......	......	......	......	......
2.10	2	1.45	1.25	1.10	− .95	8.3	6.7	1.5	18.1	......	......	......	......
2.10	2	1.45	1.30	1.15	−1	......	......	......	......	2,450	2,450	18,147	18,147
2.10	2	1.45	1.30	1.15	− .95	10	5.9	1.9	16.4	......	......	......	......
2.10	2	1.45	1.30	1.10	−1	......	......	......	......	......	......	......	......
2.10	2	1.45	1.25	1.10	−1	9.6	6.4	1.4	17.5	......	......	......	......
2.10	2	1.45	1.25	1.10	−1	......	......	......	......	2,350	4,800	18,662	36,809
2.10	2	1.45	1.25	1.10	−1	9.2	6.5	1.7	17.5	......	......	......	......
2.10	2	1.40	1.20	1.05	−1	......	......	......	......	......	......	......	......
2.10	2	1.40	1.20	1.05	−1	9.4	6.3	2	16.9	......	......	......	......
2.10	2	1.40	1.20	1.05	−1	......	......	......	......	2,300	7,100	18,196	55,005
2.10	2	1.40	1.22	1.05	−1	9.8	6.8	1	18.2	......	......	......	......
2.10	2	1.40	1.22	1.05	−1	......	......	......	......	......	......	......	......
2.10	2	1.40	1.25	1.10	−1	10	6	1.4	16.9	......	......	......	......
2.10	2	1.40	1.25	1.10	−1	......	......	......	......	1,900	9,000	16,639	71,644
2.10	2	1.43	1.25	1.08	− .98	9.2	6.4	1.7	17.3	2,250	......	17,911	......

Ashes before beginning test, 152 pounds.
Ashes during test, 391 pounds.
Refuse, including sweepings from tubes and baffles, 732 pounds.
Per cent of moisture in coal by weighing and drying sample, 3.14.
Average interval between firings, 6 minutes. Raked and sliced alternately between firings. Frequent fires in stack. Average smoke by Ringelmann charts, ½.

No. 10.—*Test of Hohenstein water-tube*

[Eight hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
8.45 a. m	275	120	402	302	0.983	2½	62	111	525
9 a. m	275	124	402	306	.985	2¾	....	110	....
9.15 a. m	275	120	402	314	.990	2½	....	118	580
9.30 a. m	275	126	402	316	.991	2¾	....	120	....
9.45 a. m	275	126	402	311	.988	2¼	66	118	590
10 a. m	275	119	402	326	.997	3	....	120	....
10.15 a. m	275	127	402	326	.997	2½	....	122	600
10.30 a. m	275	120	404	330	.998	2¾	....	124	....
10.45 a. m	275	129	402	313	.989	2¼	62	128	560
11 a. m	275	119	402	312	.989	2½	....	129	....
11.15 a. m	275	124	402	310	.987	2½	....	124	540
11.30 a. m	275	126	402	312	.988	2½	....	125	....
11.45 a. m	275	124	402	310	.987	2½	60	126	500
12 m	275	126	402	310	.987	2½	....	124	....
12.15 p. m	275	130	402	308	.986	2½	....	126	635
12.30 p. m	275	126	402	312	.988	2½	....	127	....
12.45 p. m	275	130	403	309	.986	2½	63	124	575
1 p. m	275	130	406	311	.986	2¾	....	121	....
1.15 p. m	275	124	403	314	.989	2½	....	126	680
1.30 p. m	275	126	402	313	.989	2½	....	124	....
1.45 p. m	275	130	403	310	.987	2½	63	127	490
2 p. m	275	126	402	311	.988	2½	....	127	....
2.15 p. m	275	140	402	310	.987	2¼	....	129	495
2.30 p. m	275	120	402	309	.987	2¼	....	131	....
2.45 p. m	275	130	403	309	.986	2½	64	132	510
3 p. m	275	130	402	310	.987	2½	....	126	....
3.15 p. m	275	122	402	310	.987	2¾	....	130	495
3.30 p. m	275	134	402	310	.987	2½	....	130	....
3.45 p. m	275	126	402	310	.987	2½	63	130	527
4 p. m	275	124	402	311	.988	2¾	....	134	....
4.15 p. m	275	125	402	310	.987	2½	....	134	500
4.30 p. m	275	129	402	308	.986	2½	....	132	....
4.45 p. m	275	124	402	310	.987	2½	61	130	520
Average	275	125.94	....	....	.988	....	62.7	125	548.4

State of weather, clear and humid.
Barometer at noon, 30.20 inches.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 2,792 pounds.
Ashes before beginning test, 225 pounds.

marine boiler, November 6, 1901.

with natural draft.]

Air pressures in inches of water.					Flue gases.				Coal.		Water.	
Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
−0.05	−0.10	−0.10	−0.10	−0.50	11.1	4.7	2.2	14.7	....	....	....	....
− .05	− .10	− .12	− .10	− .50	....	....	....	....	....	....	....	....
− .05	− .10	− .12	− .10	− .50	9.5	4.5	2.7	14.5	....	....	....	....
− .05	− .10	− .12	− .15	− .50	....	....	....	....	....	....	....	....
− .05	− .12	− .12	− .20	− .50	9.9	5	2.6	15	1,582	1,582	9,251	9,251
− .05	− .14	− .12	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .20	− .14	− .20	− .50	10	5.1	2.2	15.3	....	....	....	....
− .05	− .20	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .17	− .15	− .20	− .50	9.5	4.8	1.7	15.6	988	2,570	9,843	19,094
− .05	− .18	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .15	− .15	− .20	− .50	9.6	5.3	1.7	16.1	....	....	....	....
− .05	− .20	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .18	− .15	− .20	− .50	8.8	5.5	2	16.3	1,060	3,630	9,518	28,612
− .05	− .18	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .15	− .15	− .20	− .50	9	6.2	2.3	16.7	....	....	....	....
− .05	− .20	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .20	− .15	− .20	− .50	8.9	5.1	2.7	15.2	1,114	4,744	8,931	37,543
− .05	− .20	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .18	− .16	− .20	− .50	10.2	4.6	1.6	15.2	....	....	....	....
− .05	− .15	− .16	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .15	− .15	− .20	− .50	7.6	5.7	2.5	16.6	888	5,632	8,961	46,504
− .05	− .14	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .14	− .15	− .20	− .50	7.1	6.5	2	18.5	....	....	....	....
− .05	− .14	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .14	− .14	− .20	− .50	7.6	5.3	2.6	16.1	890	6,522	7,906	54,410
− .05	− .15	− .14	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .15	− .15	− .20	− .50	8.8	5	2.4	15.4	....	....	....	....
− .05	− .15	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .15	− .15	− .20	− .50	6.3	5.6	2.8	16.8	838	7,360	7,984	62,394
− .05	− .15	− .15	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .12	− .15	− .20	− .50	8.8	4.3	1.5	15.5	....	....	....	....
− .05	− .12	− .12	− .20	− .50	....	....	....	....	....	....	....	....
− .05	− .12	− .12	− .20	− .50	8.4	4.1	1.3	15.6	939	8,299	7,754	70,148
− .05	− .15	− .14	− .19	− .50	8.89	5.14	2.16	15.8	1,037	....	8,769	....

Ashes during test, 214 pounds.

Refuse, including sweepings from tubes and baffles, 526 pounds.

Per cent of moisture in coal by weighing and drying sample, 2.04.

Fired every 6 minutes. Raked after each second firing. Sliced at intervals of about 20 minutes. 8.45 to 10.45, thick fires and frequent flames in stack. 10.45 to end of test, thin fires and little or no flaming in stack. One calorimeter out of order. Smoke by Ringelmann charts, 1.

No. 11.—*Test of Hohenstein water-tube*

[Eight hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
8.45 a.m	275	122	402	300	0.981	2½	44	92	....
9 a.m	275	106	403	302	.982	2½	....	88	512
9.15 a.m	275	124	403	304	.983	2½	....	88	....
9.30 a.m	275	120	403	305	.984	2½	....	94	515
9.45 a.m	275	128	403	306	.984	2¾	52	98	....
10 a.m	275	127	403	307	.985	2¾	....	107	512
10.15 a.m	275	124	404	308	.985	2¾	....	108	....
10.30 a.m	275	118	403	310	.986½	2¾	....	120	485
10.45 a.m	275	130	403	311	.987	2¾	52	120	....
11 a.m	275	123	404	312	.987½	2¾	....	130	505
11.15 a.m	275	125	404	312	.987½	2½	....	126	....
11.30 a.m	275	123	403	312	.988	2½	....	122	510
11.45 a.m	275	125	403	312	.987½	2½	55	126	....
12 m	275	120	403	312	.988	2¾	....	129	515
12.15 p.m	275	126	403	312	.987½	2½	....	128	....
12.30 p.m	275	112	403	313	.988	3	....	132	530
12.45 p.m	275	126	402	313	.989	2¼	59	138	....
1 p.m	275	113	402	314	.989½	3	....	136	560
1.15 p.m	275	124	403	313	.987½	2½	....	135	....
1.30 p.m	275	118	403	314	.989	2¾	....	128	530
1.45 p.m	275	132	403	314	.989	2½	57	142	....
2 p.m	275	120	403	314	.989	2¾	....	140	520
2.15 p.m	275	130	404	314	.988½	2½	....	138	....
2.30 p.m	275	122	403	314	.989	2¾	....	136	540
2.45 p.m	275	128	403	314	.989	2½	57	132	....
3 p.m	275	117	403	314	.989	2½	....	132	525
3.15 p.m	275	122	403	314	.989	2¾	....	138	....
3.30 p.m	275	122	404	314	.988½	2¾	....	136	525
3.45 p.m	275	122	404	314	.988½	2½	60	136	....
4 p.m	275	118	404	314	.988½	2½	....	139	523
4.15 p.m	275	123	404	314	.988½	2½	....	137	....
4.30 p.m	275	123	403	314	.989	2½	....	142	527
4.45 p.m	275	124	404	316	.990	2½	60	144	....
Average	275	122.3	....	....	.987	....	55.1	125.4	521

State of weather, cloudy, occasional sun.
Barometer at noon, 30.18 inches.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 1,435 pounds.

marine boiler, November 9, 1901.

with natural draft.]

Air pressures in inches of water.					Flue gases.				Coal.		Water.	
Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
					%	%	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
-0.05	-0.08	-0.08	-0.10	-0.50	....	....	....	....	....	....	....	....
- .05	- .08	- .08	- .10	- .55	9.4	4.5	2	15.1	....	....	....	....
- .05	- .08	- .08	- .10	- .55	....	....	....	....	....	....	....	....
- .05	- .08	- .08	- .10	- .55	7.6	4.5	2.1	15.6	....	....	....	....
- .05	- .08	- .08	- .10	- .55	....	....	....	....	938	938	8,455	8,455
- .05	- .08	- .08	- .10	- .55	5.3	5	2.6	16.9	....	....	....	....
- .05	- .08	- .08	- .10	- .55	....	....	....	....	....	....	....	....
- .05	- .08	- .08	- .10	- .55	6.2	4.8	2.4	16.3	....	....	....	....
- .05	- .08	- .08	- .10	- .55	....	....	....	....	937	1,875	7,067	15,522
- .05	- .08	- .08	- .10	- .55	8.4	4.6	1.7	15.9	....	....	....	....
- .05	- .10	- .10	- .12	- .55	....	....	....	....	....	....	....	....
- .05	- .10	- .10	- .12	- .55	6.9	5.3	2.6	16.4	....	....	....	....
- .05	- .10	- .10	- .12	- .55	....	....	....	....	937	2,812	7,673	23,195
- .05	- .10	- .10	- .12	- .55	8.8	4.5	2	15.3	....	....	....	....
- .05	- .10	- .10	- .12	- .55	....	....	....	....	....	....	....	....
- .05	- .10	- .10	- .12	- .55	8.9	4	1.7	15	....	....	....	....
- .05	- .10	- .10	- .12	- .55	....	....	....	....	1,014	3,826	8,768	31,963
- .05	- .10	- .10	- .12	- .55	9.3	4.3	2	14.9	....	....	....	....
- .05	- .10	- .10	- .12	- .55	....	....	....	....	....	....	....	....
- .05	- .10	- .10	- .12	- .55	7.4	4.6	3	15	....	....	....	....
- .05	- .10	- .10	- .12	- .55	....	....	....	....	968	4,794	8,772	40,735
- .05	- .10	- .10	- .12	- .55	8.6	4.8	1.9	15.8	....	....	....	....
- .05	- .10	- .10	- .12	- .55	....	....	....	....	....	....	....	....
- .05	- .10	- .10	- .12	- .55	9.4	4.2	2.5	14.4	....	....	....	....
- .05	- .10	- .10	- .12	- .55	....	....	....	....	940	5,734	8,453	49,188
- .05	- .10	- .10	- .12	- .55	8.1	4.5	2.4	15.3	....	....	....	....
- .05	- .10	- .10	- .12	- .55	....	....	....	....	....	....	....	....
- .05	- .10	- .10	- .12	- .55	7	4.6	2.3	15.8	....	....	....	....
- .02	- .10	- .10	- .12	- .55	....	....	....	....	888	6,622	8,079	57,267
- .02	- .10	- .10	- .12	- .55	8	4.6	2.4	15.3	....	....	....	....
- .02	- .10	- .10	- .12	- .55	....	....	....	....	....	....	....	....
- .02	- .10	- .10	- .12	- .55	8.6	4.1	1.4	15.5	....	....	....	....
- .02	- .10	- .10	- .12	- .55	....	....	....	....	814	7,436	8,163	65,430
- .045	- .094	- .094	- .114	- .548	8	4.6	2.2	15.15	930	....	8,179	....

Ashes before beginning test, 303 pounds.
Ashes during test, 584 pounds.
Refuse, including sweepings from tubes and baffles, 356 pounds.
Per cent of moisture in coal by weighing and drying sample, 1.15.
Fired every 6 minutes. Raked after each second firing. No slicing until last two hours, then twice each hour. Fires thin. No flaming in stack. Very little smoke; none except while firing.

No. 12.—*Test of Hohenstein water-tube*

[Six hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9 a. m	275	104	402	303	0.983	2¾	50	92	....
9.15 a. m	275	120	402	302	.982½	2½	....	92	502
9.30 a. m	275	118	402	306	.984½	2¾	....	102	....
9.45 a. m	275	132	402	301	.981½	2¼	....	104	605
10 a. m	275	112	402	302	.982½	3	51	100	....
10.15 a. m	275	131	402	297	.972½	2½	....	98	590
10.30 a. m	275	124	402	304	.983½	2½	....	105	....
10.45 a. m	275	113	402	306	.984½	2⅛	....	107	590
11 a. m	275	126	402	306	.984½	2½	52	108	....
11.15 a. m	275	117	402	306	.984½	2½	....	109	590
11.30 a. m	275	120	402	306	.984½	2½	....	109	....
11.45 a. m	275	117	402	307	.985	2½	....	106	590
12 m	275	124	402	307	.985	2½	53	106	....
12.15 p. m	375	106	402	306	.984½	2½	....	109	580
12.30 p. m	275	124	402	304	.983½	2½	....	107	....
12.45 p. m	275	124	402	302	.982½	2¾	....	108	570
1 p. m	275	119	402	302	.982½	2¾	53	110	....
1.15 p. m	275	112	401	306	.985	2	....	108	590
1.30 p. m	275	110	402	306	.984½	1¾	....	108	....
1.45 p. m	275	122	402	302	.982½	2¼	....	107	565
2 p. m	275	113	402	305	.984	4¾	53	102	....
2.15 p. m	275	110	402	305	.984	3½	....	106	600
2.30 p. m	275	126	402	302	.982½	2¾	....	106	....
2.45 p. m	275	135	402	304	.983½	2	....	106	575
3 p. m	275	134	402	303	.983	2¾	53	104	....
Average	275	119.7	....	....	.983	....	52	105	580

State of weather, gray and overcast.
Barometer at noon, 30.09 inches.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 2,762 pounds.

marine boiler, November 18, 1901.

with forced draft.]

Air pressures in inches of water.						Flue gases.				Coal.		Water.	
Fire room.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
						%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	0.95	0.80	0.75	0.52	−0.55	......	......	......	....	....	....	....	....
.4	.50	.40	40	.30	− .50	7.4	3.7	1.9	14.9	....	....	....	....
1	.95	.80	.67	.55	− .55	......	......	......	....	....	....	....	....
1	.95	.80	.70	.50	− .55	8	3.7	2.1	14.5	....	....	....	....
1	.95	.80	.70	.52	− .55	......	......	......	....	1,232	1,232	11,100	11,100
1	.99	.80	.70	.52	− .55	7.2	3.9	2.4	14.6	....	....	....	....
1	.99	.85	.70	.52	− .55	......	......	......	....	....	....	....	....
1	.99	.85	.70	.52	− .55	6.8	4	2.5	14.9	....	....	....	....
1	1	.87	.72	.52	− .55	......	......	......	....	1,383	2,615	10,625	21,725
1	.99	.80	.72	.52	− .55	7.7	3.9	2.6	14.4	....	....	....	....
1	1	.80	.70	.52	− .55	......	......	......	....	....	....	....	....
1	1	.80	.70	.52	− .55	8	3.9	1.9	15	....	....	....	....
1	1	.80	.70	.52	− .55	......	......	......	....	1,533	4,148	12,054	33,779
1	1	.80	.70	.52	− .55	6.4	3.4	3	13.9	....	....	....	....
1	1	.80	.70	.52	− .55	......	......	......	....	....	....	....	....
1	1	.80	.70	.52	− .55	6.1	3.6	3.1	14.1	....	....	....	....
1	1	.80	.70	.52	− .55	......	......	......	....	1,580	5,728	13,397	47,176
1	1	.80	.70	.52	− .55	8.2	3.7	2.1	14.5	....	....	....	....
1	1	.80	.70	.52	− .55	......	......	......	....	....	....	....	....
1	1	.80	.70	.52	− .55	6.1	4.6	2.3	16.3	....	....	....	....
1	1	.80	.68	.52	− .55	......	......	......	....	1,430	7,158	12,701	59,877
1	1	.80	.68	.52	− .55	7.4	3.9	2.3	14.8	....	....	....	....
1	1	.80	.68	.52	− .55	......	......	......	....	....	....	....	....
1	1	.80	.68	.52	− .55	6.5	3.6	2.7	14.4	....	....	....	....
1	1	.80	.68	.52	− .55	......	......	......	....	1,230	8,388	10,396	70,273
.99	.97	.79	.69	.51	− .55	7.15	3.8	2.4	14.7	1,398	....	11,712	....

Ashes before beginning test, 526 pounds.
Ashes during test, 837 pounds.
Refuse, including sweepings from tubes and baffles, 562 pounds.
Per cent of moisture in coal by weighing and drying sample, 1.59.
Fired every 7 minutes. Raked after each second firing. No slicing. Very little smoke. No flaming in stack. 9.15 a. m., temporary loss of air pressure due to window blowing out of fireroom.

No. 13.—*Test of Hohenstein water-tube*

[Four hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
1.15 p. m.	275	100	401	296	0.979	2¾	40	80	....
1.30 p. m.	275	110	401	296	.979	1¾	....	83	700
1.45 p. m.	275	96	401	295	.979	2¼	....	85	....
2 p. m.	275	82	401	297	.980	2¾	....	86	705
2.15 p. m.	275	90	401	296	.979	2½	41	86	....
2.30 p. m.	275	88	401	296	.979	2¼	....	87	685
2.45 p. m.	275	90	401	293	.977	3	....	87	....
3 p. m.	275	90	401	294	.978	2¾	....	86	680
3.15 p. m.	275	88	402	294	.978	2½	40	90	....
3.30 p. m.	275	92	401	296	.979	2½	....	88	740
3.45 p. m.	275	88	401	296	.979	2½	....	88	....
4 p. m.	275	90	401	296	.980	2¼	....	90	745
4.15 p. m.	275	94	401	291	.977	2½	40	88	....
4.30 p. m.	275	88	402	293	.977	1½	....	86	700
4.45 p. m.	275	88	402	291	.976	3¾	....	86	....
5 p. m.	275	90	401	295	.979	2	....	84	780
5.15 p. m.	275	90	401	295	.979	2¾	40	84	....
Average	275	91.4	....	....	.979	....	40.2	86	717

State of weather, thin clouds.
Barometer at noon, 30.23 inches.
Kind of fuel, Pocahontas coal, hand-picked and screened.
Wood burned in starting fires, 310 pounds.
Coal burned in starting fires, 2,762 pounds.
Ashes before beginning test, 267 pounds.

marine boiler, November 27, 1901.

with forced draft.]

Air pressures in inches of water.						Flue gases.				Coal.		Water.	
Fire room.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
						%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
2.1	2	1.90	1.2	0.90	−0.60	......	......	......	....	....	....	....	....
2.1	2	1.60	1.2	.90	− .75	9	3.2	2.6	13.5	....	....	....	....
2.1	2	1.65	1.2	.90	− .75	......	......	......	....	....	....	....	....
2.1	2	1.65	1.2	.90	− .80	9	3.5	1.7	14.4	....	....	....	....
2.1	2	1.50	1.2	.90	− .80	......	......	......	....	2,663	2,663	21,133	21,133
2.1	2	1.62	1.2	.90	− .75	7.7	3.5	2.8	13.8	....	....	....	....
2.1	2	1.60	1.2	.85	− .75	......	......	......	....	....	....	....	....
2.1	2	1.45	1.2	.80	− .75	7.4	3.4	2.8	13.8	....	....	....	....
2.1	2	1.57	1.2	.85	− .80	......	......	......	....	2,911	5,574	22,436	43,569
2.1	2	1.50	1.1	.80	− .75	9.4	3.4	2.8	13.4	....	....	....	....
2.1	2	1.40	1.1	.80	− .75	......	......	......	....	....	....	....	....
2.1	2	1.45	1.1	.82	− .80	9.3	3.3	3.8	12.8	....	....	....	....
2.1	2	1.60	1.2	.90	− .80	......	......	......	....	2,662	8,236	22,090	65,659
2.1	2	1.57	1.2	.90	− .80	8.1	3	2.9	13.2	....	....	....	....
2.1	2	1.62	1.2	.85	− .80	......	......	......	....	....	....	....	....
2.1	2	1.60	1.2	.85	− .80	9.2	2.8	2.2	13.3	....	....	....	....
2.1	2	1.60	1.2	.80	− .80	......	......	......	....	2,458	10,694	20,535	86,194
2.1	2	1.58	1.18	.86	− .767	8.64	3.26	2.7	13.5	2,674	....	21,549	....

Ashes during test, 460 pounds.
Refuse, including sweepings from tubes and baffles, 936 pounds.
Per cent of moisture in coal, by weighing and drying sample, 1.
Fired every 5 minutes. Raked after each second firing. No fires in stack. Very little smoke. Average by Ringelmann charts, ⅛. Boiler casing red hot in places opposite the combustion chamber. The uptake is about 50 per cent larger than in all previous tests.

No. 14.—*Test of Hohenstein water-tube*

[Six hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
10.30 a. m	275	124	400	295	0.979	4	29	74	....
10.45 a. m	275	104	400	292	.977	3	....	70	605
11 a. m	275	104	400	290	.976	2	....	70	....
11.15 a. m	275	100	400	294	.979	2¼	....	70	725
11.30 a. m	275	95	401	295	.979	3	32	76	....
11.45 a. m	275	100	401	293	.978	2¼	....	76	600
12 m	275	102	401	293	.978	2½	....	76	....
12.15 p. m	275	104	401	292	.977	2¼	....	70	695
12.30 p. m	275	110	402	299	.981	2¼	33	76	....
12.45 p. m	275	105	402	298	.980	3¼	....	76	740
1 p. m	275	110	401	292	.977	2½	....	78	....
1.15 p. m	275	112	401	300	.982	3½	....	80	910
1.30 p. m	275	105	401	298	.981	2½	34	80	....
1.45 p. m	275	106	402	300	.981	3½	....	79	975
2 p. m	275	102	402	304	.984	2½	....	80	....
2.15 p. m	275	104	402	297	.980	2½	....	80	765
2.30 p. m	275	100	402	296	.979	2¼	33	80	....
2.45 p. m	275	102	402	295	.979	2¼	....	76	810
3 p. m	275	108	402	296	.979	2½	....	80	....
3.15 p. m	275	104	402	296	.979	2	....	80	785
3.30 p. m	275	102	402	295	.979	2½	33	80	....
3.45 p. m	275	107	402	298	.980	2	....	79	830
4 p. m	275	102	402	294	.978	3	....	80	....
4.15 p. m	275	107	402	294	.978	2¼	....	79	740
4.30 p. m	275	96	402	294	.978	4	32	80	....
Average	275	104.6	....	....	.980	....	32.3	77	766

State of weather, smoky, with thin clouds.
Barometer at noon, 30.13 inches.
Revolutions of blower, 243 per minute.
Kind of fuel, Pocahontas coal, hand-picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 3,256 pounds.
Ashes before beginning test, 271 pounds.
Ashes during test, 714 pounds.
Refuse, including sweepings from tubes and baffles, 923 pounds.
Per cent of moisture in coal, by chemical analysis, 0.73.

marine boiler, December 16, 1901.

with forced draft.]

Air pressures in inches of water.						Flue gases, CO_2.	Coal.		Water.	
Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.		Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
						%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	0.70	0.40	0.10	−0.20	−0.50					
1	.60	.40	.10	− .20	− .50	7.2				
1	.55	.35	.08	− .20	− .55					
1	.70	.40	.06	− .20	− .60	9.4				
1	.70	.35	.10	− .20	− .60		2,364	2,364	18,756	18,756
1	.60	.30	.08	− .20	− .60	6.5				
1	.35	.30	.02	− .20	− .60					
1	.50	.30	.03	− .20	− .60	7.3				
1	.40	.25	.03	− .20	− .60		2,557	4,921	17,721	36,477
1	.65	.30	.06	− .20	− .60	8.5				
1	.55	.30	.06	− .20	− .60					
1	.50	.25	.05	− .20	− .60	9				
1	.55	.25	.03	− .20	− .60		2,468	7,389	18,055	54,532
1	.55	.25	.08	− .20	− .60	9.2				
1	.55	.30	.08	− .20	− .60					
1	.55	.28	.05	− .20	− .60	7.8				
1	.65	.32	.08	− .20	− .60		2,270	9,659	17,820	72,352
1	.55	.40	.08	− .20	− .60	8.5				
1	.55	.32	.05	− .20	− .60					
1	.55	.32	.05	− .20	− .60	8.5				
1	.55	.35	.05	− .20	− .60		2,367	12,026	18,037	90,389
1	.60	.35	.05	− .20	− .60	7.8				
1	.60	.35	.05	− .20	− .60					
1	.55	.30	.03	− .20	− .60	7.7				
1	.60	.35	.06	− .20	− .60		2,003	14,029	18,374	108,763
1	.57	.32	.06	− .20	− .59	8.1	2,338		18,127	

Start delayed by the freezing of the feed pipe. Fired every 5 minutes. Raked after each firing. Clinker in left furnace at end of second hour. The firing was even and good, except when the fires were allowed to get too thick. The usual thickness was 8 inches to 10 inches, but at one time 12 inches were carried when flames appeared in the base of the stack. The flames would last but a few seconds, during which the stack temperature would go up to 1050° F. Average smoke by Ringelmann charts, 1½. The uptake area is about twice what it was in the first twelve tests.

No. 15.—*Test of Hohenstein water tube*

[Eight hours' duration,

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
8.30 a. m	275	116	402	302	0.983	3	22	73	....
8.45 a. m	275	126	404	304	.983	2½	....	74	525
9 a. m	275	122	404	304	.983	2½	....	67	....
9.15 a. m	275	125	404	303	.982	2½	....	71	570
9.30 a. m	375	119	404	305	.983	3	25	74	....
9.45 a. m	275	130	403	306	.984	2¾	....	77	565
10 a. m	275	121	404	305	.983	2½	....	82	....
10.15 a. m	275	123	404	306	.984	2¾	....	79	570
10.30 a. m	275	117	404	306	.984	3	25	81	....
10.45 a. m	275	134	404	306	.984	3	....	82	555
11 a. m	275	128	404	307	.985	2¾	....	82	....
11.15 a. m	275	126	404	307	.985	2¾	....	83	555
11.30 a. m	275	110	404	308	.985	3	26	87	....
11.45 a. m	275	130	404	306	.984	2½	....	88	555
12 m	275	119	404	308	.985	3	....	92	....
12.15 p. m	275	120	404	308	.985	2¾	....	90	565
12.30 p. m	275	140	404	308	.986	3	26	89	....
12.45 p. m	275	126	404	308	.985	2½	....	86	570
1 p. m	275	130	404	309	.986	3	....	89	....
1.15 p. m	275	122	404	309	.986	3	....	89	595
1.30 p. m	275	118	404	310	.987	3	27	90	....
1.45 p. m	275	130	404	309	.986	2¾	....	92	565
2 p. m	275	122	404	309	.986	2¾	....	95	....
2.15 p. m	275	135	402	309	.986	3	....	99	585
2.30 p. m	275	122	404	310	.987	4¼	28	102	....
2.45 p. m	275	122	404	306	.984	2¾	....	99	580
3 p. m	275	126	404	310	.986	3	....	96	....
3.15 p. m	275	135	404	309	.986	3	....	96	585
3.30 p. m	275	126	404	309	.986	3	26	97	....
3.45 p. m	275	129	403	308	.985	3	....	92	585
4 p. m	275	125	404	309	.986	3	....	95	....
4.15 p. m	275	133	404	306	.984	2¾	....	90	570
4.30 p. m	275	119	404	306	.984	3	26	92	....
Average	275	125	....	....	.985	....	26	87	568

State of weather, smoky, with thin clouds.
Barometer at noon, 30.01 inches.
Kind of fuel, Pocahontas coal, hand-picked and screened.
Wood burned in starting fires, 360 pounds.
Coal burned in starting fires, 2,440 pounds.

marine boiler, December 18, 1901.

with natural draft.]

Air pressures in inches of water.					Flue gases.				Coal.		Water.	
Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
					%	%	%	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
−0.20	−0.20	−0.25	−0.40	−0.50								
− .20	− .20	− .25	− .35	− .50	5.8							
− .20	− .20	− .25	− .35	− .50								
− .20	− .20	− .25	− .35	− .50	7.2							
− .20	− .20	− .25	− .35	− .50					1,034	1,034	10,466	10,466
− .20	− .20	− .25	− .35	− .50	8.2							
− .20	− .20	− .25	− .35	− .50								
− .20	− .20	− .25	− .35	− .50	7.5							
− .20	− .20	− .25	− .35	− .50					1,134	2,168	10,436	20,902
− .20	− .20	− .25	− .37	− .52	7							
− .20	− .20	− .25	− .40	− .52								
− .20	− .20	− .25	− .40	− .50	6.6							
− .20	− .20	− .25	− .40	− .50					1,186	3,354	9,908	30,810
− .20	− .20	− .25	− .37	− .52	6.8							
− .20	− .20	− .25	− .37	− .50								
− .20	− .20	− .25	− .37	− .50	8.5	11.5	0	27.1				
− .20	− .20	− .25	− .37	− .50					1,183	4,537	10,083	40,893
− .20	− .20	− .25	− .40	− .50	8.1	10.9	0	27.1				
− .20	− .20	− .25	− .37	− .50								
− .20	− .20	− .25	− .38	− .50	9.4	10.4	.2	23.9				
− .20	− .20	− .25	− .40	− .50					1,183	5,720	10,525	51,418
− .20	− .20	− .25	− .37	− .50	8.2	10.6	.1	26.2				
− .20	− .20	− .25	− .37	− .50								
− .20	− .20	− .25	− .40	− .50	8.4	11.4	0	27.3				
− .20	− .20	− .25	− .40	− .50					1,184	6,904	10,150	61,568
− .20	− .20	− .25	− .35	− .55	8.9	11.1	.2	25.5				
− .20	− .20	− .25	− .40	− .50								
− .20	− .20	− .25	− .40	− .55	7.3	12.9	0	32				
− .20	− .20	− .25	− .40	− .55					1,183	8,087	9,407	70,975
− .20	− .20	− .25	− .40	− .55	8.5	11.2	.2	26.3				
− .20	− .20	− .25	− .40	− .55								
− .20	− .20	− .25	− .40	− .55	7.2	12.8	.1	31.7				
− .20	− .20	− .25	− .40	− .55					1,194	9,181	10,043	81,018
− .20	− .20	− .25	− .38	− .51	7.9	11.4	.9	27.5	1.148		10,127	

Ashes before beginning test, 235 pounds.
Ashes during test, 702 pounds.
Refuse, including sweepings from tubes and baffles, 576 pounds.
Per cent of moisture in coal, by chemical analysis, 0.73.
Fired every 10 minutes. Raked after each firing. Practically no smoke.

No. 16.—*Test of Hohenstein water-tube*

[Four hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9.45 a. m	275	112	402	286	0.973	3½	18	60	....
10 a. m	275	111	402	288	.975	2½	....	60	680
10.15 a. m	275	101	402	289	.975	2	....	60	....
10.30 a. m	275	90	402	291	.976	3	....	62	730
10.45 a. m	275	91	402	292	.977	3	20	62	....
11 a. m	275	93	402	294	.978	2½	....	63	840
11.15 a. m	275	99	402	294	.978	2	....	64	....
11.30 a. m	275	96	402	291	.976	1¾	....	65	785
11.45 a. m	275	96	402	291	.976	3	24	64	....
12 m	275	96	402	292	.977	2¾	....	65	900
12.15 p. m	275	100	402	295	.978	2½	....	68	....
12.30 p. m	275	98	402	296	.979	2¼	....	68	780
12.45 p. m	275	100	402	294	.978	2¼	24	66	....
1 p. m	275	96	402	292	.977	2½	....	68	815
1.15 p. m	375	98	402	292	.977	2½	....	68	....
1.30 p. m	275	96	402	294	.978	2	....	66	880
1.45 p. m	275	99	402	294	.978	3½	26	67	....
Average	275	98.4	....	....	.978	....	22	64	800

State of weather, smoky, no clouds.
Barometer at noon, 30.28 inches.
Revolutions of blower, 332 per minute.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 450 pounds.
Coal burned in starting fires, 3,130 pounds.

No. 17.—*Test of Hohenstein water-tube*

[Three hours' duration

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.		
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F*	*Deg. F.*
10 a. m	275	89	400	280	0.970	2¼	34	75	....
10.15 a. m	275	90	400	283	.972	2½	....	78	900
10.30 a. m	275	80	400	284	.973	2	....	77	....
10.45 a. m	275	80	400	283	.972	3	....	79	900
11 a. m	275	94	402	284	.972	2	37	77	....
11.15 a. m	275	93	402	286	.973	1½	....	76	910
11.30 a. m	275	85	402	287	.974	2	....	76	....
11.45 a. m	275	90	401	288	.975	1¾	....	77	850
12 m	275	90	400	288	.975	2	36	76	....
12.15 p. m	275	85	401	288	.975	2	....	76	1,200
12.30 p. m	275	84	402	292	.977	2½	....	76	....
12.45 p. m	275	94	400	289	.976	2	....	76	900
1 p. m	275	89	401	289	.975	2	34	76	....
Average	275	88	....	....	.974	....	35	76.5	943

State of weather, dark, fog, and smoke.
Barometer at noon, 29.58 inches.
Revolutions of blower, 423 per minute.
Kind of fuel, Pocahontas coal, hand picked and screened.
Wood burned in starting fires, 350 pounds.
Coal burned in starting fires, 3,554 pounds.
Ashes before beginning test, 151 pounds.

marine boiler December 21, 1901.

with forced draft].

Air pressures, in inches of water.						Flue gases.				Coal.		Water.	
Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
						%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
2	1.55	1.1	0.30	-0.05	-0.50	......	......	......	....	....	....	....	....
2	1.60	1	.30	-.07	-.60	7.8	11.2	3.7	20.9	....	....	....	....
2	1.40	.9	.30	-.07	-.60	......	......	......	....	....	....	....	....
2	1.35	1	.30	-.07	-.60	9	10.4	.3	24.2	....	....	....	....
2	1.20	.9	.27	-.07	-.60	......	......	......	....	3,353	3,353	22,145	22,145
2	1.30	.95	.27	-.05	-.65	9.1	9.4	1.4	21.1	....	....	....	....
2	1.40	.9	.25	-.05	-.65	......	......	......	....	....	....	....	....
2	1.35	.85	.25	-.07	-.70	8	10	1.6	22.6	....	....	....	....
2	1.45	.95	.23	-.07	-.65	......	......	......	....	3,161	6,514	23,401	45,546
2	1.45	.9	.20	-.05	-.70	8.7	9.2	.5	22.7	....	....	....	....
2	1.40	.9	.20	-.05	-.70	......	......	......	....	....	....	....	....
2	1.25	.95	.19	-.10	-.67	9	9.7	.9	22.3	....	....	....	....
2	1.45	.97	.19	-.07	-.65	......	......	......	....	3,157	9,671	23,157	68,703
2	1.35	.85	.19	-.10	-.65	9.4	10	.6	22.7	....	....	....	....
2	1.40	.9	.20	-.10	-.70	......	......	......	....	....	....	....	....
2	1.35	.9	.20	-.10	-.70	10.3	9.2	.2	21.6	....	....	....	....
2	1.50	.9	.20	-.10	-.65	......	......	......	....	2,941	12,612	23,720	92,423
2	1.40	.93	.24	-.07	-.64	8.9	9.0	1.1	22.3	3,153	....	23,106	....

Ashes before beginning test, 105 pounds.
Ashes during test, 646 pounds.
Refuse, including sweepings from tubes and baffles, 895 pounds.
Per cent of moisture in coal by chemical analysis, 0.73.
Fired every 5 minutes. Raked after each firing. Occasional flames in stack. Very little smoke.
Average by Ringelmann charts, 1.

marine boiler, January 11, 1902.

with forced draft.]

Air pressures, in inches of water.						Flue gases.				Coal.		Water.	
Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.	CO_2.	O.	CO.	Dry air per pound carbon.	Fired per hour.	Total weight fired.	Fed per hour.	Total weight fed.
						%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
3	2.20	1.30	0.75	0.10	-0.55	......	......	......	....	....	....	....	....
3	2.10	1.30	.72	.10	-.55	9	9.4	1	21.8	....	....	....	....
3	2.25	1.50	.80	.10	-.55	......	......	......	....	....	....	....	....
3	2.20	1.60	.80	.10	-.55	9.6	8.8	.6	21.2	....	....	....	....
3	1.95	1.40	.80	.10	-.55	......	......	......	....	3,749	3,749	26,430	26,430
3	2.20	1.50	.85	.10	-.55	10	9.2	.6	21.2	....	....	....	....
3	2.10	1.40	.85	.10	-.55	......	......	......	....	....	....	....	....
3	2.20	1.30	.80	.10	-.55	9.7	9.5	.4	22.2	....	....	....	....
3	2.35	1.45	.85	.10	-.55	......	......	......	....	3,552	7,301	26,037	52,467
3	2.20	1.50	.82	.10	-.55	10.4	8.1	.6	19.7	....	....	....	....
3	2	1.50	.85	.10	-.55	......	......	......	....	....	....	....	....
3	2.20	1.45	.90	.10	-.55	9.8	9.5	.3	22.2	....	....	....	....
3	2.20	1.45	.90	.10	-.55	......	......	......	....	3,561	10,862	25,390	77,857
3	2.16	1.44	.82	.10	-.55	9.7	9.1	.6	21.4	3,621	....	25,952	....

Ashes during test, 254 pounds.
Refuse, including sweepings from tubes and baffles, 1,355 pounds.
Per cent of moisture in coal by chemical analysis, 0.73.
Fired every 3 minutes. Raked after each firing. Occasional flames in stack. Practically no smoke.
At 1 p. m. the draft pressure was increased to 4 inches, and the intention was to run at that pressure until the supply of coal was exhausted, which would have taken about 45 minutes; but at 1.02 p. m. the test was brought to a sudden stop by the failure of the feed water.

Summary of seventeen tests of Hohenstein

Number of trial.	Date of trial.	Duration of trial (hours).	Kind of fuel (P., Pocahontas coal; N. R., New River coal; r. m., run of mine; h. p. s., hand picked and screened).	State of weather.	Height of barometer at noon.
1	2	3	4	5	6
	1891.				
1	Apr. 23	8	P., r. m	Clear	30.02
2	Apr. 26	6	....do	Dull and overcast	30.12
3	May 8	4	....do	....do	29.86
4	May 29	8	....do	Squally	29.70
5	June 5	6	....do	Bright and sunshiny	30.08
6	June 8	3½	....do	....do	29.95
7	Oct. 21	8	N. R., r. m	Clear	30.34
8	Oct. 23	6	....do	Cloudy	29.95
9	Oct. 26	4	....do	Smoky	30.25
10	Nov. 6	8	P., h. p. s	Clear and damp	30.20
11	Nov. 9	8	....do	Cloudy, occasional sun	30.18
12	Nov. 18	6	....do	Gray and overcast	30.09
13	Nov. 27	4	....do	Thin clouds	30.23
14	Dec. 16	6	....do	Smoky, with thin clouds	30.13
15	Dec. 18	8	....do	....do	30.01
16	Dec. 21	4	....do	Smoky, no clouds	30.28
	1892.				
17	Jan. 11	3	....do	Dark, fog and smoke	29.58

Number of trial.	Approximate fire-room air pressure.	Average temperature.					Fuel.					
		External air (Deg. F).	Air in fire room (Deg. F).	Chimney gases (Deg. F).	Feed water entering boiler (Deg. F).	Steam at gauge pressure (7) from steam tables (Deg. F).	Weight of wood used in starting fires (pounds).	Weight of coal used in starting fires (pounds).	Weight of coal used during test (pounds).	Total weight of fuel used (pounds), (21)+(22)+(23).	Weight of ashes before beginning test (pounds).	Weight of ashes during test (pounds.)
1	8	16	17	18	19	20	21	22	23	24	25	26
1	0	57.2	93.8	594	144	410.4	350	2,400	9,720	12,470	260	377
2	1	70.3	117.8	751	145.4	413.3	300	2,000	10,445	12,745	160	575
3	2	72.8	121.7	1,089	145.8	413.7	390	2,500	10,569	13,459	195	459
4	0	64.4	114	688	137	412.7	340	2,000	8,633	10,973	175	226
5	1	84.1	139.5	712	129.3	413.1	360	2,200	10,695	13,255	200	1,038
6	2	74.8	127.3	1,105	116.5	412.5	(?)	(?)	8,461	8,461	(?)	591
7	0	71.3	144	563	131.8	413.6	360	2,000	8,056	10,416	198	485
8	1	74.3	124	654	126.1	413.6	250	1,910	9,698	11,858	161	365
9	2	68	106.5	688	111.8	413.6	361	2,200	9,000	11,561	152	391
10	0	62.7	125	548	125.9	413.6	350	2,792	8,299	11,441	225	214
11	0	55.1	125.4	521	122.3	413.6	350	1,435	7,436	9,221	303	584
12	1	52	105	580	119.7	413.6	350	2,762	8,388	11,500	526	837
13	2	40.2	86	717	91.4	413.6	310	2,762	10,694	13,766	267	460
14	1	32.3	77	766	104.6	413.6	350	3,256	14,029	17,635	271	714
15	0	26	87	568	125	413.6	360	2,440	9,181	11,981	235	702
16	2	22	64	800	98.4	413.6	450	3,130	12,612	16,192	105	646
17	3	35.4	76.5	943	88	413.6	350	3,554	10,862	14,766	151	254

marine water-tube boiler, burning coal.

Average pressures.								Revolutions of blower per minute.
Steam pressure by gauge; corrected for water level, pounds per square inch.	Draft pressures, in inches of water.							
	Fire room.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Above tubes and below drums.	Base of stack.	
7	8	9	10	11	12	13	14	15
263.9	0.0	—0.05	....	....	....	....	—0.52	0
272.9	1.08	1.02	....	....	....	....	— .65	250
274.6	2.06	2	....	....	....	....	— .84	335
271.3	0.0	— .04	—0.18	—0.20	—0.21	....	— .24	0
272.5	1.06	1.02	.80	.62	....	....	— .41	243
270.5	2.03	2	1.56	1.41	....	....	— .22	375
273.5	0.0	— .05	— .16	— .12	— .22	....	— .50	0
273.5	1.07	1	.81	.72	.52	....	— .46	243
273.5	2.10	2	1.43	1.25	1.08	....	— .98	375
273.5	0.0	— .05	— .15	— .14	— .19	....	— .55	0
273.5	0.0	— .05	— .09	— .09	— .11	....	— .55	0
273.5	.99	.97	.79	.69	.51	....	— .55	240
273.5	2.10	2.00	1.58	1.18	.86	....	— .77	375
273.5	....	1.00	.57	.32	.06	—0.20	— .59	243
273.5	....	0	— .20	— .20	— .25	— .38	— .51	0
273.5	....	2.00	1.41	.93	.24	— .07	— .64	332
273.5	....	3.00	2.16	1.44	.82	.10	— .55	423

Fuel.								Steam.	
Weight of refuse from furnace, tubes, baffles, etc. (pounds).	Total weight of ashes and refuse (pounds), (25) + (26) + (27).	Percentage of ashes and refuse, (28) ÷ (24) × 100.	Weight of ashes and refuse from coal used during test (pounds), (23) × (29) ÷ 100.	Percentage of moisture in coal (*by weighing and drying sample; †by chemical analysis).	Weight of moisture in coal used during test (pounds) (23) × (31) ÷ 100.	Weight of dry coal burned during test (pounds), (23) —(32).	Weight of combustible burned during test (pounds), (33) — (30).	Quality of steam.	Percentage of moisture in steam, 100 — 100 × (35).
27	28	29	30	31	32	33	34	35	36
640	1,277	10.24	995	*0.50	49	9,761	8,676	0.980	2
550	1,285	10.08	1,053	* .50	52	10,393	9,340	.968	3.2
815	1,469	10.91	1,153	* .50	53	10,516	9,363	.989	1.1
549	950	8.66	747	† .79	68	8,565	7,818	.990	1
539	1,777	13.40	1,432	† .79	85	10,610	9,178	.988	1.2
626	1,217	14.37	1,216	† .79	67	8,394	7,178	.990	1
561	1,244	11.95	963	*3.14	253	7,803	840	.986	1.4
528	1,054	8.89	862	*3.14	304	9,394	8,532	.976	2.4
732	1,275	11.03	993	*3.14	283	8,717	7,724	.980	2
526	965	8.44	700	*2.04	169	8,130	7,430	.988	1.2
356	1,243	13.48	1,003	*1.15	85	7,351	6,348	.987	1.3
562	1,925	16.75	1,405	*1.59	134	8,254	6,849	.983	1.7
936	1,663	12.08	1,292	*1	107	10,587	9,295	.979	2.1
923	1,908	10.82	1,518	† .73	102	13,927	12,409	.980	2
576	1,513	12.63	1,160	† .73	67	9,114	7,954	.985	1.5
895	1,646	10.18	1,285	† .73	92	12,520	11,235	.978	2.2
1,355	1,760	11.92	1,295	† .73	79	10,783	9,488	.974	2.6

Summary of seventeen tests of Hohenstein

Number of trial.	Approximate fire-room air pressure.	Water. Total weight of water fed to boiler (pounds), (corrected for inequality of water level and steam pressure at beginning and end of test).	Water. Equivalent weight of water evaporated into dry steam (pounds), (**37**) × (**35**).	Water. Factor of evaporation (H−h) ÷ 965.7.	Water. Equivalent weight of water evaporated into dry steam from and at 212° F. (pounds), (**38**) × (**39**).	Economic results. Feed water per pound of coal as fired (pounds), (**37**) ÷ (**23**).	Economic results. Equivalent evaporation from and at 212° F. per pound of coal as fired (pounds), (**40**) ÷ (**23**).	Economic results. Equivalent evaporation from and at 212° F. per pound of dry coal (pounds), (**40**) ÷ (**33**).	Economic results. Equivalent evaporation from and at 212° F. per pound of combustible (pounds), (**40**) ÷ (**34**).
1	**8**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
1.....	0	76,016	74,455	1.134	84,430	7.82	8.69	8.73	9.74
2.....	1	86,673	81,260	1.133	92,060	8.30	8.81	8.86	9.86
3.....	2	79,803	78,700	1.133	89,170	7.55	8.44	8.48	9.52
4.....	0	77,953	77,120	1.142	88,070	9.03	10.20	10.28	11.26
5.....	1	92,458	91,300	1.150	104,740	8.65	9.79	9.87	11.41
6.....	2	60,539	59,800	1.163	69,540	7.15	8.22	8.28	9.69
7.....	0	68,415	67,450	1.147	77,360	8.50	9.60	9.91	11.30
8.....	1	80,747	78,800	1.153	90,950	8.33	9.38	9.68	10.66
9.....	2	71,644	70,200	1.169	82,070	7.96	9.12	9.42	10.63
10.....	0	70,148	69,300	1.154	79,980	8.45	9.64	9.84	10.76
11.....	0	65,430	64,570	1.157	74,710	8.80	10.05	10.16	11.77
12.....	1	70,273	69,070	1.159	80,060	8.38	9.55	9.70	11.69
13.....	2	86,194	84,370	1.189	100,320	8.06	9.38	9.48	10.79
14.....	1	108,763	106,580	1.176	125,350	7.75	8.94	9.00	10.10
15.....	0	81,018	79,790	1.155	92,160	8.82	10.04	10.11	11.59
16.....	2	92,423	90,390	1.182	106,840	7.33	8.47	8.53	9.52
17.....	3	77,857	75,820	1.193	90,450	7.17	8.33	8.39	9.53

Number of trial.	Approximate fire-room air-pressure.	Chimney-gas analysis. Carbonic acid, CO_2 (per cent).	Chimney-gas analysis. Oxygen, O (per cent).	Chimney-gas analysis. Carbonic oxide, CO (per cent).	Chimney-gas analysis. Nitrogen, N (per cent by difference).	Pounds of dry gas per pound of carbon [11(**56**)+8(**57**)+7(**58**)+7(**59**)] ÷ [3(**56**)+3(**58**)].	Heat balance or distribution of the heating value of the combustible. Heat absorbed by the boiler (B. T. U.'s), (**44**) × 965.7.	Heat balance. Loss due to moisture in coal (B. T. U.'s).	Heat balance. Loss due to the moisture formed by the burning of hydrogen (B. T. U.'s).	Heat balance. Loss due to heat carried away in the dry chimney gases (B. T. U.'s).
1	**8**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**
1.....	0	9.85	6.85	1.67	81.63	21.5	9,400	7	486	2,320
2.....	1	9.46	6.50	1.96	82.08	21.7	9,520	7	505	2,970
3.....	2	12.42	4.85	1	81.73	18.7	9,190	8	566	3,930
4.....	0	11.08	4.75	2.19	81.98	18.8	10,870	11	492	2,290
5.....	1	10.35	5.03	2.20	82.42	19.8	11,020	12	487	2,400
6.....	2	13.77	3.73	.93	81.57	17.2	9,360	14	564	3,570
7.....	0	9.26	6.48	1.52	82.74	23	10,910	43	555	2,050
8.....	1	8.87	6.94	1.59	82.60	23.6	10,290	44	584	2,650
9.....	2	9.20	6.40	1.70	82.70	23.7	10,260	46	600	2,800
10.....	0	8.89	....	....	....	....	10,390	27	501	....
11.....	0	8	....	....	....	....	11,360	16	496	....
12.....	1	7.15	....	....	....	....	11,290	24	516	....
13.....	2	8.64	....	....	....	....	10,410	15	551	....
14.....	1	8.10	....	....	....	....	9,750	11	565	....
15.....	0	7.90	11.4	.90	79.80	28.1	11,190	11	521	2,740
16.....	2	8.90	9	1.10	81	24.8	9,190	11	577	3,880
17.....	3	9.70	9.1	.60	80.60	23.8	9,200	12	600	4,380

marine boiler, December 21, 1901—Continued.

Fuel per hour.						Water per hour.				
Coal as fired per hour (pounds) (**23**) ÷ (**3**).	Dry coal per hour (pounds), (**33**) ÷ (**3**).	Combustible per hour (pounds), (**34**) ÷ (**3**).	Coal as fired per hour per square foot of grate (pounds), (**45**) ÷ 50.14.	Dry coal per hour per square foot of grate (pounds), (**46**) ÷ 50.14.	Combustible per hour per square foot of grate (pounds), (**47**) ÷ 50.14.	Feed water per hour (pounds), (**37**) ÷ (**3**).	Water per hour corrected for quality of steam (pounds), (**38**) ÷ (**3**).	Equivalent evaporation from and at 212° F. per hour (pounds), (**40**) ÷ (**3**).	Equivalent evaporation from and at 212° F. per hour per square foot of grate (pounds), (**53**) ÷ 50.14.	Equivalent evaporation from and at 212° F. per hour per square foot of heating surface (pounds), (**53**) ÷ heating surface.
45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**
1,215	1,209	1,085	24.2	24.1	21.6	9,502	9,307	10,554	210	4.85
1,741	1,732	1,557	34.7	34.5	31	14,446	13,543	15,343	306	7.05
2,642	2,629	2,341	52.6	52.4	46.7	19,951	19,675	22,292	445	10.25
1,079	1,071	977	21.5	21.3	19.5	9,744	9,640	11,009	219	5.06
1,782	1,769	1,530	35.5	35.2	30.5	15,410	15,180	17,457	348	8.03
2,417	2,398	2,051	48.2	47.8	40.8	17,297	17,086	19,869	396	9.14
1,007	975	855	20.1	19.4	17	8,552	8,431	9,670	193	4.53
1,616	1,566	1,422	32.2	31.2	28.3	13,458	13,133	15,158	302	7.11
2,250	2,179	1,931	44.8	43.4	38.4	17,911	17,554	20,518	411	9.64
1,037	1,016	929	20.7	20.2	18.5	8,769	8,663	9,998	199	4.69
930	919	794	18.5	18.3	15.8	8,179	8.071	9,339	186	4.38
1,398	1,376	1,142	27.8	27.4	22.7	11,712	11,512	13,343	266	6.26
2,674	2,647	2,324	53.4	52.8	46.2	21,549	21,092	25,080	500	11.77
2,338	2,321	2,068	46.6	46.3	41.2	18,127	17,763	20,892	417	9.81
1,148	1,139	994	22.9	22.7	19.8	10,127	9,974	11,520	229	5.40
3,153	3,130	2,809	62.9	62.4	56	23,106	22,598	26,710	533	12.54
3,621	3,594	3,163	72.2	71.7	63.1	25,952	25,273	30,150	602	14.15

Heat balance or distribution of the heating value of the combustible.									Efficiency.	
Loss due to the incomplete combustion of carbon (B. T. U.'s).	Loss due to unconsumed hydrogen, etc., to heating moisture in air, to radiation, etc. (B. T. U.'s).	Heat value of one pound of combustible calculated from ultimate chemical analysis (B. T. U.'s).	Heat absorbed by boiler (per cent.)	Loss due to moisture in coal (per cent).	Loss due to moisture formed by the burning of hydrogen (per cent).	Loss due to heat carried away in the dry chimney gases (per cent).	Loss due to incomplete combustion of carbon (per cent).	Other losses due to radiation, etc. (per cent by difference).	Of boiler (per cent), (**61**) ÷ (**67**) × 100.	Of boiler and furnace (per cent), 965.7 (**43**) ÷ B. T. U.'s per pound of dry coal × 100.
65	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
1,325	1,853	15,391	61	0.1	3.2	15.1	8.6	12	61	60
1,571	818	15,391	61.8	.1	3.3	19.3	10.2	5.3	61.8	60.8
682	1,015	15,391	59.7	.1	3.7	25.5	4.4	6.6	59.7	58.2
1,388	73	15,124	71.8	.1	3.3	15.1	9.2	.5	71.8	68.3
1,569	−364	15,124	72.8	.1	3.2	15.9	10.4	−2.4	72.8	65.6
567	1,049	15,124	62	.1	3.7	23.6	3.7	6.9	61.9	55
1,265	861	15,684	69.5	.3	3.5	13.1	8.1	5.5	69.6	64.4
1,362	754	15,684	65.6	.3	3.7	16.9	8.7	4.8	65.6	63
1,398	580	15,684	65.5	.3	3.8	17.8	8.9	3.7	65.4	61.3
....	....	15,475	67.1	....	3.2	....	....	....	67.1	63.3
....	....	15,475	73.4	....	3.2	....	....	....	73.4	65.4
....	....	15,475	72.9	....	3.3	....	....	....	73	62.4
....	....	15,475	67.2	....	3.6	....	....	....	67.2	61
....	....	15,475	63	....	3.7	....	....	....	63	57.9
908	105	15,475	72.2	.1	3.4	17.7	5.9	.7	72.3	65
989	828	15,475	59.4	.1	3.7	25.1	6.4	5.3	59.4	54.9
519	764	15,475	59.4	.1	3.9	28.3	3.4	4.9	59.4	54

LIQUID FUEL FOR NAVAL PURPOSES.

The use of crude oil as a combustible for marine purposes has probably increased to a greater extent during the past two years than during the previous century. This has been due to several causes. The character of the oil lately discovered throughout the world is particularly applicable for use as a fuel. The oil fields are likewise near tide water, and therefore it is possible to construct pipe lines to the sea and deliver the product on board the tank steamers at comparatively slight cost. There is also good reason for believing that the wells are not likely to be soon exhausted and that an ample supply can be assured for an increased demand of the future.

It is evident that there is a very strong desire and purpose upon the part of many shipowners to substitute oil for coal. The thermal, mechanical, and commercial advantages that would result from a change are so well known that it is unnecessary to recount them. Nearly every reason that can be advanced for using oil as a fuel in the mercantile marine is also applicable to the Navy. In the case of warships, however, there are also military benefits to be secured that are as important as the commercial and mechanical advantages.

Any fuel installation which will obviate the smoke nuisance, reduce the complement in the fire room, extend the steaming radius of the war vessels, and permit maximum speed to be obtained at shorter notice, increases the efficiency and value of the fighting ship.

The numerous experiments that have been made by several naval powers during the past forty years in the attempt to use oil as a fuel show how important this question is regarded by military experts. It is now plain why success was not attained. There was too much effort exerted to burn oil in the same manner as coal. It is now realized that the oil should be atomized (it is impossible to completely gasify it) before ignition, and that the length of the furnace, the volume of the combustion chamber, and the calorimetric area are factors which must be considered. In fact, it is highly probable that it may be found advisable to design a special boiler for burning oil.

As more time, talent, and money are now being devoted to the solution of the problem, the hope of securing success has been greatly strengthened. Many unreliable statements have been published as to the success secured, but careful investigation shows that they were inspired by interested parties. It can be well understood that it is exceedingly difficult to secure reliable data at the present time. The several shipowners, manufacturers, and inventors are not inclined to tell of their disappointments, reverses, or failures. Those who have attained success as a result of experiment and experience do not feel called upon to give the world information that has been obtained at considerable cost and trouble.

Expert testimony is often of doubtful value. With regard to such testimony, a distinguished jurist once remarked that its character frequently depended upon who paid the retaining and professional fee. In view, therefore, of the trifling amount of reliable data extant, the Bureau has projected an extended series of tests to determine the value of liquid fuel for naval purposes. These experiments commenced a few months ago. Taking into consideration the inevitable delay that must result from the installation of various burners, and recognizing the fact that competitors expect and should be permitted to make preliminary trials, it can be stated that the experiments have been conducted with considerable rapidity. It takes about one week to install a new burner, make preliminary tests, and conduct two official trials.

In some quarters there seems to be a prevailing idea that the Government has established an experimental plant where inventors can have the opportunity of developing and perfecting their appliances. The Bureau has no such purpose in conducting the tests, for it is expected that each competitor will carefully study the detailed drawings furnished him of the experimental plant, and therefore be prepared to fit his appliance and be ready for a preliminary trial in two days from the time the plant is placed at his disposal.

The problem of using liquid fuel for naval purposes is quite distinct from the problem of its use in the mercantile marine, although the conditions on passenger and freight ships approximate very closely in some respects to service requirements. For ships of war the problem can therefore be solved only by the Department making its own tests and experiments. The performances, however, of the merchant ships having oil-fuel installations have been carefully observed. Representatives of the Bureau have been officially directed to report and observe upon the efficiency and sufficiency of such installations. Some of the most successful marine installations on both the Atlantic and Pacific coasts have been examined. The owners of the steamers *J. M. Guffey*, *Paraguay*, *City of Everett*, and *Mariposa*, having permitted the Bureau to report upon the oil-fuel installations of those vessels, a careful and extended investigation as to the character of each of their plants has been made. The liquid-fuel board has also examined the method of refining oil, and the Department has communicated with scores of individuals and corporations who have demonstrated by actual experience that they possess an intricate knowledge of some phases of the question.

The more this question is investigated the more intricate seems the problem of successfully installing an oil-fuel appliance on board a battle ship. It ought to be successfully used on the torpedo boats, as well as upon auxiliary naval vessels that steam between regular ports. For the army transport service it might prove very desirable, since a supply of oil could be maintained at the several calling ports. In regard to the installation on the large powered battle ships and armored cruisers, there are three distinct features which must be considered, viz: The mechanical, commercial, and the structural. Regarded from two of these view points it seems as if it would be some time before "coaling ship" ceases to be an evolution upon the war vessel. While both the naval and mercantile vessels traverse the ocean, there is a wide difference in their construction as well as in the nature of the duty performed, and this must be taken into account in designing the motive plant.

In the investigation of the subject of using liquid fuel for naval purposes it will be necessary to give due weight to the various features that will influence, if not determine, the solution of the problem. The question, therefore, comprises the following divisions:

First. The engineering or mechanical feature.

This relates to the efficient and economical burning of oil, and to the possibilities of increasing the consumption at short notice, so that maximum power can be readily and easily obtained. From the time the mechanical experts realized that the efficient, economical, and rapid burning of liquid fuel was greatly dependent upon the success secured in atomizing the oil there was rapid development. It was only a few years ago when the oil was simply thrown into the furnace by means of an injector. When that method was used the evaporation was dependent to a great extent upon the amount of incandescent surface that could be secured to ignite the fuel. It has only been within the last three years that the exceeding importance of atomizing the oil has been recognized.

It may therefore be affirmed that the efficiency of the burner is simply proportionate to its power to atomize the oil and then to turn these minute particles of oil into a mixture of combustible gas and fine particles of carbon, so that complete combustion, as well as ability to force the consumption of the oil, can be secured. There are many burners which can atomize the oil quite satisfactorily, and, as constant and progressive improvement is being made in this direction, the engineering and mechanical problem is nearing solution. The heating of the oil, as well as the heating of the air required for combustion, must be provided for, and extended experiments should be made to determine the simplest and the cheapest methods of attaining these objects.

The necessity for heating the air requisite for combustion should be impressed upon all contemplating the use of liquid fuel as a combustible. It would be best to force the passage of this air over heated surfaces either by forced or induced draft, but as this might involve considerable expenditure for installation, it is possible that simpler means might be effectual. The Bureau hopes before these experiments are concluded to make a special series of tests showing the evaporative efficiency secured when admitting the air to the furnace at different degrees of temperature.

The mechanical method of introducing the oil was so inefficient in the past that even experts were not able to burn the amount of oil desired. It has always been possible to burn some oil and to secure nearly the full thermal efficiency of the combustible. The great difficulty in the past was due to the fact that no one seemed to know how to burn enough oil and yet have it under control. There is therefore no record that, previous to two years ago, any boiler ever evaporated the amount of water with oil as a combustible that was secured under forced-draft conditions with coal as a fuel. Stated in another way, the boiler could not be forced with oil to the same extent as with coal. The experiments conducted by the liquid-fuel board have shown that it is now possible to force the combustion of oil, and that the greatest evaporation per square foot of heating surface secured with coal can be greatly exceeded by an oil-fuel installation of modern design where provision has been made for atomizing the combustible and heating the air and oil. Continued experiments should therefore be conducted under Government supervision.

The liquid-fuel board has already secured valuable information upon most of these points. A great service will be rendered the engineering interests of the country if further experiments can be conducted under the auspices of disinterested officials of the Navy, who, by reason of their training and experience, should be particularly qualified to carry on such tests. The engineering or mechanical features of the problem will undoubtedly be solved in a degree materially satisfactory to maritime and manufacturing interests, if not to naval experts, by further experimental work of the character that has been performed.

Second. The commercial feature.

This relates to the question of cost and supply. It may be regarded as a certainty that, except wherein unusual conditions prevail, the cost of oil for marine purposes will generally be greater than that of coal. The cost is even now less for vessels departing from the Gulf and California sea ports, but the rule will hold elsewhere. While the question of cost should be of secondary importance in military matters, it must be taken into consideration in industrial matters. It is the expense of transportation that now prevents the oil from being a cheap combustible for marine purposes, but this disadvantage ought to be soon removed. While it may be put on the tank steamer very cheaply at ports like Point Sabine, its commercial value will be determined by the cost of delivery at commercial and maritime centers. This feature of the problem is beyond the ability of the Navy to control, but it must be regarded as an important phase of the subject.

In considering the matter of cost the fact should be remembered however that but comparatively few tank steamers are carrying oil between Point Sabine and the North Atlantic seaports. The expense of fitting up these vessels has been very heavy, due to the fact that unexpected difficulties developed in the cost of making the installations. This has compelled the owners of the oil steamers to charge comparatively high prices for transportation of the fuel. It can certainly be expected that when a large fleet of vessels are used for carrying oil and when terminal storage facilities are provided that there will be a material decrease in the price of oil in the leading cities on the coast. This is a very important commercial phase of the question, and should be carefully considered in determining the probable relative value of the two combustibles in the early future.

It is undoubtedly a fact that the transportation charges per mile for oil at the present time are excessive compared with the freightage for coal, and this incongruity of expense account against oil can not continue much longer.

As regards the question of supply, it may be more expensive if not difficult to transport and to store oil than coal. The fumes of all petroleum compounds have great searching qualities, and therefore extreme precaution will have to be taken to guard the storage tanks. If it be true that for military purposes it is best in time of war to keep all reserve fuel afloat, then liquid fuel is at a disadvantage in this respect. The mining and railroad companies have invested so heavily in the coal industry, and the transportation facilities have been so perfected, that it is now possible to quickly deliver a cargo of coal at any point in the world. There has been, likewise, a development in the method of loading and unloading cargoes of coal. Since it will require progressive development to perfect the transportation and the storage of oil, and as the world's supply is still an unknown quantity, it will be some time before there may be a reserve supply of oil at the principal seaports.

It must also be remembered, when considering the problem of supply, that the naval vessel must be kept in readiness for orders to proceed at any time to any port within her steaming radius. The merchant vessel steams between regular seaports, where it would not be difficult to induce merchants to keep a supply of oil as soon as there is a regular and constant demand for it. The question of supply for battle ships and cruisers may therefore not only be a commercial affair, but prove to be a military problem, since the oil requirements of naval vessels for service conditions might only be met by the Government establishing oil-fuel stations. The military aspect of the question may prove to be a serious problem, since it not only necessitates heavy expenditures, but it may involve the greater question as to the wisdom of maintaining a complete chain of fuel stations between country and colony.

Third. While the engineer may be most interested in the mechanical features and the shipowners in the commercial aspect, the constructor will meet with difficulties in solving the structural problem relating to the installation of oil fuel on board ship.

The structural feature of the battle ship may prove a serious detriment to the installation of an oil-fuel appliance. The problem of storing oil on board war ships which possess protective decks is much more complex than the problem of its storage in vessels of the merchant marine. Everything on board the battle ship is subordinated to making the vessel a gun platform. There are many more compartments in the war vessel than in the merchant ship.

In all probability the great bulk of the oil in the war ship would have to be kept in the double bottoms. As the petroleum vapors are quite heavy, it may be a difficult matter to free these compartments of explosive gases, especially when the compartments are partly empty. By reason of the great number of electrical appliances in use on board the war ship, thousands of sparks are likely to be caused, any one of which might cause an explosion and set the oil fuel on fire. Our limited experience with submarine boats may give us an object lesson as to the liability of hydrocarbon gases to explode.

In the merchant service the oil is often stored in expansion tanks or trunks which rise to the height of the deck, and on some of the vessels there is a cofferdam around these tanks so that any leakage of oil can be quickly discovered. It is also a comparatively easy matter to free such tanks of any dangerous gases that may accumulate. Inspection of the tanks at all times can also be readily accomplished.

In view, therefore, of the more difficult conditions under which the oil will have to be carried in the naval service, the structural features are certain to have an important bearing upon the question as to whether or not an oil installation is possible in large ships of war.

The Bureau is not inclined to be pessimistic in regard to the successful solution of the problem. It believes that it is expedient to frankly state the difficulties that are likely to be encountered, so that every means can be considered for overcoming them.

The Bureau has no hesitation, however, in declaring that in view of the results already secured by the liquid-fuel board an installation should be effected without delay on at least a third of the torpedo boats and destroyers. The junior officers of the service are very much interested in the matter, and if several boats are equipped entirely with oil-fuel appliances, a spirited and keen but friendly rivalry will be created which will result in a material increase in the efficiency of the torpedo-boat flotilla. Such an installation would also permit a competition to be established between the boats using coal and those using oil, and this would be another incentive to cause systematic and careful study of the subject upon the part of all connected with the torpedo fleet.

The data which have been secured by the liquid-fuel board will be exceedingly appreciated in maritime and industrial circles. A careful analysis of these data will show how complete it is and how carefully it has been collected. Although the experiments have only been in progress for a short time, practically every engineering principle that enters into the oil-fuel question has been touched upon by the board. The tests that have been conducted have been of such a diversified nature, and so many deductions can be made, that other experimenters will now be enabled to ascertain in what direction research should be carried on to secure further definite information.

The completeness and character of the experimental plant has probably never been surpassed, and it is due to this fact that the data collected will command attention in the engineering world.

While the information secured may not hasten the introduction of oil as a fuel in armored cruisers and battle ships, it will materially increase oil-fuel installation in ships of the merchant marine and in shore establishments.

It is the engineering or mechanical feature which is of commanding importance in the industrial or mercantile marine world. The structural disadvantages which are so serious as regards naval development will only be encountered in a less degree in ships of the mercantile marine.

The structural disadvantages that may prove so serious in the Navy will not be encountered in the installation of liquid fuel appliances in shore establishments. The insuring of a reserve supply of the fuel ought also to be a less serious problem for industrial plants. It should therefore be understood that the naval problem is distinct unto itself, and that while the experiments so far conducted show that an installation on a battle ship is a serious question, the tests also prove that for manufacturing purposes crude petroleum is in many respects an incomparable fuel.

Probably not over a fraction of 1 per cent of the oil used as fuel would be consumed by the Navy; and therefore, while further investigation may be necessary to show the adaptability of oil for large war vessels, the tests already conducted will be of great value and afford considerable information to all present consumers of liquid fuel, as well as to those contemplating the installation of oil-fuel appliances.

The engineering information which is being obtained by the liquid-fuel board will secure increased efficiency of the motive power of the naval stations in the future and also conduce to the benefit of the torpedo-boat flotilla. It will also afford another illustration of the manner in which the industrial world has been aided by naval experimental research.

The data collected during the official oil tests should be compared with the results secured under the same boiler when coal was used. The evaporative efficiency, as well as the ability to force the boiler with two kinds of fuel, can thus be compared and the engineering advance that has been made of late can best be appreciated. It will be mainly by reason of the fact that this comparative data is obtainable that important conclusions can be drawn from the information already secured.

The Bureau submits a copy of the report of Lieut. Ward P. Winchell as to the performance of the steamer *Mariposa* when using oil exclusively under her boilers in making the round trip between San Francisco and Tahiti.

The Bureau also submits a copy of the preliminary report of the liquid-fuel board.

THE VOYAGE OF S. S. MARIPOSA, USING AN OIL-FUEL INSTALLATION EXCLUSIVELY UNDER HER BOILERS.

The following is a description of the steamer *Mariposa*, of the Oceanic Steamship Company, as fitted for oil-fuel burning, with an account of the preliminary trial trips of the vessel as witnessed by Commander H. N. Stevenson, United States Navy; also the report of Lieut. Ward P. Winchell, U. S. Navy, who officially represented the Department on the round trip of the steamer between San Francisco and Tahiti.

The *Mariposa* is a single-screw iron steamer, built at the yard of William Cramp & Sons, Philadelphia, Pa., in 1883. She has just had new engines and boilers installed by the Risdon Iron Works, San Francisco, Cal. The oil-burning plant has just been installed by the same company.

This vessel has been employed in the Pacific trade, and is now running to Tahiti from San Francisco, making the round-trip voyage of 7,320 knots each month.

Description of the Mariposa.

Gross tonnage		3,160
Length between perpendiculars	feet	314
Beam	do	41
Mean draft	do	22
Depth of hold	do	$17\frac{3}{12}$

There is a single bottom with four water-tight athwartship bulkheads, and two masts, square rigged on the foremast.

The total crew was formerly 81, but since the change from coal to oil burning 16 men have been taken out of the engineer's force, reducing the crew to 65 men and making the engineer's force for oil burning 20 men, as follows: 1 chief engineer, 3 assistant engineers, 3 oilers, 1 electrician, 1 attendant for ice machine, 1 attendant for air compressor, 3 water tenders, 6 firemen, 1 storekeeper; total, 20.

THE ENGINES AND BOILERS.

There is one triple-expansion engine of the inverted direct-acting type, with cylinders 29 inches, 47 inches, and 78 inches by 51-inch stroke, designed for 2,500 indicated horsepower, fitted with piston valves on the high pressure and intermediate pressure, and slide valve on the low-pressure cylinders, all driven by link motion. The condenser is part of the back framing. The cylinders are not jacketed.

The air, feed, and bilge pumps, of which there are two sets, are driven from the forward and after crossheads. The centrifugal circulating pump is driven by a separate engine. The 4-bladed propeller is 16 feet 6 inches diameter and has a pitch of 23 feet.

There are three cylindrical tank boilers placed fore and aft in the line of the ship—two are double ended, 15 feet 3 inches diameter by 17 feet 3 inches long, and one single ended, 14 feet diameter by 9 feet 9 inches long, the latter placed amidships forward of and worked from the forward fire room. Each double-ended boiler has six corrugated furnaces; the double-ended boilers have a common combustion chamber for opposite furnaces, while the single-ended one has a common combustion chamber for its three furnaces. There is one smokestack for all the boilers. The combustion chambers of the double-ended boilers have a brick bridge wall, and the back sheet of the single-ended one is covered with fire brick. The decision to use oil in place of coal was not made until the changes in engines and boilers were well under way, and it was decided to put the ship on the route to Tahiti. The steam pressure is 180 pounds. There is one auxiliary boiler, two-furnace return-tube type, in upper fire-room hatch, and fitted to burn coal only.

THE OIL TANKS.

These were constructed out of the old coal-bunker space forward of the boilers, and as the steamer is intended to carry oil for the round trip of about 7,320 miles some additional space had to be taken from the fore hold. They are arranged as follows: Just forward of the boiler space a solid water-tight bulkhead, well braced, was built from the berth deck to the single bottom of the ship, extending to the single skin of the ship, from side to side; 4 feet, or two frame spaces, forward of this was also built another similar solid bulkhead, which formed the after ends of the oil tanks; 48 feet farther forward another similar solid bulkhead was built to form the forward ends of the oil tanks, and 4 feet forward of this another solid bulkhead. The spaces of 4 feet at each end of the tanks being a cofferdam space to catch any oil from leakage or accident, these cofferdam spaces can be filled with water if necessary. The tank space is divided into six tanks by a middle bulkhead and two side partitions. Splash plates to break the impact of rolling are placed in each tank, a small opening at the top allowing any accumulation of gas to pass off to ventilating trunk. Small openings at the bottom allow free communication for the oil. Along the top of the tanks is provided an expansion head or trunk, being 4½ feet high and 4½ feet wide. Over each a ventilating trunk connecting with the top of each tank extends up to about 5 feet above the hurricane deck. The cofferdam spaces are ventilated by tubes reaching to the upper deck, fitted with cowls, one tube reaching to near the bottom to carry off any heavy gas that might accumulate there. From the upper deck the sounding pipes to each tank are reached. There are no pipes in or through the tanks except those connected with the oil service. The total capacity of the tanks, exclusive of expansion trunk, is 6,338 barrels of oil—about 905.43 tons. One barrel of oil equals 42 gallons.

To fill the tanks, on the port side outside the ship a 6-inch hose connection is fitted; from this a pipe leads to the forward fire room where the tank oil pump is placed. This pump, horizontal duplex, steam cylinders, 9 inches, oil cylinders 8½ inches, stroke 10 inches, can be used to draw its supply from the pipe and deliver into each of the tanks, or by using by-passes, which are provided, the oil barge alongside can fill all the tanks; an overflow pipe from each tank, carried at height of the deck above them, leads to an overflow outside the ship near the supply-hose coupling.

There are two service or settling tanks placed in pockets formed on either side of the single-ended boiler. They are reached by doors from the forward fire room; each of these tanks holds about twelve hours supply. They are filled by the oil-tank pump and have overflows back to the main tanks, ventilating tubes lead from near the bottom of the pockets in which they are placed to the smoke stack.

Each service tank is provided with glass gauges by means of which the amount used every hour or watch can be easily measured.

Each settling tank has two suction pipes, one at bottom to draw off water if necessary, the other at a height of about two feet for the oil supply to the service pumps. All the tanks are provided with manholes to reach the interior.

THE OIL-SERVICE PUMPS.

The oil-service pumps, of which there are two, horizontal duplex, steam cylinders 6 inches, oil cylinders 4 inches, and stroke of 6 inches, one being large enough to supply all the burners, are placed in the forward fire room on either side. They draw their supply from the settling or receiving tank through removable strainers placed so they can be easily changed for cleaning, and discharge into the bottom of the small heating tank near them where the oil is heated by a steam coil to not more than 150° F., and thence by a pipe to the burners. The air from the compressors, under a pressure limited to 40 pounds, discharges into the top of the heater tank on its way to the burners, so that the oil and the air go to the burners under the same pressure. The heater tank is provided with glass gauges, also a float to work a telltale and automatic control of oil-supply pump.

THE AIR COMPRESSOR.

The air compressor is placed in a pocket off the upper engine-room platform, and consists of duplicate steam and air cylinders connected to a crank shaft carrying a fly wheel turning between the cylinders. Either set is large enough to supply all the air necessary. The air compressor is horizontal, double-acting, duplex. Air cylinders 22 inches, steam cylinders 12 inches, diameter, by 18-inch stroke for all cylinders. Capacity equals 1,000 cubic feet of free air per minute compressed up to 30 pounds at 120 revolutions per minute. Air is used at the heat of compression, or as heated by the air heater.

THE ATOMIZER.

The atomizer, for which patents are pending, is the joint invention of Messrs. Grundell and Tucker, San Francisco.

The atomizer, shown in fig. 5, consists of a hollow plunger for the oil, screwed into a pipe through which the air passes. The outlet for the oil is through a series of small holes at right angles to the central hole, the air meets the oil through spiral directors and is sprayed into a rose shape by the expanded end of the atomizer.

The air and oil pipes have globe valves to regulate the supply of either, also plug cocks connected together to a handle by means of which each burner can be shut off immediately, in case of necessity, a slow-down bell, or other cause. The air-supply pipe is also connected to the steam line so that steam can be quickly substituted for air, if desired. The length of the oil plunger is adjustable, to give the best form to the rose-shaped flame. Two burners are fitted to each furnace.

THE AIR HEATER.

A part of each furnace front is a hollow iron casting through which the air passes on its way to the atomizers and becomes heated. The chamber surrounding the burner is lined with a crucible lead lining,

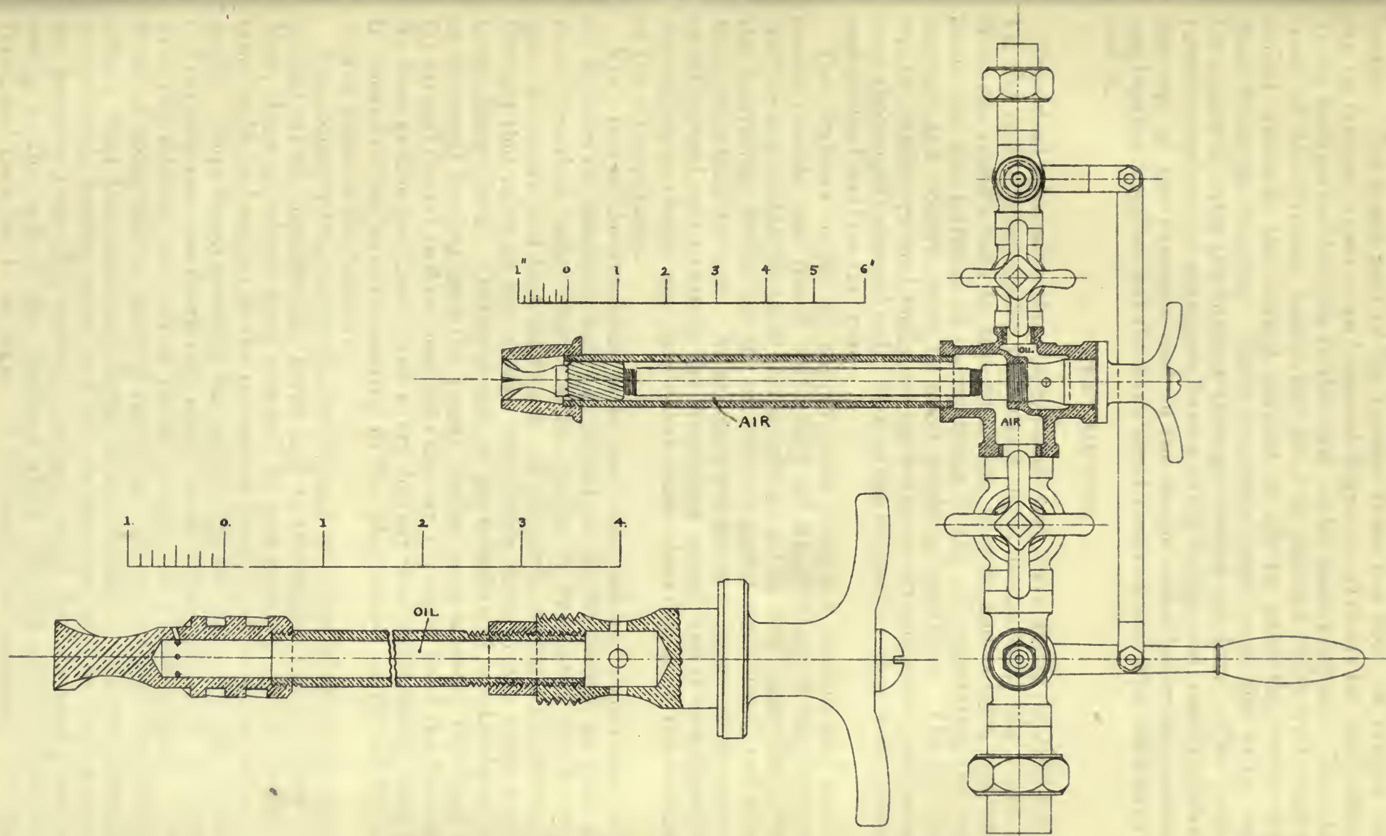


Fig. 5.—THE GRUNDELL-TUCKER BURNER USED ON STEAMSHIP *MARIPOSA*.

a by-pass to the burners is provided for use in case of accident to the heater. The lower part of the furnace front is a door on hinges that can be fastened open at any desired degree to give air for combustion. There are also two louvres in the door for the same purpose. Near the front of the furnace inside the door is placed a brick wall made to deflect upwards the inward current of air to meet the rose-shaped flame from the burners. There is ample space over the brick wall for a man to enter the furnace through the ash-pit door. The double furnace combustion chambers have a brick bridge wall reaching above the top of the furnaces, and in the single ended boiler the common combustion chamber has the back sheet covered with fire brick to protect it.

THE TRIAL TRIPS.

Two trial trips with the vessel under way were made on July 5 and 11, the vessel being under way about eight hours each day, running from the vessel's dock to the Farallone Islands and return, and were made for the purpose of ascertaining if the oil apparatus, the new engines and boilers, were in good working condition. On the first run the boilers primed badly, owing to the construction dirt not having been thoroughly cleaned out. Before the second run they were cleaned and worked well on this run.

The strainers on the oil supply pipes were not finished and considerable trouble was found with dirty oil which clogged the burners. Neither the telltale to show the height of oil in the heater tank, nor the controlling device for the oil service pump were fitted, not being finished in time for use. No attempt was made to measure the amount of oil burned, nor to attain the maximum speed, and it was therefore impossible to obtain any data other than observation of the working of the oil apparatus.

Very few of the fire-room force had ever had any experience with oil burners on steamers, and one object of the trials was to give the force practical experience. When properly regulated the burners gave no smoke, but that they were not properly regulated is shown by the fact that more or less smoke was visible most of the time, and at times dense black. Owing to lack of the telltale and regulating device of the small heating tank the pump tender once allowed this tank to fill up and the oil to flow over into the air pipe and flood the burners. As soon as this was discovered every burner was immediately shut off by means of the lever connecting to the plug cocks on the oil and air supply pipes at the burners.

The atomizer tubes were unscrewed and on some of them, where the oil had caked, considerable force had to be applied to pull them out. New, clean atomizers were screwed in, and as soon as the oil-heater tank could be brought to the proper oil level the burners were started again. Some steam pressure was lost during this delay, but the engines did not stop nor slow down very much; some of the burners were started in a few minutes and all of them in not over fifteen minutes. The value of being able to shut off the oil and air quickly and clean or substitute other atomizers was shown by this mishap. The burners made considerable roaring noise, and the air pressure was, in order to clean the burners from dirt, carried at about twice the intended pressure, owing to the lack of the strainers which allowed dirty oil to choke them, and they had to be taken out frequently for cleaning. By shutting off with the lever the regulating valves were left in adjustment for starting the fire again provided it was right before. The new fire is started by a torch inserted into the plug hole around the burner.

On the second run the strainers and regulating device for the heater tank had been completed. The oil apparatus was handled with greater ease and uniformity, and the less amount of smoke was very noticeable. For intervals of an hour or more scarcely any or none would be observed. On the run in from the Farallones the engine was speeded up to 74 to 77 turns, and an average speed of 14¼ knots was obtained. The steam pressure was uniformly maintained at the point desired without difficulty, and the oil-burning apparatus gave no trouble whatever and worked well.

The oil used on both runs was from the Kern River district, near Bakersfield, Cal.

The following data was observed:

Steam pressure	pounds	160–170
Revolutions of engine		74–77
Revolutions of air compressor		60
Pressure of air	pounds	20
Temperature of oil entering heater	degrees F	80
Temperature of oil leaving heater	do	120–130
Temperature at base of stack	do	750

It is regretted that the nature of the trials did not permit of obtaining a greater amount of data beyond observing the apparatus in use.

The chemist at the New York yard submitted the following report upon the sample of the Kern River district oil sent him for analysis:

The sample is practically free from low boiling naphtha, as on distillation only a small percentage passed over below 150° C., and less than 10 per cent below 225° C. A boiling point above 360° C. was reached before the second 10 per cent was collected.

It shows on ultimate analysis the following composition:

	Per cent.
Carbon	84.43
Hydrogen	10.99
Nitrogen	.65
Sulphur	.59
Oxygen	3.34

This gives a calorific value, by Dulong's formula, of 18,806 B. T. U. The specific gravity at 60° F. is 0.962. Flash point, 228° F. Fire point, 258° F. Vaporization point, 178° F. Loss for six hours at 212° F., 12.01 per cent.

REPORT OF LIEUT. WARD WINCHELL ON THE VOYAGE OF THE MARIPOSA.

U. S. S. Boston,
At Sea, August 15, 1902.

Sir: In accordance with the Department's telegraphic order of July 7, 1902, delivered July 8, 1902, and the instructions from the Bureau of Steam Engineering, dated July 7, delivered a few minutes before sailing, I took passage on the Oceanic Steamship Company's steamer *Mariposa*, leaving San Francisco at 10 a. m. July 15, 1902, for the round trip to Tahiti.

In accordance with the instructions of the Bureau, I took two sets of indicator cards each day, making 45 sets in all, the data of which were worked up.

There have been no tests to determine the evaporative efficiency of the two main double-ended boilers used on the run, and I regret to report that the chief engineer of the ship was unable to improvise any apparatus by which the amount of feed water could be determined with accuracy enough to give data of any value.

The amount of oil is a matter of much importance, since the tanks hold barely enough to make the round trip and but one day's supply of coal is aboard. The oil was measured first by the amount pumped into the two settling tanks, as shown in inches on the scale back of the gauge glasses on the tanks; second, this amount was checked by the number of inches used out of each tank for each watch; third, another check, and the one considered most accurate as dealing with large quantities and small errors, was by sounding the tanks from time to time and comparing the amounts taken out with the expenditures in the log. The latter method gave a correction which was applied to the daily log, increasing the daily expenditure slightly, as summed up by inches in the settling tank.

The most careful inspection at Tahiti failed to show any bad effect of the flame upon the boilers. No leaks nor defects developed anywhere about them and there was no difficulty at any time in feeding them. As I was ordered to the *Boston* immediately on my arrival at San Francisco, I lost the opportunity of again inspecting the boilers, but no defects showed from the outside. At Tahiti the tubes were swept by tube scrapers, and back connections, uptakes, ash pans, and furnaces were cleaned. All the refuse from these various places barely filled two ash buckets.

This refuse, mainly soot, was the result not only of the twelve days' run to Tahiti, but also of the three preliminary trials by the contractors. The first one, a four-hour trial of engines and boilers, was made with Comax coal, and the other two were free runs at sea, of about eight hours' duration each, burning oil. The tubes had never been cleaned previous to arrival at Tahiti. It is the intention hereafter to make the round trip of twenty-four days' steaming without sweeping tubes.

There are no precautions other than those usually taken on board ship to guard against fire or explosion. All spaces to which oil has access are well ventilated by both inlet and outlet ducts. The oil is a thick, dark fluid, like molasses, and in the open air burns slowly, giving off much smoke. But it gives off volatile gases which form explosive mixtures with air, tanks empty or nearly so being more dangerous than full ones in this respect. The ship is electrically lighted, but in addition an open hand lamp is burning in the fire room all the time to light the burners; the firemen smoke on watch, and the oil is treated no more tenderly than if it were coal. On the run back, the cargo of copra was stored all about the expansion trunk, which projects up 4½ feet between decks; completely covering the tanks and making them inaccessible for examination.

Of the 6 firemen, 3 were relieved from watch the second day out, leaving but 1 man on a watch to fire 12 furnaces in two different fire rooms separated by the length of the double-ended boilers. The water tender did not touch the burners except in emergency, his duty being to 'tend water, fill settling tanks and record height of oil in them, record temperatures of oil at settling tank and in heater of fire room and of superheated air, take reading of lower pyrometer where the two uptakes meet, and run oil pump supplying oil to the settling tanks and small oil pump supplying oil to the oil heater.

As a coal burner the *Mariposa* formerly had the following engineer force: 1 chief engineer, 3 assistant engineers, 3 oilers, 12 firemen, 12 coal passers, 3 water tenders, 1 messenger, 1 storekeeper; total, 36.

A reduction of 16 men in the fire-room force is effected by oil burning. At sea she needs now but 3 firemen, but carried 6. This would reduce the force by 19 men.

Temperatures of fire rooms seem to be about what one would expect in coal burning, but the temperature of the uptake and smoke-pipe gases run high, the maximum being 925, which shows an undue loss of heat here. The temperature of the oil in the settling tanks ranged between 68° and 100° F. on the trip out and between 90° and 108° F. on the trip back.

The oil auxiliaries comprise 1 large oil pump, 2 small oil pumps, 2 oil heaters, 1 air compressor, and 4 strainers.

There is a steam-pipe connection to blow out the oil strainers, and another one to blow out the oil burners when clogged.

On August 3 the air compressor needed overhauling, and steam atomizing was kept up for two and one-half hours until the compressor was again working. During this time the evaporator supplied enough feed water to use 20 burners; the engines were not stopped while shifting from steam to air atomizing, and averaged 67.8 turns for the two and one-half hours. They had before been making 70 turns. Also during the four days in port at Tahiti the forward main single end 3-furnace boiler was used, atomizing with steam. Generally 2 burners in the middle furnace gave ample steam to run the following auxiliaries,all exhausting into the atmosphere, the boiler being fed with fresh water from the dock: Ice machine, dynamo, flushing pump, feed injector, 2 cargo winches, small portable steam pump, and steam for cooking, bath tubs, etc.

At first 2 firemen and a water tender were on watch at a time, each fireman having 1 fire room of 6 furnaces or 12 burners. The men had but little experience, combustion was poor, much smoke was made, much oil burned, and poor speed attained. To locate the responsibility for bad adjustment of burner valves, but 1 fireman was put on at a time to attend 12 furnaces (24 burners). This made an improvement in the combustion.

Unfortunately, the top of the funnel can not be seen from either fire room, and while the fireman can tell by the appearance of the flame as shown in the sight-hole, or even by the roar of the burner, when the combustion is perfect, in designing a boiler room for liquid fuel the ventilators should be so arranged that a view of the top of the smoke pipe can be had from each fire room.

The work of the fireman would be even easier than it is and better results attained if the oil and air pressure is kept constant and the heated temperature of the oil constant. The apparatus then, once properly adjusted, would need very little change. To get these results is a mere matter of detail easily arranged. If the temperature of the oil rises it feeds more freely and a readjustment is necessary, and the same conditions hold with regard to the pressure.

It will be noticed that in addition to the independent oil and air supply valves the burners are fitted with an air plug cock and an oil plug cock connected to one lever, which then controls both air and oil supply, enabling the operator to shut them both off at once in emergency. At first when steam went up too high and a burner was shut down this lever was used; but shutting off the air thus gave the air compressor less work, and as its governor is not sensitive the air pressure increased, making a readjustment of all oil and air supply valves necessary, with consequent smoke. Later on, when it was desirable to shut down a burner, the oil alone was shut off by the independent feed valve on the burner, and the untouched air valve kept the air compressor's work more nearly constant; then when the burner was again required, the oil valve was opened and immediately lighted from the flame of the adjacent burner.

In starting fires with everything cold, steam is raised on the auxiliary boiler, which burns coal, and the air compressor, oil pumps, and oil heater are started. The oil is lighted by inserting oil-soaked rags in the air space surrounding the burner and touching a lamp to them, or an arrangement like a gas lighter may be used.

Sometimes when the air pressure is too high, or insufficient oil is feeding, the flame flickers and may go out. If the oil is kept feeding under these conditions, on relighting there is a small explosion of the gases in the furnace, with a momentary back draft through the peepholes and ash pans.

When shut down July 19, for two and one-half hours, plugging condenser tubes, one burner at each end of each boiler (4 burners in all), furnished steam to run all auxiliaries, including feed pump, bilge pump, air compressor, ice machine, dynamo, and flushing pump, all of which were exhausting into the atmosphere.

During the four days in port at Tahiti the forward main single-end 3-furnace boiler was used, atomizing with steam. Generally two burners in the middle furnace gave ample steam to run the following auxiliaries, all exhausting into the atmosphere, with boiler fed from fresh water on the dock: Ice machine, dynamo, flushing pump, feed injector, two cargo winches, and small portable steam pump.

In the Grundell-Tucker burner (see fig. 5) the oil, heated by a steam coil under boiler pressure throttled down, passes through the inside pipe and is thrown out radially through the series of small holes. The air, first heated by compression up to 20 pounds, is further heated to a temperature of about 350° F. in the air chamber surrounding the burner, and called the air superheater. Air can be used at the temperature at which it leaves the compressor, and was so used on the trip down until July 17, when the superheaters were connected up. This air under the pressure of about 20 pounds surrounds the oil pipe in the burner and passes axially along the pipe until near the end, where it is given a whirling motion through small helical passages arranged like the rifling of a gun. It crosses axially and whirling through the fine oil streams spurting radially from the end of the burner, breaking up the oil into fine spray, the drops of which can be seen before they ignite. A further air supply (cold) is admitted through the hinged door of the ash pan, and is directed up across the path of the flame and heated also by a curved fire-brick wall built in the ash pan close to the front.

This ash-pan door is not moved much, but the regulation of the air supply is by the valve control of the air and oil in the burner. The flame should be a steady, full, white or yellowish white one, filling the furnace.

The principal difficulties encountered were in the regulation of the supply of oil to the heaters by the pump and the consequent variation of the temperature of the heated oil and the freedom of flow through the burners. An automatic submerged float, arranged like a steam trap and fitted in the oil heater to control the throttle of the pump, failed to give good automatic results, and the supply of oil was regulated by hand. If the oil is heated too much (above 150° F.) some of the volatile gases are given off and mingle with the air pressing on top of the oil in the heater, thence passing with the air into the air superheaters and burners, the result being that on one occasion a heater got red hot from this cause.

Another difficulty was due to the choking of the strainers by foreign matter and impurities in the oil, shutting off the supply of oil, and on one occasion, August 10, putting out all the fires. Just previous to the fires going out, and while the usual air supply was on, and an insufficient amount of oil being fed, a dense white smoke like steam arose from the funnel.

This strainer difficulty will be solved by fitting the strainers in pairs, so that a clean one can always be switched in while the choked one is being cleaned.

Generally the revolutions of the engines did not vary much during the day, and in calculating the horsepower for each day's average revolutions, when the cards for that day differed much, that set was selected whose revolutions were near the average for the day with the indicated horsepower, assumed to vary as the cube of the revolutions. If the two sets of cards for the day had the same number of revolutions their average indicated horsepower was used as a basis to compute the day's horsepower as before.

It will be noted that the log accompanying this report is kept from noon to noon. This was done as the patent log was inaccurate, and the speed of the ship was got from noon positions as given by sights.

It will be noted that speed was much higher on the return trip than on the outgoing, which is ascribed partly to the better combustion as the firemen got experience, partly to the overhauling of the bearings at Tahiti by the force on board, and mostly to the increased oil consumption allowed after the run down had proved that there was plenty of oil for the return trip, which was a matter of some doubt before, the ship being provided with coal for twenty-four hours to cover possible emergency.

Full power was not developed in the two boilers used, as schedule time was easily exceeded with from 2 to 4 burners shut off, though it would not appear, from the tabulated results, that the indicated horsepower would equal what can be got by a good system of forced draft. This burner, however, works well with the Howden system of forced draft, as seen on the tank steamer *George Loomis*.

It must be remembered that the tabulated calculations are all based on the indicated horsepower of the main engines only, as it was considered better to use only data actually obtained, and afterwards estimated data, such as indicated horsepower of auxiliaries, could be applied without vitiating the observed data and results. No cards could be taken from any of the auxiliaries, but careful estimates give the following results:

	I. H. P.
Air compressor, at 60 revolutions per minute	110
Auxiliary feed pump and two oil pumps, one in intermittent use	30
Dynamos	30
Ice machine	7
Circulating pump	5
Flushing pump	2
Baths, steam tables, evaporator, cooking, etc	11
Total	195

The steering engine is not used except near port.

The size of air compressor was based on the assumption that it requires 1 cubic foot of free air for every pound of water evaporated from and at 212° F., as shown by tests of various oil burners at Western Sugar Refinery, San Francisco.

The weights of oil auxiliaries are as follows:

	Tons.
Air compressor	9
Two settling tanks	12
Two oil heaters	2
Two oil pumps (small)	.5
One oil pump (large)	1.25
Fifteen superheaters (air) front	3.1
All pipe, valves, fittings, ventilators, etc	8

It should be remembered that the boilers were designed for coal burning; that the oil-burning plant was fitted in a hurry, the machinists not leaving the ship until the gong rang for people to go ashore; that the firemen were without experience in oil burning, and that most of the automatic gear did not function properly.

With the air pressure constant; with the oil heated at constant temperature near 140° F.; with oil strainers arranged in pairs, so that one is always efficient, and with experience in firing, the results in economy of oil should be much better on the next trip; and the fireman's work, already very easy, will approach supervising automatic regulation. The fireman does not need strength nor previous training with coal. He should have a good eye, good ear, some common sense, and a desire to learn a new and easy trade.

In conclusion, I wish to state that every facility was given me by all the officers of the company, the chief engineer of the ship being particularly zealous in arranging for the taking of required data.

Very respectfully,

WARD WINCHELL,
Lieutenant, United States Navy.

CHIEF OF BUREAU OF STEAM ENGINEERING,
Navy Department, Washington, D. C.

General summary of log of Mariposa, burning oil, round trip, Tahiti and San Francisco, July and August, 1902.

NOTE.—For convenience in comparing with engineer's log, the day is taken from noon until noon. July 16 begins at noon July 15 and ends noon July 16. This leaves but two hours' run on July 15, which was thrown out of the calculations. The average indicated horsepower of main engines was got not by averaging the daily runs, but by taking average revolutions for the eleven days' run, and taking the cards near these revolutions as a basis in computing the horsepower.

Date.	Knots per day.	Knots per hour.	Revolutions per minute.	I. H. P. main engines only.	Oil used per day (barrels).	Oil used per day (tons of 2,240 pounds).	Oil used per hour (pounds).	Grate surface, two double-ended boilers.	Heating surface, two double-ended boilers.	I. H. P. main engines per square foot of grate.	I. H. P. main engines per pound of oil per hour.	Square feet of heating surface per I. H. P.	Pounds of oil per hour per I. H. P.	Pounds of oil per knot run.	Knots made per ton of oil.	Knots made per barrel of oil.	Slip of screw in per cent.	Actual time.	Remarks.
San Francisco to Tahiti.																		*h. m.*	
July 16	289	12.08	58.74	1,475	258	36.86	3,451	258	8,302	5.64	0.427	5.63	2.33	286	7.84	1.12	9	23 55	
July 17	298	12.3	61.1	1,768	260	37.14	3,438	258	8,302	6.85	.51	4.70	1.94	279	8.02	1.15	11	24 12	
July 18	302	12.5	62.5	1,950	260	37.14	3,438	258	8,302	7.55	.57	4.25	1.76	275	8.13	1.16	12	24 12	
July 19	311	12.8	63.4	1,864	260	37.14	3,440	258	8,302	7.20	.54	4.44	1.84	267	8.38	1.20	10.4	24 8	
July 20	285	13.1	65.7	2,200	230	32.86	3,484	258	8,302	8.50	.63	3.77	1.58	258	8.67	1.24	12.1	21 7	July 20 stopped 2½ hours to plug leaky tubes in condensers.
July 21	321	13.26	65.6	2,398	235	33.60	3,133	258	8,302	9.30	.76	3.60	1.30	234	9.55	1.36	10.8	24 11	
July 22	306	12.6	65.8	2,270	255	36.43	3,365	258	8,302	8.80	.67	3.66	1.48	270	8.40	1.20	15.5	24 15	
July 23	307	12.5	65.7	2,240	240	34.30	3,200	258	8,302	8.70	.70	3.70	1.43	253	8.95	1.28	15.7	24 27	
July 24	335	13.8	68	2,386	250	35.71	3,299	258	8,302	9.20	.72	3.60	1.39	239	9.35	1.34	10.7	24 16	
July 25	351	14.5	69.8	2,470	257	36.71	3,398	258	8,302	9.57	.72	3.36	1.38	234.8	9.59	1.27	8.3	24 11	Jib and fore try-sail set, trade wind port beam.
July 26	333	13.9	69.1	2,129	258	36.86	3,432	258	8,302	8.25	.65	3.90	1.61	244.6	9.03	1.29	11.7	24 3	
Total	3,438				2,803	400.43												262 57	
Average		13.12	65.2	2,193	254.8	36.40	3,412	258	8,302	8.593	.643	3.786	1.556	260.9	8.585	1.22	13.14		
Tahiti to San Francisco.																			
August 1	298	12.6	65.3	2,172	240	34.3	3,222	258	8,302	8.42	.674	3.82	1.49	258	8.7	1.24	15.6	23 50	
August 2	323	13.6	70.1	2,490	280	40	3,774	258	8,302	9.65	.66	3.33	1.51	277.4	8.08	1.15	15	23 44	
August 3	322	13.6	70.1	2,646	280	40	3,772	258	8,302	10.24	.70	3.14	1.428	278.2	8.85	1.15	15	23 45	
August 4	334	14	71.3	2,785	290	41.43	3,954	258	8,302	10.8	.704	2.98	1.42	277.8	8.06	1.15	13	23 46	
August 5	357	15.04	72.4	2,892	305	43.57	4,111	258	8,302	11.21	.703	2.87	1.39	274	7.96	1.14	9	23 44	
August 6	346	14.6	71.9	2,772	310	44.3	4,177	258	8,302	10.8	.66	3	1.50	287	7.8	1.11	10	23 45	

August 7	322	13.5	71	2,777	310	44.3	4,177	258	8,302	10.7	.66	2.98	1.50	308	7.27	1.04	15.7	23	45	Strong head wind and sea.
August 8	343	14.4	71.9	2,936	315	45	4,207	258	8,302	11.38	.698	2.83	1.402	297	7.62	1.09	11.3	23	43	Wind and sea moderate ahead.
August 9	327	13.7	69.4	2,553	305	43.57	4,109	258	8,302	9.89	.621	3.212	1.606	295.4	7.272	1.07	12.6	23	45	
August 10	347	14.6	72.9	2,863	320	45.71	4,313	258	8,302	11.10	.663	2.90	1.507	295.1	7.60	1.084	11.7	23	44	
August 11	341.1	14.8	73.54	2,968	322	46	4,480	258	8,302	11.5	.663	2.79	1.51	302.8	7.407	1.06	12	23		
Total	3,660.1				3,277	468.14												260	31	
Average		14.05	70.91	2,770	302	43.18	4,026	258	8,302	10.73	.688	3	1.45	286.3	7.818	1.111	12.8			
Total knots	7,098.1				6,080															
Average, 2 runs	3,549	13.58	68.05	2,481	278.4	34.29	3,719	258	8,302	9.661	.665	3.393	1.503	273.6	8.201	1.165	12.97			
Average speed made during round trip.	325.7																			

NOTE.—The Bureau has also received the following summary of the second voyage of the steamship *Mariposa* on the round trip between San Francisco and Tahiti. This data shows that the oil consumption on the second voyage was considerably less than that on the first, due to two causes: Improvements in detail of the oil-fuel installation and increased skill and intelligence upon the part of the engine-room force.

The Occidental Steamship Company is fitting an oil-fuel installation on the sister ship *Alameda*, and it can be expected that when a spirited rivalry is created between the crews of the *Alameda* and *Mariposa* that even better results can be anticipated.

O. S. S. Mariposa, voyage No. 2, from San Francisco to Tahiti, 1902.

Date.	Knots per day.	Knots per hour.	Revolutions per minute.	Oil used per day, in barrels.	Oil used per day, in tons of 2,240 pounds.	Oil used per hour, in pounds.	Pounds of oil per knot run.	Knots made per ton of oil.	Distance run per barrel of oil, in knots.	Slip of propeller, per cent.
August 21	328	13.3	63.7	255	36.43	3,400	248.8	9.00	1.29	7
22	297	12.3	62.6	225	32.14	3,000	242.8	9.24	1.32	13.4
23	282	13.3	64	210	30.00	2,800	237.4	9.43	1.35	9
24	330	13.6	65.9	235	33.59	3,133	227.9	9.82	1.40	8.8
25	310	12.8	62	220	31.43	2,933	227.1	9.86	1.41	8.8
26	311	12.8	62	210	30.09	2,800	216.1	10.37	1.48	8.5
27	292	12.1	62	220	31.43	2,933	241.1	9.29	1.33	13.8
28	305	12.6	62.1	220	31.43	2,933	230.8	9.70	1.39	10.3
29	305	12.6	62.2	220	31.43	2,933	230.8	9.70	1.39	10.5
30	322	13.3	65	230	32.86	3,066	228.6	9.80	1.40	9.5
31	326	13.5	66	240	34.28	3,200	235.6	9.51	1.35	9.4
Average, 11 days	309.9	12.96	63.4	226	32.28	3,013	233.3	9.60	1.37	9.9
Voyage 1, 11 days	312.7	13.12	65.2	254.8	36.40	3,412	260.9	8.585	1.22	13.14

Average temperature of uptake, 548°; average temperature of superheaters, 360°; average temperature of cold oil, 91°.

O. S. S. Mariposa, voyage No. 2, from Tahiti to San Francisco, 1902.

Date.	Knots per day.	Knots per hour.	Revolutions per minute.	Oil used per day, in barrels.	Oil used per day, in tons of 2,240 pounds.	Oil used per hour, in pounds.	Pounds of oil per knot run.	Knots made per ton of oil.	Distance run per barrel of oil, in knots.	Slip of propeller, per cent.
September 6	292	12.2	62.1	215	30.71	2,867	235.6	9.51	1.36	12.6
7	301	12.6	62.6	220	31.43	2,933	233.8	9.57	1.37	11.2
8	288	12.1	62.9	220	31.43	2,933	244.4	9.16	1.31	15.5
9	298	12.5	63.1	220	31.43	2,933	236.2	9.48	1.35	12.6
10	276	12.2	64.7	220	31.43	2,933	255.1	8.46	1.25	13.4
11	327	13.7	66.9	245	35	3,267	240	9.34	1.33	9.4
12	303	12.7	67.1	250	35.71	3,333	264	8.48	1.21	16.5
13	317	13.2	67.3	265	37.44	3,533	267.5	8.53	1.20	13
14	307	13.2	67.4	260	37.45	3,466	271	8.20	1.18	13
15	324	13.8	69	265	37.94	3,533	261.7	8.54	1.22	12
16	321	13.5	69.2	270	38.57	3,600	269.1	8.32	1.19	13.9
Average, 11 days	304.9	12.7	65.7	241	34.46	3,212	252.6	8.87	1.27	13.01
Voyage 1, 10 days	331.9	13.96	70.6	295.5	42.22	3,981.6	284.79	7.841	1.122	12.89

Average temperature of uptake, 546°; average temperature of superheaters, 360°; average temperature of cold oil, 90°.

REPORT OF BOARD ON TESTS OF LIQUID FUEL FOR NAVAL PURPOSES.

DEPARTMENT OF THE NAVY,
BUREAU OF STEAM ENGINEERING,
Washington, D. C., October 1, 1902.

SIR: The board appointed to conduct an extended series of tests to determine the value of liquid fuel for naval purposes submits the following preliminary report:

The board is of the opinion that the best interests of the Navy will be subserved by making public at this time the data and information collected during the fourteen official experiments that have been conducted. There are many persons outside the naval service who are interested in the subject, and who would cheerfully render assistance along special lines if they could secure a knowledge of the general purpose and work of the board. These engineering experts in the mercantile marine, as well as in civil life, will in return obtain trustworthy information from the data secured, and thus be able to make important deductions. The benefit of submitting a preliminary report will thus redound to the material advantage of all interested in the development of the use of liquid fuel, whether or not they are connected with the naval service.

NECESSITY FOR NAVY DEPARTMENT TO CONDUCT TESTS.

Before laying out the work the board realized that there was in existence a wealth of literature bearing upon the subject. Thousands of interested persons had done some experimentation, but many of these people had no inclination to turn their data over to the general public. By the action of the Navy Department in organizing an official board it was possible to secure data that could only have been gathered with difficulty by private parties.

Upon investigation the board finds that much of the data published is very unreliable, particularly upon the most important features of the problem. As an illustration, it has been asserted that the boilers of some merchant vessels only consume, for sustained sea work, 1 pound of oil to develop 1 horsepower. When it comes to checking this information by the consumption from the storage tanks it will be found that a much larger quantity is used.

The Navy Department can secure information that individuals can not. It is well understood that any information obtained by a naval board will be published in official reports, providing there are no military objections to such publication, and that it is to the mutual interest of the shipbuilding and manufacturing concerns to have the information extant collated by Government officials who are only bent upon stating facts and who have only a professional interest in the investigation of the subject.

It is somewhat expensive work to collect trustworthy data in regard to the performance of marine vessels possessing an oil-fuel installation. The steamship companies that have gone to a considerable financial outlay in securing information can not be expected to assume the rôle of public benefactors, and therefore it is directly within the sphere of the Navy Department to conduct an extended series of experiments that will be of great value to the shipbuilding and manufacturing interests, even if the Navy does not receive an immediate return.

The naval problem is a quite complicated one, and an extended series of experiments to determine the value of liquid fuel for ships of war should be conducted for at least a year. The board recognizes the fact that the commercial phase of the liquid-fuel question as regards the Navy is quite different from what it is in the merchant marine, and that it will be much more difficult to insure an adequate supply for ships of war than for merchant vessels. It will also tax the ability of the naval constructor to solve the construction problem involved in installing oil-fuel appliances on board the battle ship, since it will not be possible to find such satisfactory storage compartments in the fighting ship as in the freighter.

ENGINEERING FEATURES OF THE OIL-FUEL PROBLEM.

It is the engineering or mechanical feature of the problem that the board is concentrating its energies upon. Therefore the board proposes to try to solve some of the following problems in connection with the subject:

1. The relative advantages of air and steam as an atomizing agent for liquid fuel. The question of supply of fresh water is very important in the Navy, and therefore the use of steam should be obviated, if possible. On the other hand, the air compressors are quite heavy and take up considerable room. As air compressors, however, are used for many purposes on board ship, it might be possible to have a central plant for all purposes. It is also important to know to what extent it will be necessary to superheat the steam in case it is used as the atomizing agent.

2. There is a wide divergence of opinion as to the pressures at which oil, steam, and air should be delivered to the burners. Progressive tests may afford valuable information upon this point.

3. The design of the steam generator. As the experimental boiler now in use by the liquid-fuel board is of the water-tube type, it will be possible to extend the length of the furnace and make other changes which will give important information as to whether or not it would be advisable to design a special form of marine boiler for oil-fuel installation.

4. The simplest and most economical means of heating the air and the oil. In view of the result of the present experiments and of the information obtained from outside sources, there is no doubt but that the air should be heated; and it would seem that, particularly in a water-tube boiler, such heating could be effected in a simple and cheap manner by utilizing the heat radiated to the ash pit.

5. The value or necessity of an air receiver when compressed air is used as the atomizing medium. Can the pulsations of the compressor be reduced or minimized by installing such an intermediate receiver between the compressor and the burner?

6. Experiments could be made concerning the baffling of the gases, for the tests already conducted show that the calorimeter area can be somewhat reduced when using oil.

7. The relative value of leading types of burners. Particularly is it necessary to know whether a simple burner should be installed and provision made for heating the air, or whether an appliance should be installed which partially gasifies the oil before ignition. There are on file in this Bureau over 2,000 drawings and specifications pertaining to the use of liquid fuel, and it is said that new patents are being issued at the rate of about 30 a week. In view of such widespread interest in the subject, the board deems it important to test representative types of the various classes of burners.

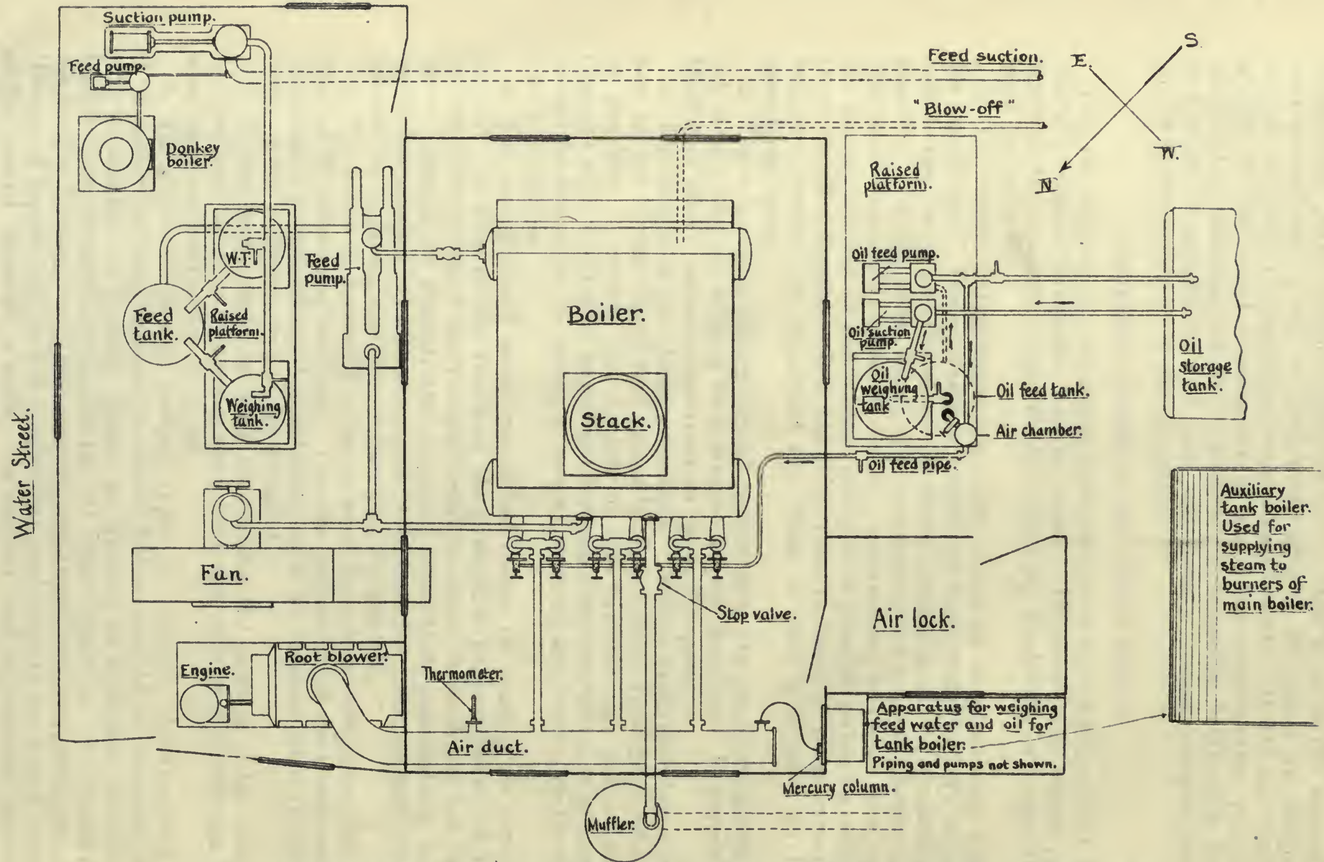


FIG. 6.—ARRANGEMENT OF HOHENSTEIN EXPERIMENTAL BOILER PLANT FOR LIQUID-FUEL TESTS

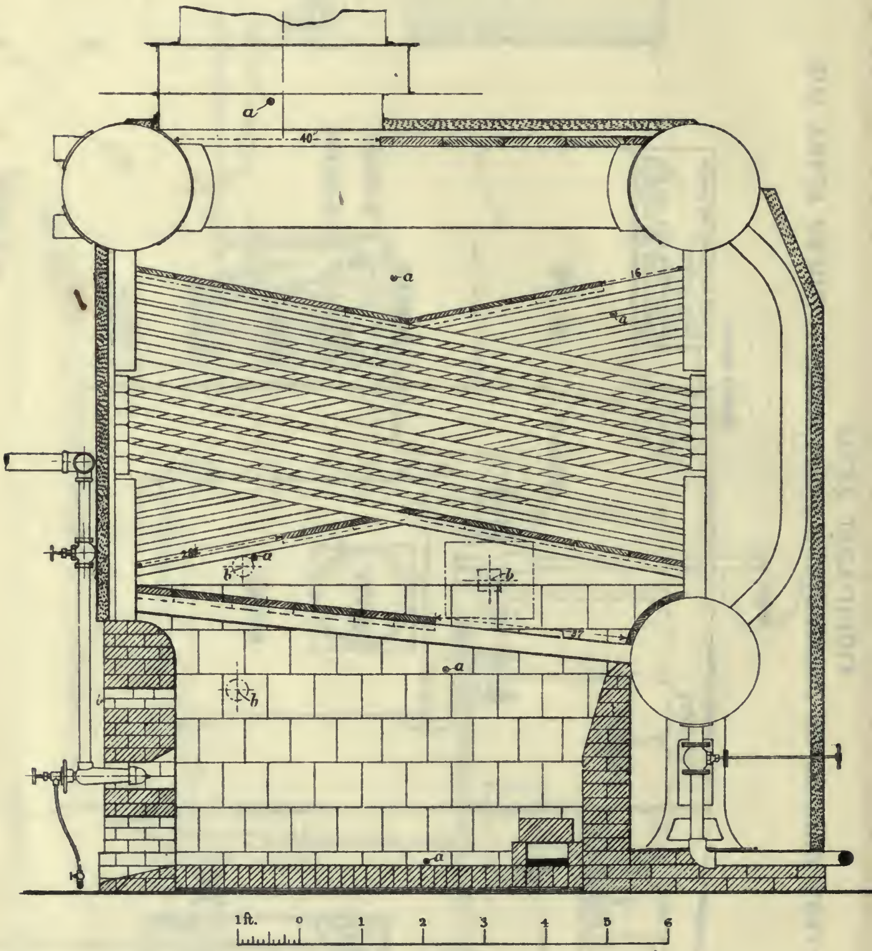


FIG. 8.—THE HOHENSTEIN EXPERIMENTAL BOILER AS ARRANGED FOR LIQUID-FUEL TRIALS.
a, DRAFT-GAUGE CONNECTIONS. *b*, MICA WINDOWS.

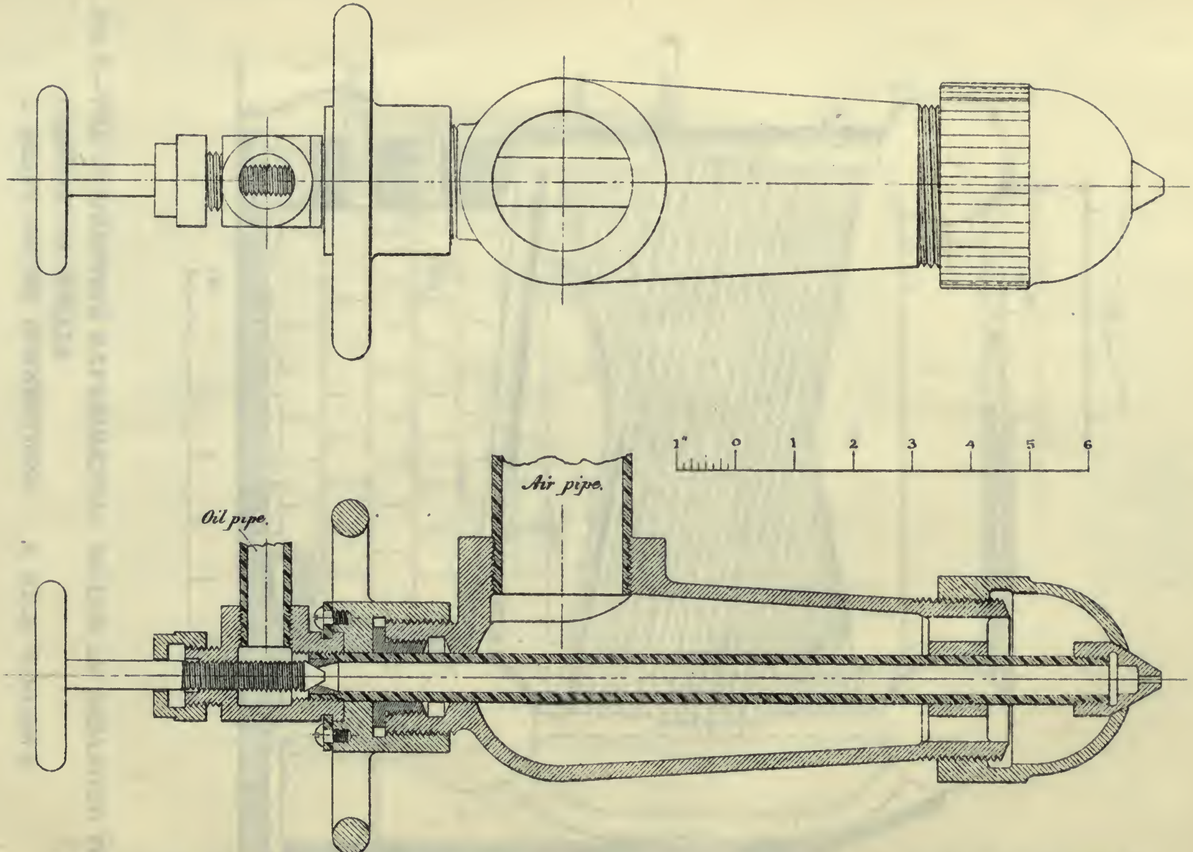


FIG. 9.—THE OIL CITY BOILER WORKS BURNER, USED IN TESTS NOS. 1 TO 8, INCLUSIVE.

8. The problem as to whether the oil could be consumed under all conditions without producing smoke. In the naval service this is an important question. As there is also a tendency to compel manufacturers to take means to prevent smoke issuing from the stacks of their plants, the question also concerns the general public.

OPPORTUNITIES POSSESSED BY THE BOARD FOR SECURING TRUSTWORTHY DATA.

The board considers it but just to acknowledge that through the generosity of the Oil City Boiler Works the Bureau of Steam Engineering has had placed at its disposal without cost for rental a thoroughly equipped experimental plant. The experimental boiler is of the Hohenstein design, and it is the same boiler that was used by the Navy Department in conducting the extended series of tests that were made with coal at various rates of combustion. The value of the data collected during the liquid-fuel experiments can only be appreciated in its fullness by comparing the various tables with those secured during similar tests when coal was used as a combustible. The appropriation of $20,000 that was made by the Fifty-seventh Congress for determining the value of liquid fuel for naval purposes will therefore be devoted, in great part, to original investigation and research. The board has also had at its disposal an unexpended balance of $7,088.09 from a former appropriation. In view also of the fact that everybody now performing duty in connection with the experiments is in the naval service, the appropriation available represents only a portion of the actual expense of the experimental work.

The Bureau of Steam Engineering has supplemented the work of the board by calling upon officers in various parts of the world for information upon the subject. The board has visited the steamers *J. M. Guffey*, *Paraguay*, and *City of Everett*, and has carefully observed the particular features of each installation. Some of the experts of the fuel-oil department of the Standard Oil Company have visited the experimental plant and given valuable advice along certain lines. The board has also been placed in possession of the extensive correspondence carried on by the Bureau of Steam Engineering during the past year with experts and manufacturers. It can therefore be expected that if the tests can continue, valuable information will not only be secured, but it will be possible for the Navy to render a direct service to all who have a professional or financial interest in the general solution of the liquid-fuel question.

GENERAL DESCRIPTION OF THE PLANT.

Fig. 6 is a ground plan of the plant. Fig. 7 is a half-tone view. Fig. 8 shows a longitudinal section of the boiler with the oil burners in place. Fig. 9 shows the construction of an air burner of the Oil City Boiler Works design. This burner was used during the seven general tests that were conducted to show, among other things, whether or not it would be possible to secure a greater evaporative efficiency from the boiler with oil than was secured with coal. Six of these burners, spaced 18 inches apart, were ranged across the front of the furnace, there being a separate opening in the furnace wall for each burner. Considering the burners as arranged in pairs, those of each pair were inclined toward each other at an angle such that their flame impinged near the transverse center line of the furnace.

The arrangements for weighing the feed water were substantially the same as during the coal-burning tests. The facilities for securing forced draft were likewise the same.

UNIFORM QUALITY OF OIL USED DURING EXPERIMENTS.

While the Bureau received many offers from various sources to furnish oil free of cost at the wells, careful inquiry showed that there was no certainty when this oil could be delivered at the experimental plant. Since time is a great element in the matter, the board deemed it necessary to use means whereby a steady supply of oil would be assured and no delay ensue from a lack of liquid fuel in the storage tank. The oil was therefore secured from the Standard Oil Company. The product of different localities will be tested, for the evaporative efficiencies of each field should be ascertained.

METHOD OF WEIGHING OIL USED.

From the storage tank the oil was pumped, as desired, into a weighing tank, from which it flowed by gravity into the oil-feed tank. From this reservoir the oil was pumped into a pipe leading to the burners, constancy of the pressure being secured by an air chamber and a relief valve. An overflow pipe led from relief valve back to the feed tank. The weighing and feed tanks were fitted with gauge glasses graduated to 5 pounds, by the aid of which the exact weight of oil was secured at the end of each hour, the same as with the feed water.

The air for atomizing the oil is supplied by a Root blower driven by a direct connected engine. This blower delivered 8 cubic feet of free air per revolution, at pressures ranging from 0.78 pound to 4.68 pounds per square inch. The air pressure was measured by a mercury column, the location of which was such that it gave substantially the same pressure as at the discharge of the blower. The temperature of the compressed air was taken near the same point. A Rand air compressor has been bought and will be installed, enabling higher pressures of air to be used.

The process of getting up steam in the main boiler was somewhat slow, as dependence had to be placed on a small auxiliary boiler for driving the Root blower until sufficient steam pressure could be secured for that purpose from the main boiler. The auxiliary boiler was only equal to the task of supplying the air to two burners.

The oil used was from the Beaumont, Tex., field. It is said to have been subjected to an inexpensive treatment which removed the sulphur and some of the more volatile hydrocarbons. The board believed that it would be best to use an oil that had been thus treated until some positive information could be secured as to whether or not it was advisable to attempt to use crude oil. It should also be stated that delay might have ensued if it had been attempted to depend upon individual shipments. The judgment of the board in this respect has been vindicated, for there have been times since the experiments commenced when other parties in the city have been unable to secure any oil at any price.

CHEMICAL COMPOSITION OF THE OIL USED DURING TESTS COMPARED WITH THE CRUDE PRODUCT.

The character of the oil used during the official tests can be best appreciated by comparing it with the average grade of the crude product. The changes wrought by the refining process can thus be clearly seen by comparing the analyses of the crude Beaumont product and that used in the experiments.

Analysis of Beaumont crude oil.

	Per cent.
Carbon (C)	84.60
Hydrogen (H)	10.90
Sulphur (S)	1.63
Oxygen (O)	2.87

The amount of sulphur in different samples of the crude Beaumont oil varies from 2 to 3 per cent.

Calorific value per pound of combustible	B. T. U.	19,060
Specific gravity		0.924
Flash point	degrees Fahrenheit	180
Fire point	do	200

On distillation at atmospheric pressure to 524° F. it was found that the—

	Degrees Fahrenheit.
First 10 per cent passed over below	428
Second 10 per cent passed over between	428 and 485
Third 10 per cent passed over between	485 and 524
Fourth 10 per cent passed over between	524 and 554

ANALYSIS OF OIL USED BY LIQUID-FUEL BOARD AS DETERMINED BY THE CHEMIST OF THE NAVY-YARD, NEW YORK.

On distillation at atmospheric pressure to 680° F. it was found that with the oil used during the tests.

	Degrees Fahrenheit.
First 10 per cent passed over between	216 and 482
Second 10 per cent passed over between	482 and 523
Third 10 per cent passed over between	523 and 552
Fourth 10 per cent passed over between	552 and 680

This oil showed on analysis to be composed of the following constituents:

	Per cent.
Carbon (C)	83.26
Hydrogen (H)	12.41
Sulphur (S)	.50
Oxygen (O)	3.83

The sulphur was determined by oxidation with fuming nitric acid in an open capsule.

Specific gravity at 60° F		0.926
Flash point	degrees Fahrenheit	216
Fire point	do	240
Vaporization point	do	142
Loss for six hours at 212° F	per cent	21.65

The calorific value of the the combustible, calculated on the analysis of the United States Chemist by Dulong's formula, viz:

$$\text{British thermal units} = 14500\ C + 62100\ (H - O/8)$$
$$= 19481$$

These analyses show that nearly all the sulphur was removed from the crude petroleum.

It will probably be best to continue using a uniform grade of oil for some time, so that comparisons can be made of the burners as well as the efficiency and advantages of the various methods of atomizing the combustible.

CONDITIONS BETWEEN THE COMBUSTION CHAMBER AND SMOKESTACK.

The temperatures in the base of the stack were remarkably free from the rapid fluctuations that characterized the coal-burning trials. There was no flaming in the stack except during the last two hours of the eighth test, and even then the fluctuations of temperature were absent. This was a test where everything was forced to the utmost, and therefore unusual conditions prevailed. The stack temperatures were noted by a Tagliabue mercury-nitrogen thermometer. It was used without mishap throughout the series of trials. Advantage was taken of the constancy of the stack temperature to check the readings of a Brown quick-reading pyrometer. The pyrometer was afterwards used in the furnace and elsewhere to record temperatures that were not excessive. For temperatures higher than 1,600° F. a platinum-rhodium electric pyrometer was used. The measurements secured with this instrument show a maximum furnace temperature of 2,200° F. for both natural and forced draft conditions.

The draft pressures were measured at the same points as in the series of coal-burning tests, and the average readings are shown diagramatically in fig. 10.

As an aid to the proper regulation of the supply of oil and air to the burners, a mirror was so placed that the man in charge of the fire room could quickly note the color of the gases that issued from the top of the stack. The board considered it of great importance that those operating an oil-fuel installation should possess some device whereby the condition of affairs at the top of the stack can be immediately ascertained.

After considerable study and discussion it was decided that it would be best to give each burner an excess of oil, and this would be shown by the smoke issuing from the stack. Then there was a gradual reduction of the quantity of oil until just a faint trace of smoke could be noticed.

Provision was made for introducing extra air at the sides of the furnace. Holes were cut 8 inches by 1½ inches through the side walls, on a level with the furnace floor and close to its back wall. A flue was built of loose fire brick across the furnace floor, thus connecting the two openings. The roof of the flue had openings between the bricks, thus permitting extra air to be introduced where the combustion was most intense. This extra air supply was cut off during the natural draft and maximum forced-draft trials. The aggregate area of all openings for the admission of atmospheric air into the furnace is given in the detailed report of each trial.

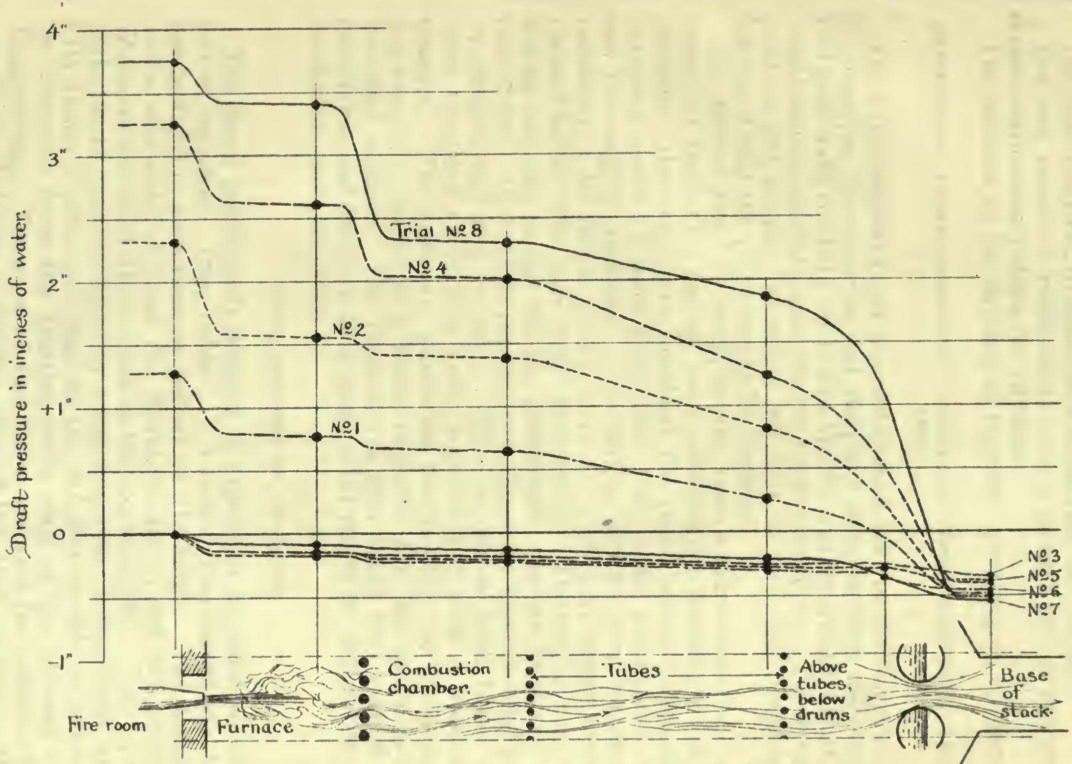
CHARACTER OF THE INFORMATION DESIRED.

Before attempting to test the relative merits of individual burners, the board sought general information along the following lines:

The evaporative efficiency of oil as compared with coal under like conditions.

The degree to which the combustion of oil could be forced with both steam and air as atomizers when using both natural and forced draft.

The ability of a hydrocarbon burner to work under forced draft conditions.



Abscissas are roughly proportional to measurements along the path of gases.

FIG. 10.—CURVES SHOWING VARIATION OF AIR PRESSURE WITHIN THE BOILER DURING CERTAIN OIL-BURNING TRIALS. *SPOTS* INDICATE POINTS WHERE MEASUREMENTS WERE MADE.

The liability of the boiler to injury when using oil under forced draft conditions.

The amount of steam or air requisite for atomizing purposes.

The degree of pressure which should be applied when steam or air was used as the atomizing medium.

The effect of preheating the air necessary for combustion.

The time required to train men to operate the burners.

The best means of reducing the noise caused by the numerous but minute explosions within the furnace.

The attitude of the firemen as regards operating an oil installation.

EXPERIMENTAL PLANT THOROUGHLY OVERHAULED BEFORE COMMENCING LIQUID-FUEL TESTS.

The experimental plant was not turned over to the Bureau of Steam Engineering for experimental purposes in connection with the liquid-fuel tests until the Oil City Boiler Works was assured that the Congress would make a special appropriation for this purpose. The naval appropriation bill having become a law July 3, 1902, the board was then informed that the plant was at its disposal.

The test of June 27, 1902, having been a very severe one, and the casing of the boiler having been considerably warped, it was deemed necessary thoroughly to overhaul the plant before commencing the extended series of tests projected. The boiler was opened, cleaned, and thoroughly examined. The baffling bricks were renewed where necessary. As these bricks were of particular shape, some time elapsed before new ones could be secured. The casing was repaired, and an asbestos lining was put underneath the fire bricks of the furnace floor. All auxiliary machinery about the experimental plant was overhauled and put in order. The cylindrical-tank boiler received from the navy-yard, New York, was covered with a nonconducting material. The necessary platforms for holding the scales and tanks for weighing the oil and water required for this extra boiler were installed in place. The request was also made that several warrant machinists and the crew of a small naval vessel be detailed for duty in connection with the tests.

ENDURANCE TEST OF 116 HOURS.

The board particularly deemed it expedient to make an endurance test of the plant. (See Table 6.) A test of this nature was therefore conducted for a continuous period of 116 hours. The torpedo boat *Gwin* was ordered from the Naval Academy, and the torpedo boat *Rodgers* from Norfolk, to assist in the experiments. The day watch of eight hours was conducted by a regular crew of employees of the Oil City Boiler Works, although all the data during this period was taken by observers from the drafting-room staff of the Bureau of Steam Engineering. The crew of the *Gwin* operated the boiler and auxiliaries during half the night, the crew of the *Rodgers* taking the other night watch during the entire test. The data during the night was taken by the leading petty officers of the two torpedo boats, the commissioned and warrant officers in charge of the respective watches checking and verifying the data. The character of the data collected during the night, compared with that secured during the day, shows the efficiency of the crews of the torpedo boats even as compared with the highly trained force of draftsmen in the Bureau of Steam Engineering.

The test was conducted under the general supervision of the oil-fuel board. The following four commissioned officers had entire charge of the crews and observers during successive watches: Lieut. A. M Procter, United States Navy; Lieut. G. S. Lincoln, United States Navy; Lieut. William R. White, United States Navy; Ensign John Halligan, jr., United States Navy. These officers not only supervised the work of the entire watch, but checked and counter-checked the data.

Four warrant machinists, Messrs. Steele, Johnson, Schreiber, and Rowe were detailed to assist the commissioned officers. These warrant officers were placed in charge of the fire room.

After a preliminary run for the purpose of training officers and crews in taking data and operating the plant, the test was commenced at noon on August 4. Experts from the Oil City Boiler Works and from the fuel-oil department of the Standard Oil Company were present during each day, and at times visited the plant at night. The members of the board, the commissioned officers in charge of the watches, the warrant machinists in the fire rooms, as well as the enlisted force of the torpedo boats, availed themselves of the opportunity to secure advice and assistance from these experts, who, by reason of their training, experience, and opportunity are and ought to be particularly well posted upon the subject. After the first day it was seldom that these experts even offered a suggestion as to operating the burners. They declared that the commissioned officers in charge of the watch and the warrant machinists took such interest in the work and had so quickly grasped the salient points of securing complete combustion that it was best to turn the plant completely over to the direction of such interested parties.

The oil burners during the endurance test were so regulated that they consumed about 830 pounds of oil per hour. Although the data was only recorded at hourly intervals throughout the test, there were unofficial readings and checks made between the hours, thus insuring uniformity in the performance of the boiler.

At 10.40 p. m. on August 5, the transformer on the electric-light circuit of the plant was burned out, it having been overloaded by the extra lights installed for night work. Through the resoucefulness of the officers in charge of the test, this accident did not interfere with the endurance trial. Candles and lanterns were quickly obtained from the torpedo boats, so that the appliances could continue to be efficiently operated and the regular data secured.

The smoke issuing from the stack was quite light and uniform in color. From the records of ten observations made during the day watches it appears that the maximum variation was from 0 to 1 by Ringelmann's charts. The average color throughout the day being 0.4.

Temperatures taken with a platinum-rhodium pyrometer showed 1,980° F. near the middle of the furnace. At the receiving end of the combustion chamber the temperature was 1,900° F

Toward the end of the test the water in the boiler became very muddy. It should be stated that during the entire endurance trial the boiler was fed with Potomac River water that had not been filtered. It might also be stated that during the past eighteen months the experimental boiler has been subjected to just this kind of work. The notes

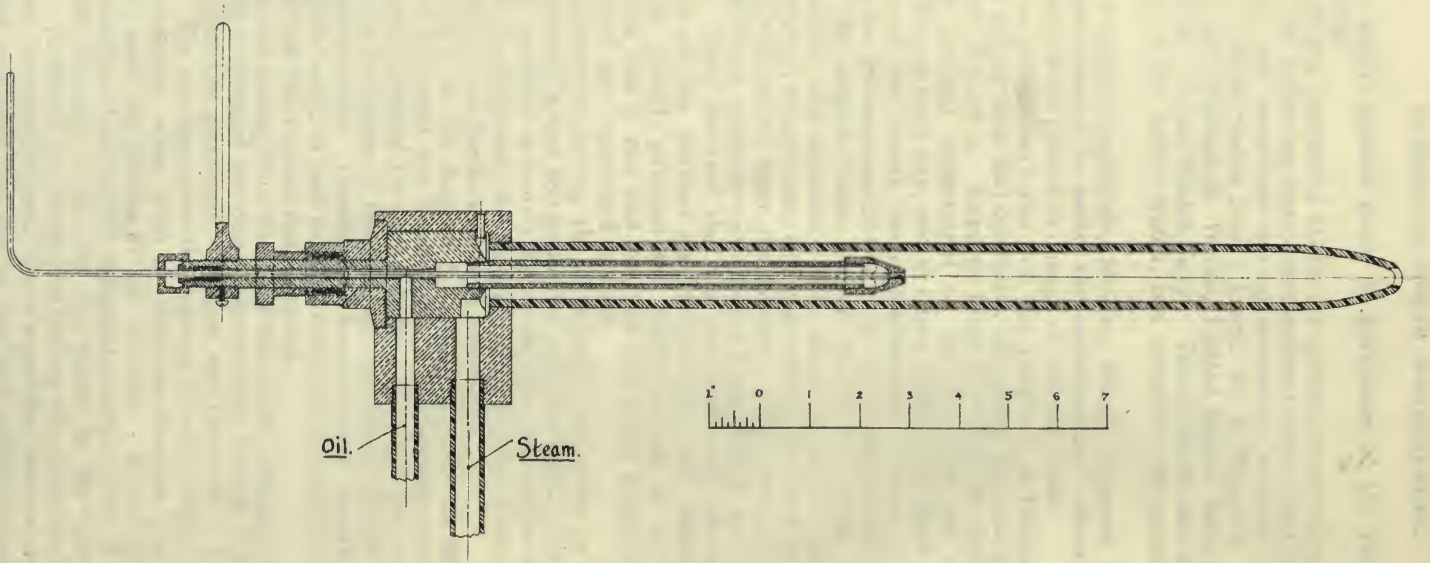


Fig. 11.—THE HAYES BURNER, USED IN TEST NO. 9.

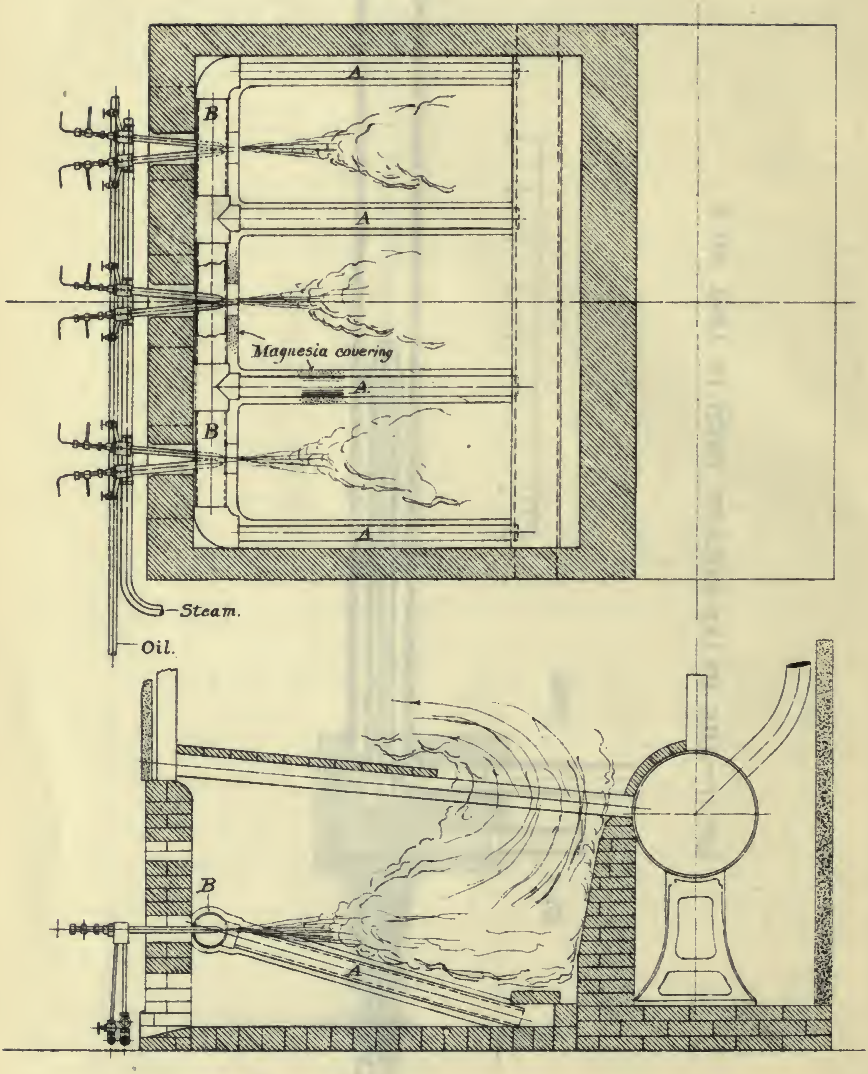


Fig. 12.—INSTALLATION OF HAYES BURNERS. TEST NO. 9.

appended to the coal and oil tests will show in detail the treatment the boiler received. Occasionally the gauge-glass connections would get clogged with mud, and toward the end of the endurance test it was necessary to blow steam through them every half hour.

Two pieces of carbon were removed from the vicinity of the second burner from the left; one piece on August 7 and the other on August 9. Each piece was about 64 cubic inches and was caused by the burner being so placed as to permit the flame to impinge on the brickwork of the front furnace wall.

THE HAYES HYDROCARBON BURNER.

The construction of this burner is shown in fig. 11 and the manner of its installation in fig. 12. Part of the air supply is introduced at the sides of the furnace near the back wall. It then passes through heating pipes *AA* to the pipe *B*, the latter extending across the furnace just inside the front wall.

The burners project diametrically through the pipe *B*, and it is contended that the hot air in this pipe will cause the oil to be completely gasified before it escapes from the burner orifices. There is no doubt but that the heating of the air is a direct benefit. Careful and extended experiments will have to be made to show whether this heating could best be effected as in the Howden system of forced draft, or by a simple arrangement of pipes which receive the direct heat of the furnace. The experience of simply heating the pipes during these tests would rather tend to show that this arrangement would not have much endurance. The edges of the holes in the pipe *B* were found somewhat burned upon completion of the official test. If such impairment could occur after the pipe had been in actual service about twenty hours, it is probable that very little endurance can be expected of such an installation under forced draft conditions.

Two preliminary tests were made. Some representatives of the company owning the burner were present during these trials, and suggestions were sought of these men who were supposed to have expert knowledge of that particular appliance. At no time were they able to secure from the boiler an actual evaporation of 11 pounds of water. During the first experimental trial, on September 10, it was manifest that the bulk of the combustion was above the tubes and in the uptake and stack. In consequence of this loss of heat, and before the second unofficial trial was attempted, the draft opening above the tubes was reduced in the proportion of 16 to 10¼. This caused a noticeable improvement. It should be stated that it required ten days for the company to prepare for the first preliminary trial. Their experts had been furnished blue prints showing in detail the character of the experimental plant, also the position and arrangement of the baffle plates in the experimental boiler. Representatives of the company had also been permitted to witness some of the previous tests. The experience with this company has now caused the liquid-fuel board to compel every inventor to make arrangements whereby he can install his appliance within three days.

Steam for the burners was supplied from an independent boiler at a uniform pressure of 90 pounds. During the unofficial trials the steam was not superheated, the inventor having previously maintained that he could use exhaust steam and attain the object desired. It might also be incidentally stated that the claim was made that one single burner would consume all the oil that would be required for even forced-draft purposes.

Oil was supplied to the six burners during the unofficial tests at a uniform pressure of 80 pounds. Besides the air introduced through the heating tubes, some additional air was admitted through what were formerly the ash-pit openings. The aggregate area of these ash-pit openings was about 60 square inches.

During the official trial (test No. 9), which continued for six hours, the steam for the burners was superheated. There was fitted, in the opening above the tubes and below the steam drum of the main boiler, 44 feet of 1½-inch pipe. This pipe was in the form of three return bends. Steam from the cylindrical tank boilers was led through this pipe and thence to the burners.

The leading experts of the company did not attend this official trial. The mechanics who installed the burners, however, operated these appliances under the direction of the warrant machinists. The board was informed that it was these mechanics who operated the burners during an official test that had been made at an electric-light station in the city, where it was claimed that there had been evaporated 18 pounds of water per pound of combustible. It is needless to say that no such results were secured under the experimental boiler.

PROGRESSIVE TESTS WITH BURNERS USING STEAM FOR ATOMIZING.

These tests were made September 19, 20, and 22. One of the special purposes of conducting these trials was to ascertain the exact amount of steam that would be required for atomizing the oil. Every possible check was used to secure trustworthy data. All during the trials there were searches for leaks, but none were discovered.

The board was desirous of ascertaining just how much steam was required for atomizing, and therefore a separate boiler was installed for generating steam for this purpose. It is a cylindrical return-tube boiler with two plain cylindrical furnaces. This boiler is piped to furnish steam for the oil burners, and has no other steam pipe leading from it. The opening from the safety valve was blanked. This boiler is fitted with two oil burners of Oil City Boiler Works' design in each furnace, these burners using air for atomizing purposes. After steam was raised one burner in one furnace was found sufficient to keep the steam pressure uniform.

This boiler was put in thorough order at the navy-yard, New York, and carefully made tight at 100 pounds pressure. During the oil-burning test great care was taken to keep both the water level and the steam pressures in this boiler uniform. The water used was carefully weighed in a separate weighing apparatus, in exactly the same manner as the water supplied to the experimental boiler.

The pressure for atomizing purposes, as well as the pressure at which the oil was forced to the burner, was increased each day. It was found that the higher the pressure the greater the amount of water that was evaporated. The efficiency was also slightly greater as higher pressures were used. The percentage of steam required for atomizing the oil, however, also slightly increased as higher pressures were used.

During these tests deflectors were placed in the ash-pan openings, so as to cause the air to be drawn up near the burners, thus effecting

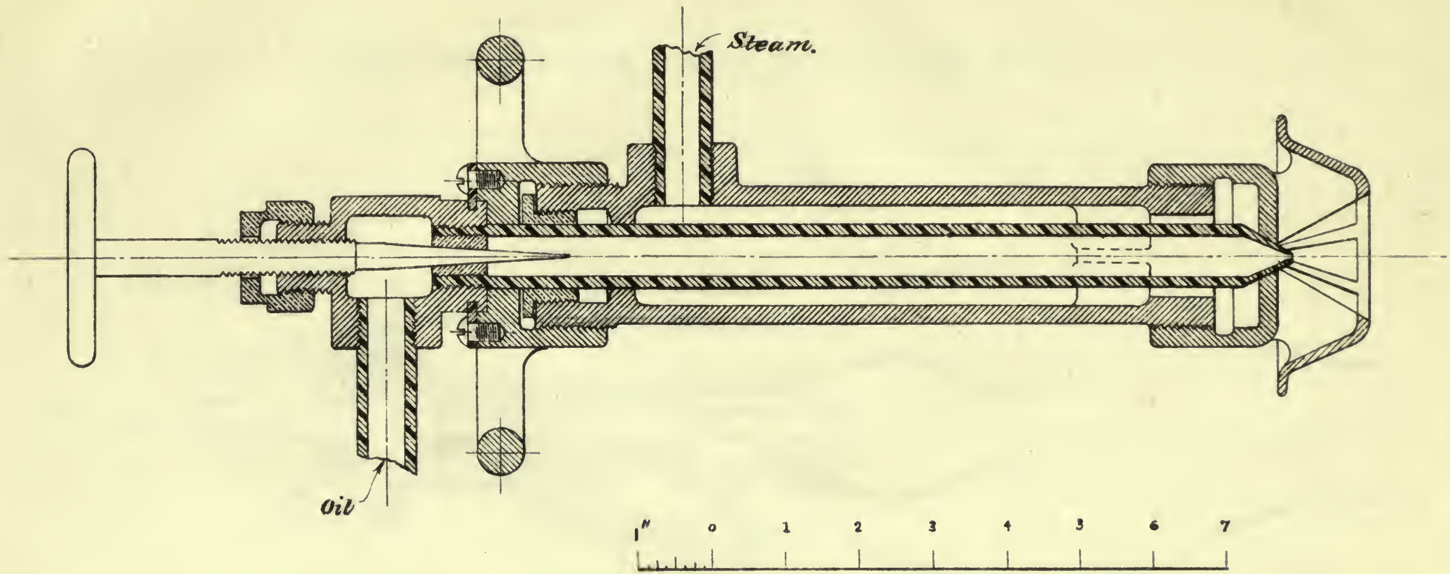
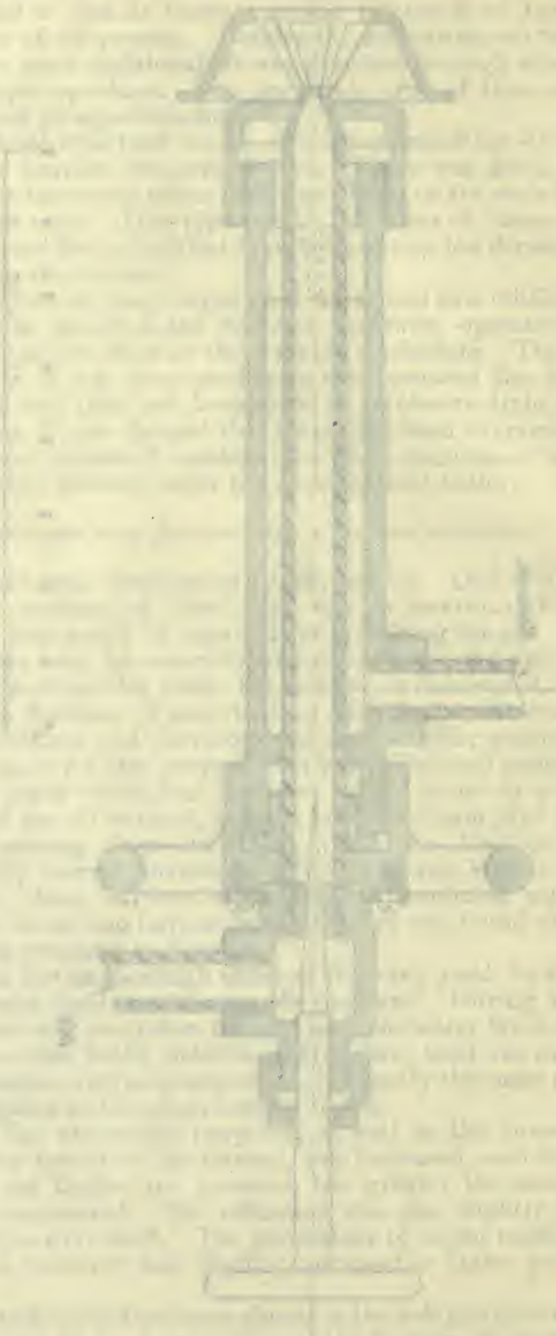


FIG. 13.—THE OIL CITY BOILER WORKS BURNER, USED IN TESTS NOS. 10, 11, AND 12.



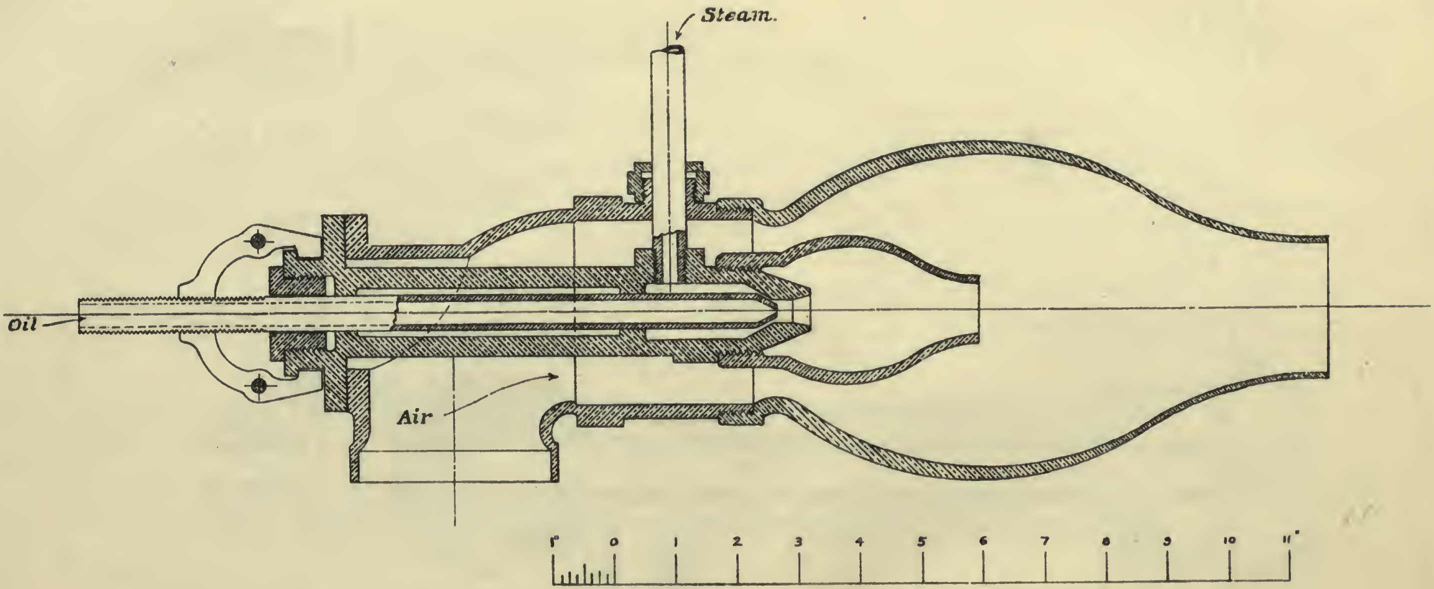


Fig. 14.—THE F. M. REED BURNER, USED IN TESTS NOS. 13 AND 14.

combustion nearer the front of the furnace. The average percentage required for atomizing purposes was about 4½ per cent of the entire evaporation.

In these three tests the side burners were directed toward the center of the furnace more than heretofore in order to reduce the amount of heat absorbed by the side walls. The amount so absorbed was judged of by the condition of glow immediately after extinguishing the burners. This glow of the side walls, and also of the back and bridge walls, generally showed a more intense combustion on the right side of the furnace than on the left. The fact that the steam and oil connections to the burners were also at the right side of the furnace front suggests the desirability of proportioning the piping, both as to size and location, so as to get substantially equal pressure at all burners.

Before making further tests the front wall of the furnace was rebuilt with ferruled openings 8 inches in diameter for the burners. Ample latitude was thus allowed for the angular setting of the burners, and there was also opportunity for trying the effect of admitting air around the burners.

An accident to the engine of the fan blower prevented the continuance of these trials with different pressures of forced draft. It should be ascertained just how much steam is required for atomizing purposes when the boiler is forced to its utmost.

The board deems it important, when opportunity will permit, to make an extended series of tests with steam as the atomizing agent. Fresh water can be secured in unlimited quantities at nearly all naval stations, and it might not be a difficult matter to make arrangements whereby the torpedo boats and destroyers could be furnished with an ample supply in specially constructed tanks, thus obviating the risk of being compelled to feed salt water into the boilers.

Even if compressed air should be used on the torpedo boats as the atomizing agent, an accident might happen to the compressor plant which would compel the temporary use of steam. There is therefore an urgent necessity to secure reliable data upon the subject of how much steam is required for spraying purposes under various conditions of natural and forced draft.

THE F. M. REED COMBINED AIR AND STEAM BURNER.

One preliminary and two official tests were made with this burner, whose construction is shown in fig. 14. The "from and at" evaporation during the first official experiment fell short of the best yet attained in these trials (test No. 3) by only about one-half of 1 per cent. On the other hand, the amount of steam consumed in spraying the oil was excessive, being about 1 pound of steam per pound of oil, or several times as much as in test No. 3. Apart from any question of furnace efficiency, the board considers that the combined use of both air and steam in the burners is undesirable. Such an installation involves unnecessary expense and complication and requires much more skill and attention in the adjustment and manipulation of the burners.

The board gave particular attention to watching the operation of this burner, since it is desirous of securing definite information upon the subject as to whether or not it was advantageous to use a combination of both air and steam as the atomizing agent. The inventor personally operated the burner, and every effort was made to reduce the amount of air and steam used for spraying purposes.

It is by a process of eliminating undesirable classes of burners that the best form can be secured, and therefore the board has no hesitation in stating that further experimentation with the combined air and steam burner should not be made.

THERMAL EFFICIENCY NOT INCREASED BY THE USE OF STEAM.

There is quite a widespread misconception regarding the part that the steam which is used for atomizing purposes plays in effecting combustion. It is supposed by many that after atomizing the oil the steam is decomposed and that the hydrogen and carbon are again united, thus producing heat and adding to the heat value of the fuel. While it may be true that the presence of steam may change the character and sequence of the chemical reaction, and result in the production of a higher temperature at some part of the flame, such an advantage will be offset by lower temperatures elsewhere between the grate and the base of the stack. All steam that enters the furnace will, if combustion is complete, pass up the stack as steam, also carrying with it a certain quantity of waste heat. The amount of this waste heat will depend upon the amount of steam and its temperature at entrance of the furnace. The quantity of available heat, measured in thermal units, is undoubtedly diminished by the introduction of steam. In an efficient boiler it is quantity of heat rather than intensity that is wanted. For many manufacturing purposes intensity of heat may be of primary importance, but in a marine steam generator a local intense heat is objectionable on other grounds than those of economy, viz, its liability to cause leaky tubes and seams from the unequal expansion of heating surfaces.

INFORMATION ALREADY OBTAINED.

It is believed that expert engineers will be able to make important deductions from the trustworthy data that has been so carefully collected. The tables should be carefully studied in connection with the information secured during the coal tests, and the board enjoins that the two reports be studied together.

The following information has undoubtedly been secured:

(a) That oil can be burned in a very uniform manner.

(b) That the evaporative efficiency of nearly every kind of oil per pound of combustible is probably the same. While the crude oil may be rich in hydrocarbons, it also contains sulphur, so that, after refining, the distilled oil has probably the same calorific value as the crude product.

(c) That a marine steam generator can be forced to even as high a degree with oil as with coal.

(d) That up to the present time no ill effects have been shown upon the boiler.

(e) That the firemen are disposed to favor oil, and therefore no impediment will be met in this respect.

(f) That the air requisite for combustion should be heated if possible before entering the furnace. Such action undoubtedly assists the gasification of the oil product.

(g) That the oil should be heated so that it could be atomized more readily.

(h) That when using steam higher pressures are undoubtedly more advantageous than lower pressures for atomizing the oil.

(i) That under heavy forced-draft conditions, and particularly when steam is used, the board has not yet found it possible to prevent smoke from issuing from the stack, although all connected with the tests made special efforts to secure complete combustion. Particularly for naval purposes is it desirable that the smoke nuisance be eradicated in order that the presence of a war ship might not be detected from this cause. As there has been a tendency of late years to force the boilers of industrial plants, the inability to prevent the smoke nuisance under forced-draft conditions may have an important influence upon the increased use of liquid fuel.

(j) That the consumption of liquid fuel can not probably be forced to as great an extent with steam as the atomizing agent as when compressed air is used for this purpose. This is probably due to the fact that the air used for atomizing purposes, after entering the furnace, supplies oxygen for the combustible, while in the case of steam the rarefied vapor simply displaces air that is needed to complete combustion.

(k) That the efficiency of oil fuel plants will be greatly dependent upon the general character of the installation of auxiliaries and fittings, and therefore the work should only be intrusted to those who have given careful study to the matter, and who have had extended experience in burning the crude product. The form of the burner will play a very small part in increasing the use of crude petroleum. The method and character of the installation will count for much, but where burners are simple in design and are constructed in accordance with scientific principles there will be very little difference in their efficiency. Consumers should principally look out that they do not purchase appliances that have been untried and have been designed by persons who have had but limited experience in operating oil devices.

NECESSITY OF PERMITTING UNOFFICIAL OR PRELIMINARY TRIALS.

Between the several official tests there are invariably conducted a number of unofficial trials, and by reason of this experimentation valuable suggestions are received. Those who have received permission to install their appliance find that it is quite a different matter to apply it to a boiler that is capable of developing 2,000 horsepower from what it was to install it on some boiler that supplied steam to a small vessel or medium-sized manufacturing plant.

Up to the present time no firm has been able to tell the board the best manner in which their device should be operated. In fact, the details of installation of every burner yet tested are quite different when completed from that projected at the beginning of the test. The two or three days that are given to experimental trials invariably furnish surprises to the inventor. Probably no better illustration could be given of the lack of definite knowledge in regard to the correct way of operating burners than has been shown during these experiments. The experience of the board in this particular respect shows the necessity of having some disinterested experts conduct an extended series of tests to determine the guiding principles which should be followed in the burning of liquid fuel. There has been sufficient evidence already produced to prove that in all probability special forms of burner will be required for different types of boilers.

It can hardly be expected that a burner which could do efficient and economical work in some small steam generator would be equally applicable to the largest steam generators of the marine type.

In noting the evaporative efficiency secured, it should be remembered that the experimental boiler was designed for actual Navy conditions, and that the limitations prescribed by the Department as to height, weight, and floor space were of a severe nature. There is not only considerable radiation from the boiler, but the proportion of heating to grate surface is not as large as in land boilers. Taking these facts into consideration, the results are exceedingly satisfactory. The engineering world is looking for comparative results from the series of tests that are now being conducted, and trustworthy information in this respect will be furnished.

AN OIL INSTALLATION SHOULD BE FITTED TO BOILERS OF SEVERAL TORPEDO BOATS.

The information and data already secured warrants the immediate installation of oil-fuel appliances on two torpedo boats and two torpedo-boat destroyers, to test the adaptability for use with water-tube boilers of bent-tube type. The installation could be effected on boats of similar character, so that an earnest but friendly rivalry would be created between the crews of the several vessels. There will come development and success by boldly equipping several boats with different types of installation. The morale of the torpedo-boat flotilla can be strengthened in no better way than by experimenting along this line.

In all probability but one or two of the bent-tube types of boilers fitted in our torpedo boats or destroyers will burn oil efficiently, unless extensive baffling is resorted to in the furnaces so as to direct the products of combustion among the tubes. Extended tests should be made with torpedo boats, to find out the best means of securing effective baffling.

SOME JUNIOR OFFICERS OF THE LINE SHOULD ACCOMPANY LIQUID-FUEL BOARD ON INSPECTION TRIPS.

If the Department should decide to authorize the installation of oil-fuel appliances on several torpedo boats, then a number of the officers who are eventually to command these boats should be detailed for temporary duty in connection with the liquid-fuel board. Two or three months of such duty would give them practical experience which would be of inestimable value in the conduct of their future work. These junior officers should also be given the opportunity of inspecting installations on merchant ships, as well as the privilege of visiting establishments on shore where liquid fuel is the sole combustible for generating the motive power.

The board has been greatly impressed with the necessity of keeping in close touch with experts throughout the country who are making a particular study of this subject. The information secured by making careful inspection of efficient installations and by personal interviews with recognized authorities upon the subject can hardly be overestimated. It is hoped that it will be compatible with the interests of the Department to permit some junior officers of the line to accompany the board on every such inspection, for the resulting benefits to the naval service would be very great.

AN EFFICIENT EXPERIMENTAL CREW SECURED.

The experience of the past two months has undoubtedly caused the crew of the torpedo boat *Rodgers* to be well trained in the handling and operating of oil-fuel devices. This crew has been so well drilled and has been so receptive for information that they can now quickly tell whether the burners are efficiently or properly regulated. By noting the character and length of the flame, the color of the escaping gases from the chimney, the condition of affairs in the furnace and combustion chamber as observed through the sight holes, the roar of the air as combustion takes place, and the appearance of the bridge wall, they can quickly adjust the several valves and secure the best possible results. The efficiency of the crew in this respect has been due in great part to the zeal, intelligence, and ability of the commanding officer of the boat, Ensign John Halligan, jr.

THE EXPERIMENTS SHOULD BE CONDUCTED ENTIRELY BY PERSONS WITHIN THE NAVY.

The board desires to state that these experiments can not be conducted to the best interest of the service without the aid of a Navy crew of firemen and observers. It is essential that the board should be able to call upon such crew for either day or night work. While most of the official tests are only of eight hours' duration, it requires several hours properly to warm up the boiler and get things in good running shape. Then it requires one or two hours after the completion of the test to secure the plant and guard against fire.

A civilian crew will only work eight hours, and then at stated intervals. They demand extra compensation for overtime, and it is no easy matter to get them to stand up to forced-draft conditions, particularly when the higher air pressures are used. A crew of firemen that is changed from day to day, and who are apprehensive of their personal safety when forced-draft trials are made, can not be interested in the work. The experiences of the Oil City Boiler Works for over a year in the conduct of the coal experiments show excessive trouble, annoyance, expense, and delay, arising from attempting to use such employees in experimental research.

The experimental crew must be under military control and discipline, and this can only be secured by having some regular vessel of the Navy, regularly in commission, assigned to duty in connection with the experimental board.

The data submitted will best tell the work done during the past three months. Every member of the board has other duties to perform. In the collection of such data it is the character and quality rather than the quantity which the engineering world desires. From this time forward it can be expected that the experiments can be conducted with greater rapidity, providing, of course, the board can have the service of a trained Navy crew to work the experimental plant.

Very respectfully,

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WYTHE M. PARKS,
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Lieutenant-Commander, U. S. Navy.

The CHIEF OF THE BUREAU OF STEAM ENGINEERING.

No. 1.—*Test of oil fuel in a Hohenstein*

[Six hours duration with forced

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.			Oil-spraying air pressure per square inch.
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.	
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Lbs.*
11 a. m	275	120	402	302	0.982	2.125	84	117		3.20
11.15 a. m	275	112	402	302	.983	1.75		118	663	3.11
11.30 a. m	275	112	402	303	.983	2.5		116		3.14
11.45 a. m	275	110	402	304	.984	3.5		118	705	3.23
12 m	275	122	402	302	.982	2.75	86	119		3.17
12.15 p. m	275	122	402	303	.983	1.75		119	709	3.17
12.30 p. m	275	120	402	304	.984	2		120		3.23
12.45 p. m	275	112	402	304	.984	3		121	717	3.23
1 p. m	275	118	402	304	.984	2.13	86	121		3.23
1.15 p. m	275	120	402	304	.984	2.75		122	715	3.17
1.30 p. m	275	120	402	304	.934	2.75		122		3.11
1.45 p. m	275	118	402	304	.984	3		122	712	3.23
2 p. m	275	123	402	303	.983	2.25	86	122		3.23
2.15 p. m	275	124	402	304	.984	2.25		122	711	3.17
2.30 p. m	275	122	402	304	.984	2.5		122		3.23
2.45 p. m	275	126	402	304	.984	2		122	714	3.23
3 p. m	275	122	402	303	.983	2.75	86	122		3.23
3.15 p. m	275	120	402	304	.984	2.13		122	706	3.23
3.30 p. m	275	128	402	302	.983	2.13		122		3.23
3.45 p. m	275	129	402	303	.983	2.13		122	690	3.23
4 p. m	275	124	402	303	.983	2.13	85	122		3.23
4.15 p. m	275	124	402	304	.984	2.13		122	704	3.23
4.30 p. m	275	121	402	303	.983	2.13		124		3.23
4.45 p. m	275	124	402	303	.983	2.13		123	709	3.17
5 p. m	275	125	402	304	.984	2.125	85	124		3.17
Average	275	120.7			.9834		85.4	121	704.6	3.20

State of weather, bright sun, clear sky.
Barometer at noon, 30.02 inches.
Kind of fuel, Beaumont oil.
Revolutions of fan blower, 327 per minute.
Revolutions of Root blower, 126 per minute.
Draft openings into furnace, 666 square inches.

9.10 a. m.: Two middle burners lighted. Root blower driven by steam from small independent boiler.

10.05 a. m.: Steam pressure in main boiler, 100 pounds. All auxiliary machinery begun to be driven by steam from main boiler. All six burners alight.

Smoke very uniform and much thinner than corresponds to chart No. 1.

water-tube marine boiler June 11, 1902.

draft, using air burners.]

Draft air pressures in inches of water.					Flue gases.			Oil.		Water.	
Fire room.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Burned per hour.	Total weight burned.	Fed per hour.	Total weight fed.
					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1.20	0.80	0.60	0.25	−0.45	....	....	....	0	0	0	0
1.20	.80	.60	.25	− .45	6.8	8.2	(?)	....	....	....	....
1.20	.80	.60	.25	− .50	....	....	....	....	....	....	....
1.20	.80	.65	.25	− .45	7.4	8.3	(?)	....	....	....	....
1.25	.85	.65	.25	− .45	....	....	....	1,769	1,769	19,406	19,406
1.30	.80	.65	.25	− .45	7.6	9.2	0.4	....	....	....	....
1.25	.80	.60	.25	− .50	....	....	....	....	....	....	....
1.25	.80	.65	.25	− .50	7	8.6	1.8	....	....	....	....
1.25	.80	.65	.25	− .50	....	....	....	1,819	3,588	20,023	39,429
1.25	.80	.65	.25	− .50	7.1	9.3	1.4	....	....	....	....
1.25	.80	.65	.25	− .50	....	....	....	....	....	....	....
1.25	.80	.65	.25	− .50	7.1	9	1.3	....	....	....	....
1.25	.80	.65	.25	− .50	....	....	....	1,776	5,364	19,990	59,419
1.30	.75	.65	.25	− .45	7.1	8	2	....	....	....	....
1.30	.80	.65	.25	− .50	....	....	....	....	....	....	....
1.30	.75	.65	.25	− .50	6.8	7.4	2.6	....	....	....	....
1.30	.75	.65	.25	− .50	....	....	....	1,777	7,141	20,000	79,419
1.30	.75	.65	.25	− .50	6.6	8.8	1.3	....	....	....	....
1.30	.75	.65	.25	− .50	....	....	....	....	....	....	....
1.30	.75	.65	.25	− .50	6.3	9.8	1.7	....	....	....	....
1.30	.75	.65	.25	− .50	....	....	....	1,705	8,846	18,823	98,242
1.30	.75	.65	.25	− .50	6.8	9	1.7	....	....	....	....
1.30	.75	.65	.25	− .50	....	....	....	....	....	....	....
1.30	.75	.65	.25	− .50	7	9.6	.8	....	....	....	....
1.30	.75	.65	.25	− .50	....	....	....	1,738	10,584	19,734	117,976
1.27	.78	.642	.25	− .488	6.97	8.77	1.5	1,764	....	19,663	....

5 p. m.: The floor of the furnace is badly warped from the heat. The floor consists of one layer of fire brick on wrought-iron floor plates on wooden sleepers with dirt rammed between the sleepers. The floor of furnace, back wall of same, and first two baffles are red hot. There are two disk-like accumulations of red-hot carbon on the back wall. The middle and larger one is about 15 inches in diameter.

Next day: The disk of carbon has been removed and examined. Structurally the carbon is indistinguishable from coke. The shape is that of a crater, 5 inches thick around the edges and 2 inches thick in the center. The larger crater was opposite the middle burners. A smaller one was opposite the left-hand burners and there was practically none opposite the right-hand burners. Evidently a very slight difference of conditions will cause or prevent their formation.

No. 2.—*Test of oil fuel in a Hohenstein*

[Four hours duration with

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.			Oil spraying air pressure per square inch.
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.	
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Lbs.*
11.30 a. m.	275	104	402	297	0.980	1.125	82	112	....	4.63
11.45 a. m.	275	106	402	301	.982	1.13	....	114	785	4.63
12 m.	275	100	402	302	.982	1.13	....	116	....	4.50
12.15 p. m.	275	102	402	302	.982	2.5	....	118	775	4.26
12.30 p. m.	275	102	404	302	.982	1.13	86	118	....	3.16
12.45 p. m.	275	103	404	303	.982	1.5	....	119	775	4.50
1 p. m.	275	102	403	300	.981	1.5	....	120	....	4.63
1.15 p. m.	275	102	402	296	.979	1.13	....	122	787	4.87
1.30 p. m.	275	102	402	296	.979	1.13	86	123	....	4.87
1.45 p. m.	275	104	402	301	.982	2	....	124	795	4.87
2 p. m.	275	108	402	296	.979	1.13	....	124	....	4.87
2.15 p. m.	275	102	402	301	.982	1.5	....	125	770	4.87
2.30 p. m.	275	102	403	302	.982	1.75	88	125	....	4.87
2.45 p. m.	275	104	402	299	.981	1.75	....	126	760	4.87
3 p. m.	275	105	402	300	.981	1.5	....	126	....	4.69
3.15 p. m.	275	102	402	300	.981	2	....	126	770	4.87
3.30 p. m.	275	104	402	278	.969	2.125	88	127	....	4.63
Average	275	103.2	....	....	.980	....	86	121.5	779	4.62

State of weather, bright sun, clear sky.
Barometer at noon, 30 inches.
Kind of fuel, Beaumont oil.
Revolutions of fan blower, 423 per minute.
Revolutions of Root blower, 179 per minute.
Draft openings into furnace, 666 square inches.
9.15 a. m.: Lighted two middle burners.
10.07 a. m.: Pressure begins to show on main boiler steam gauge.
10.30 a. m.: 100 pounds pressure in main boiler. Oil-spraying air pressure, 1.75 pounds.
10.35 a. m.: All six burners alight. All auxiliaries driven by main boiler steam. Oil-spraying air pressure, 2.8 pounds.
10.38 a. m.: 270 pounds pressure in main boiler.
11.30 a. m.: Test begins.

water-tube marine boiler June 12, 1902.

forced draft, using air burners.]

Draft air pressures in inches of water.					Flue gases.			Oil.		Water.	
Fire room.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Burned per hour.	Total weight burned.	Fed per hour.	Total weight fed.
					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
2.25	1.60	1.50	0.90	−0.50	....	....	....	0	0	0	0
2.25	1.60	1.50	.90	− .50	6.8	9	1.2	....	....	....	....
2.25	1.60	1.40	.80	− .50	....	....	....	....	....	....	....
2.25	1.50	1.35	.80	− .50	7.1	8.6	1.8	....	....	....	....
2.30	1.50	1.35	.85	− .50	....	....	....	2,396	2,396	25,216	25,216
2.35	1.50	1.40	.85	− .50	6.5	8.7	1.4	....	....	....	....
2.35	1.50	1.40	.85	− .50	....	....	....	....	....	....	....
2.35	1.50	1.40	.85	− .50	7.3	9.2	.8	....	....	....	....
2.35	1.50	1.40	.85	− .50	....	....	....	2,300	4,696	24,217	49,433
2.35	1.50	1.35	.80	− .50	7.3	8	1.8	....	....	....	....
2.35	1.55	1.35	.80	− .50	....	....	....	....	....	....	....
2.30	1.55	1.35	.80	− .50	6.9	8.5	1.6	....	....	....	....
2.30	1.55	1.35	.80	− .50	....	....	....	2,301	6,997	24,361	73,794
2.30	1.55	1.35	.80	− .50	6.9	10.5	.6	....	....	....	....
2.30	1.55	1.35	.80	− .50	....	....	....	....	....	....	....
2.30	1.60	1.35	.80	− .50	6.9	11.1	.4	....	....	....	....
2.30	1.60	1.35	.80	− .50	....	....	....	2,183	9,180	23,134	96,928
2.31	1.55	1.38	.83	− .50	6.96	9.2	1.2	2,295	....	24,232	....

12.30 p. m.: The casing of the Root blower being rather warm some one thought to cool it by playing a hose on it. The result was that the casing got very hot, the speed of the Root blower was reduced, and the oil-spraying air pressure fell to about 2 pounds. Under these conditions, which lasted about ten minutes, the smoke from the stack was very dense. Normal conditions were quickly restored by lubricating the blower impellers with graphite.

1.30 p. m.: There is a red hot area of about 30 square inches on the outside of the boiler casing opposite the tube chamber. The bulging out of the casing allows the hot gases to take a short cut from the combustion chamber, which is lined with fire brick, to the tube chamber, which is lined with magnesia.

3.10 p. m.: The red hot area has increased to about 1 square foot.

3.30 p. m., end of test: There is a carbon crater 12 inches in diameter on the back wall opposite the central burners and one 25 inches in diameter opposite the left-hand burners. None opposite the right-hand burners. The smoke during this test averaged about ½ by Ringelmann's charts.

No. 3.—*Test of oil fuel in a Hohenstein*

[Eight hours duration with

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.			
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.	Air from Root blower.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9 a. m	275	122	404	305	0.983	2.5	72	94	....	90
9.15 a. m	275	130	404	306	.984	2.5	....	97	520	91
9.30 a. m	275	130	404	306	.984	2.5	....	100	....	92
9.45 a. m	275	134	404	307	.985	2.25	....	100	525	94
10 a. m	275	122	404	308	.985	2.5	74	99	....	95
10.15 a. m	275	130	404	308	.985	2.5	....	101	525	96
10.30 a. m	275	130	404	308	.985	2.5	....	102	....	97
10.45 a. m	275	128	404	308	.985	2.5	....	102	508	98
11 a. m	275	140	404	307	.984	2.5	76	103	....	99
11.15 a. m	275	125	404	306	.984	2.25	....	102	500	100
11.30 a. m	275	130	404	307	.985	2.25	....	103	....	100
11.45 a. m	275	124	404	307	.984	2.5	....	104	495	100
12 m	275	138	404	306	.984	2	78	105	....	102
12.15 p. m	275	134	404	307	.985	2	....	105	495	102
12.30 p. m	275	129	404	306	.984	2.25	....	104	....	102
12.45 p. m	275	124	404	304	.983	2	....	106	497	103
1 p. m	275	129	404	307	.984	2.25	80	106	....	103
1.15 p. m	275	128	404	307	.985	2	....	108	497	104
1.30 p. m	275	130	404	307	.984	2	....	109	....	104
1.45 p. m	275	123	404	307	.985	2.5	....	109	495	105
2 p. m	275	122	404	306	.984	2.5	82	110	....	106
2.15 p. m	275	130	404	308	.985	2	....	109	497	106
2.30 p. m	275	136	404	307	.984	2.13	....	111	....	106
2.45 p. m	275	124	404	307	.985	2.13	....	112	497	107
3 p. m	275	132	404	306	.984	2	82	111	....	108
3.15 p. m	275	130	404	307	.984	2	....	109	500	108
3.30 p. m	275	130	404	307	.985	2.13	....	112	....	108
3.45 p. m	275	130	404	307	.984	2.25	....	110	502	108
4 p. m	275	124	404	307	.985	2.25	82	111	....	109
4.15 p. m	275	129	404	307	.984	2.5	....	114	500	110
4.30 p. m	275	130	404	306	.984	2.25	....	112	....	110
4.45 p. m	275	122	404	307	.985	2.5	....	112	505	110
5 p. m	275	122	404	307	.984	2.5	82	114	....	111
Average	275	128.5	....	....	.984	....	79	106	503.6	102.5

State of weather, bright sun, no clouds.
Barometer at noon, 29.70 inches.
Kind of fuel, Beaumont oil.
Revolutions of Root blower, 100 per minute.
Draft openings into furnace, 124 square inches.

water-tube marine boiler June 26, 1902.

natural draft, using air burners.]

Air from Root blower, pressure per square inch.	Draft pressures in inches of water.				Flue gases.			Oil.		Water.	
	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Burned per hour.	Total weight burned.	Fed per hour.	Total weight fed.
Lbs.					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
0.73	−0.15	−0.15	−0.25	−0.35	....	....	....	0	0	0	0
.73	− .15	− .15	− .25	− .35	6.5	11.5	0.2	....	....	....	....
.73	− .15	− .15	− .25	− .40	....	....	....	....	....	....	....
.67	− .15	− .15	− .25	− .35	6.4	11	.6	....	....	....	....
.67	− .15	− .15	− .25	− .35	....	....	....	786	786	9,503	9,503
.79	− .15	− .15	− .25	− .35	6.6	10	1.3	....	....	....	....
.79	− .15	− .15	− .25	− .35	....	....	....	....	....	....	....
.73	− .15	− .15	− .25	− .35	6.6	10.2	.9	....	....	....	....
.73	− .15	− .20	− .25	− .35	....	....	....	748	1,534	9,061	18,564
.85	− .15	− .25	− .25	− .35	7.1	9.6	.6	....	....	....	....
.85	− .15	− .20	− .25	− .40	....	....	....	....	....	....	....
.85	− .15	− .20	− .25	− .35	7.8	9.6	.5	....	....	....	....
.85	− .15	− .20	− .25	− .35	....	....	....	759	2,293	9,537	28,101
.79	− .15	− .20	− .25	− .35	7	10.3	.6	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	....	....	....	....
.79	− .15	− .20	− .25	− .35	7.2	9.3	.9	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	751	3,044	9,895	37,996
.79	− .15	− .20	− .25	− .35	7.5	9.5	0	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	....	....	....	....
.79	− .15	− .20	− .25	− .35	7.8	9.7	0	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	765	3,809	10,066	48,062
.79	− .15	− .20	− .25	− .35	7.4	10.6	.3	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	....	....	....	....
.79	− .15	− .20	− .25	− .35	7	11.4	0	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	769	4,578	9,482	57,544
.79	− .15	− .20	− .25	− .35	7.8	10.2	.1	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	....	....	....	....
.79	− .15	− .20	− .25	− .35	7.5	10.5	.2	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	773	5,351	10,373	67,917
.79	− .15	− .20	− .25	− .35	7.8	9.9	.2	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	....	....	....	....
.79	− .15	− .20	− .25	− .35	7.8	9.9	.4	....	....	....	....
.79	− .15	− .20	− .25	− .35	....	....	....	771	6,122	10,083	78,000
.78	− .15	− .19	− .25	− .35	7.24	10.2	.425	765	....	9,750	....

A Brown quick-reading pyrometer placed on the floor of the furnace with the platinum fully exposed to the direct radiations from the flames registers 1,600° F. under the middle burners. At a point about 18 inches in front of the burner tip and 6 inches below its center line the temperature is 1,950° F. The corresponding temperatures for the side burners are about 100° lower. The flames reach for the most part to the middle of the combustion chamber. Only rarely do flames penetrate the tube chamber.

5.10 p. m. The smoke was very uniform throughout the test and so slight as to be barely visible. There are three irregular patches of carbon deposit, one on each side wall of the furnace and one on the back wall. The largest one, on the right side, is dome-shaped, and fully 4 inches thick in the center.

No. 4.—*Test of oil fuel in a Hohenstein*

[Three hours' duration, with forced

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.			
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.	Air from Root blower.
	Lbs.	Deg. F.	Deg. F.	Deg. F.		Ins.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
10 a. m	275	128	402	298	0.980	2	....	102	....	116
10.15 a. m	275	122	402	298	.980	1.75	80	103	760	119
10.30 a. m	275	120	402	300	.981	2	....	106	....	120
10.45 a. m	275	118	402	300	.981	2	....	108	785	121
11 a. m	275	116	402	300	.982	2.5	....	106	....	121
11.15 a. m	275	118	402	300	.981	2	82	107	835	122
11.30 a. m	275	118	402	300	.981	2	....	108	....	122
11.45 a. m	275	118	402	298	.980	1.75	....	109	875	122
12 m	275	120	402	298	.981	2	....	110	....	123
12.15 p. m	275	118	402	300	.982	2	82	111	917	124
12.30 p. m	275	116	402	300	.981	2	....	111	....	124
12.45 p. m	275	118	402	300	.981	1.75	....	111	950	126
1 p. m	275	118	402	300	.982	2	....	111	....	126
Average	275	119	....	....	.981	....	81	108	854	122

State of weather, bright sun, few clouds.
Barometer at noon, 29.94 inches.
Kind of fuel, Beaumont oil.
Revolutions of fan blower, 483 per minute.
Revolutions of Root blower, 219 per minute.
Draft openings into furnace, 666 square inches.

11.20 a. m.: Where the smoke is densest near the stack, it has a peculiar pale blue tint different from the smoke from a coal fire. It is the color of the smoke as seen against the dark background of the smoke itself—i. e., it is the color by reflected light. The phenomenon suggests that the particles of soot are much finer than in the smoke from coal. Generally the smoke is more like that from a coal fire.

No. 5.—*Test of oil fuel in a Hohenstein*

[Five hours' duration with

Time.	Steam pressure by guage	Temperature of feed water.	Calorimeter.			Height of water in gauge glass	Temperature.			
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.	Air from Root blower.
	Lbs.	Deg. F.	Deg. F.	Deg. F.		Ins.	Deg. F.	Deg. F.	Deg. F.	Deg. F.
10 a. m	275	....	405	308	0.985	2.75	82	100	....	107
10.15 a. m	275	130	404	308	.985	2.75	82	102	565	110
10.30 a. m	275	124	404	308	.985	2	83	106	....	112
10.45 a. m	275	123	404	309	.986	2.75	85	108	550	115
11 a. m	275	134	404	308	.985	2.25	86	109	....	116
11.15 a. m	275	118	404	308	.985	2.25	86	110	550	118
11.30 a. m	275	126	404	309	.985	3.25	87	110	....	118
11.45 a. m	275	125	404	309	.986	2.75	87	112	555	119
12 m	275	122	404	310	.987	2.75	87	113	....	120
12.15 p. m	275	132	404	310	.986	2.75	87	113	560	120
12.30 p. m	275	132	404	310	.986	2.5	88	115	....	121
12.45 p. m	275	127	404	310	.987	2.25	89	117	563	122
1 p. m	275	136	404	310	.986	2.75	89	118	....	123
1.15 p. m	275	140	404	310	.986	2.75	88	116	550	123
1.30 p. m	275	138	404	310	.987	2.75	88	114	....	123
1.45 p. m	275	136	404	310	.986	2.5	88	112	560	123
2 p. m	275	140	404	310	.986	2.5	87	112	....	123
2.15 p. m	275	110	404	310	.987	2.75	87	113	560	123
2.30 p. m	275	124	404	310	.986	2.75	87	116	....	124
2.45 p. m	275	136	404	310	.986	2.75	88	118	558	124
3 p. m	375	134	404	310	.987	2.75	88	114	....	126
Average	275	129	....	....	.986	....	87	112	557	120

State of weather, bright sunny day.
Barometer at noon, 30.13 inches.
Kind of fuel, Beaumont oil.
Revolutions of Root blower, 135.8 per minute.
Draft openings into furnace, 275 square inches.

water-tube marine boiler June 27, 1902.

draft, using air burners.]

Air from Root blower, pressure per square inch.	Draft pressures in inches of water.					Flue gases.			Oil.		Water.	
	Fire room.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Burned per hour.	Total weight burned.	Fed per hour.	Total weight fed.
Lbs.						%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
3.65	3.20	2.75	2	1.25	−0.35	......	......	......	0	0	0	0
3.65	3.20	2.75	2.10	1.25	− .35	6.7	11.5	0.5	....	....	....	....
3.65	3.20	2.75	2.10	1.25	− .35	......	......	......	....	....	....	....
3.41	3.20	2.75	2	1.25	− .35	6.9	11	.2	....	....	....	....
3.29	3.20	2.75	2.10	1.25	− .35	......	......	......	2,685	2,685	27,844	27,844
3.16	3.20	2.75	2	1.25	− .35	7.5	10.3	.2	....	....	....	....
3.29	3.20	2.75	2	1.25	− .35	......	......	......	....	....	....	....
3.29	3.20	2.50	2	1.25	− .40	8.1	9.8	.4	....	....	....	....
3.16	3.20	2.40	2	1.25	− .45	......	......	......	2,846	5,531	29,388	57,232
3.10	3.20	2.40	2	1.25	− .50	8	9.7	.2	....	....	....	....
3.16	3.30	2.40	2	1.25	− .50	......	......	......	....	....	....	....
3.41	3.40	2.40	2	1.25	− .50	7.7	10.1	.2	....	....	....	....
3.65	3.50	2.40	2	1.25	− .50	......	......	......	3,071	8,602	31,372	88,604
3.37	3.25	2.60	2.02	1.25	− .41	7.5	10.4	.3	2,867	....	29,535	....

11.43 a. m.: A pane of glass (southwest window), weakened by the direct radiations from a large red hot area of the casing about 3 feet away, blew out. A board was placed over the opening within fifteen seconds. About one-third of the casing opposite the combustion chamber on the southwest side of the boiler is red hot. Six bricks, fallen from the second baffle, lie on the floor of the combustion chamber. The Root blower engine crank pin got smoking hot, and a stream of water had to be played on it during the second half of the test. Water leaked from the feed stop valve, but was caught in a pail and returned to the feed tank.

1 p. m., end of test: There is very little caked carbon on the walls of the furnace. The second baffle is badly damaged. Average smoke during the test, 2.5 by Ringelmann charts. As the test progressed the amount of smoke gradually increased from 1 to 4, due, doubtless, to the short circuiting of the hot gases through the damaged baffle.

water-tube marine boiler August 2, 1902.

natural draft, using air burners.]

Air from Root blower pressure per square inch.	Draft pressures in inches of water.				Flue gases.			Oil.		Water.	
	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.	CO_2.	O.	CO.	Burned per hour.	Total weight burned.	Fed per hour.	Total weight fed.
Lbs.					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1.46	−0.2	−0.275	−0.30	−0.4	....	....	....	0	0	0	0
1.46	− .2	− .275	− .30	− .4	8.2	9.6	0	....	....	....	....
1.46	− .2	− .275	− .30	− .4	....	....	....	....	....	....	....
1.46	− .175	− .275	− .30	− .4	7.8	9.6	.3	....	....	....	....
1.46	− .175	− .275	− .33	− .4	....	....	....	984	984	11,531	11,531
1.40	− .175	− .275	− .32	− .4	7.8	9.9	.2	....	....	....	....
1.40	− .2	− .275	− .33	− .4	....	....	....	....	....	....	....
1.40	− .2	· .275	− .32	− .4	7.8	10.1	0	....	....	....	....
1.40	- .2	− .275	− .33	− .4	....	....	....	935	1,919	11,894	23,425
1.40	− .2	− .275	− .32	− .4	7.7	10.1	.1	....	....	....	....
1.40	− .2	− .3	− .33	− .4	....	....	....	....	....	....	....
1.40	− .2	− .3	− .32	− .4	7.9	9.6	.2	....	....	....	....
1.40	− .2	− .275	− .33	− .4	....	....	....	950	2,869	12,047	35,472
1.40	− .2	− .3	− .32	− .4	7.5	10.2	.1	....	....	....	....
1.40	− .2	− .3	− .28	− .4	....	....	....	....	....	....	....
1.40	− .2	− .3	− .25	− .4	7.7	10.5	.3	....	....	....	....
1.40	− .225	− .275	− .25	− .4	....	....	....	896	3,765	11,507	46,979
1.40	− .225	− .3	− .23	− .4	7.5	10.4	0	....	....	....	....
1.40	− .225	− .285	− .25	− .4	....	....	....	....	....	....	....
1.40	− .2	− .285	− .23	− .4	7.3	10.4	.1	....	....	....	....
1.40	− .225	− .3	− .22	− .4	....	....	....	903	4,668	11,550	58,529
1.41	− .201	− .284	− .29	− .4	7.7	10.0	.13	933.6	....	11,706	....

The casing and baffles have been overhauled and repaired since the last test (on June 27) and asbestos boards have been placed underneath the fire-brick floor of the furnace. All parts of the casing remained comparatively cool throughout the test.

Temperature in furnace over flames from middle burners, 2,200° F.

Smoke very uniform, averaging 0.4 by Ringelmann charts.

No. 6.—*Test of oil fuel in a Hohenstein water*

[Endurance test of 116 hours' duration

Date.	Watch.	Maximum and minimum values observed during each watch.									
		Steam pressure by gauge.	Temperature of feed water.	Quality of steam.	Height of water in gauge glass.	Temperature.				Root blower.	
						Outside air.	Air in fire room.	Gases at base of stack.	Air from Root blower.	Revolutions per minute.	Air pressure per square inch.
		Lbs.	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Lbs.*
Monday, Aug. 4	Noon to 4 p. m	275	127	0.986	3.50	93	121	558	122	98	1.34
		275	117	.984	2	88	110	550	106	85	85
	4 p. m. to midnight	275	119	.987	4	88	124	575	126	99	1.40
		275	116	.986	2	75	110	558	110	97	1.28
Tuesday, Aug. 5	Midnight to 8 a. m	275	122	.986	3	80	112	575	112	98	1.34
		275	117	.986	2	70	104	572	104	90	1.22
	8 a. m. to 4 p. m	275	122	.986	3.25	88	120	590	122	104	1.34
		275	112	.986	2.50	80	108	570	108	92	1.22
	4 p. m. to midnight	275	120	.987	2.75	88	120	590	122	100	1.34
		275	118	.986	2	80	116	585	118	97	1.34
Wednesday, Aug. 6	Midnight to 8 a. m	275	122	.987	3	82	116	610	118	104	1.40
		255	102	.985	2	73	104	585	107	84	1.22
	8 a. m. to 4 p. m	275	120	.987	5	95	125	610	122	104	1.34
		255	102	.985	2.50	73	108	565	112	91	1.16
	4 p. m. to midnight	275	130	.987	3.50	73	112	605	118	104	1.40
		270	112	.985	2.50	72	104	565	106	90	1.16
Thursday, Aug. 7	Midnight to 8 a. m	270	124	.987	3	74	116	598	114	100	1.40
		270	118	.986	2	69	107	590	110	92	1.22
	8 a. m. to 4 p. m	276	128	.987	4	90	116	600	114	100	1.40
		270	112	.985	2	74	108	585	108	95	1.22
	4 p. m. to midnight	275	124	.985	4	81	118	595	116	100	1.40
		270	110	.985	2	74	100	595	108	97	1.34
Friday, Aug. 8	Midnight to 8 a. m	275	124	.985	3.75	74	106	595	108	103	1.40
		265	119	.983	1.50	70	98	550	101	92	1.34
	8 a. m. to 4 p. m	274	128	.985	3.75	88	119	625	124	95	1.40
		272	114	.983	1.50	73	101	565	102	92	1.28
	4 p. m to midnight	274	125	.983	2.50	87	121	605	129	102	1.40
		271	116	.982	1.75	74	111	585	110	92	1.40
Saturday	Midnight to 8 a. m	275	128	.982	3	80	118	590	116	95	1.40
		273	120	.982	2	74	103	590	105	94	1.34
Average of hourly observations.		273	119.4	.985	......	79	112	585	113.5	96	1.31

Kind of fuel, Beaumont oil.
Draft openings into furnace, 348 square inches.

tube marine boiler August 4 to 9, 1902.

with natural draft, using air burners.]

Maximum and minimum values observed during each watch. Draft pressure in inches of water. Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.	Oil. Burned per hour and during watch.	Oil. Total weight burned.	Water. Fed per hour and during watch.	Water. Total weight fed.	Flue gases. Time sample was drawn.	CO_2.	O.	CO.	Height of barometer at mid-watch.	State of weather.
					Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*P. M.*	%	%	%	*Ins.*	
—0.25	—0.20	—0.30	—0.40	—0.40	818	......	9,942	....	1.45	7.4	10.8	0.1	29.99	
—.15	—.20	—.20	—.35	—.40	3,270	3,270	39,769	39,769	2	7.4	10.7	0		Clear.
—.20	—.20	—.30	—.40	—.45	864	......	10,580	....					29.82	
—.15	—.20	—.25	—.30	—.40	6,912	10,182	84,638	124,407						
—.20	—.25	—.33	—.40	—.50	826	......	10,133	....	*A. M.*				30.03	Clear.
—.13	—.20	—.28	—.33	—.45	6,608	16,790	81,064	205,471						
—.18	—.25	—.30	—.38	—.48	847	......	10,520	....	8.45	7.5	10.3	.1	30.00	Cloudy; thunderstorm.
—.15	—.20	—.27	—.35	—.40	6,773	23,563	84,156	289,627	9.15	7.6	10.2	0		
—.18	—.25	—.28	—.35	—.46	847	......	10,518	....					29.76	
—.17	—.22	—.25	—.33	—.40	6,772	30,335	84,148	373,775						
—.20	—.28	—.30	—.40	—.50	872	......	10,657	....					29.87	
—.15	—.25	—.25	—.33	—.45	6,974	37,309	85,253	459,028						Rain.
—.18	—.28	—.35	—.40	—.50	848	......	10,437	....	9.30	7.8	10.1	0	29.86	Thunderstorm.
—.13	—.22	—.30	—.35	—.45	6,780	44,089	83,495	542,523	10	7.8	10	0		
—.20	—.28	—.35	—.45	—.50	838	......	10,256	....					29.69	
—.13	—.23	—.28	—.40	—.48	6,704	50,793	82,044	624,567						
—.20	—.25	—.35	—.45	—.50	837	......	10,251	....					29.89	
—.18	—.23	—.30	—.40	—.50	6,694	57,487	82,007	706,574						
—.18	—.25	—.33	—.43	—.50	836	......	10,414	....	10.30	7.9	10.8	.3	29.98	Clear and cool.
—.15	—.23	—.30	—.40	—.48	6,687	64,174	83,315	789,889	10.45	7.8	10.1	.1		
—.20	—.25	—.33	—.40	—.48	820	......	10,140	....					29.77	
—.15	—.23	—.28	—.35	—.48	6,559	70,733	81,119	871,008						
—.20	—.25	—.35	—.45	—.50	819	......	10,151	....					29.89	
—.20	—.23	—.28	—.40	—.48	6,551	77,284	81,204	952,212						Clear; then partly cloudy.
—.20	—.25	—.33	—.40	—.50	816	......	10,127	....	9.30	7.8	9.7	0	29.91	
—.18	—.20	—.25	—.35	—.45	6,529	83,813	81,013	1,033,225	10	7.8	9.8	0		
—.19	—.22	—.31	—.40	—.48	809	......	10,145	....					29.81	
—.15	—.20	—.28	—.35	—.41	6,452	90,265	81,163	1,114,388						
—.18	—.22	—.30	—.40	—.43	782	......	9,762	....					30.05	Partly cloudy.
—.15	—.20	—.30	—.35	—.42	6,252	96,517	78,094	1,192,482	......	......	......	......		
—.17	—.23	—.30	—.36	—.46	832	......	10,280	....	Average.	7.68	10.25	.06	29.89	

No. 7.—*Test of oil fuel in a Hohenstein*

[Six hours duration with natural draft, but with

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.			
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.	Air from Root blower.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
10.15 a. m	265	116	390	305	0.989	1.5	73	95	....	124
10.30 a. m	265	114	390	312	.993	2	73	98	710	132
10.45 a. m	273	114	392	312	.992	3	74	100	....	138
11 a. m	274	120	392	314	.993	3	74	101	710	143
11.15 a. m	274	120	392	314	.993	2.5	75	104	....	148
11.30 a. m	274	119	392	314	.993	2.5	75	108	730	149
11.45 a. m	274	122	391	314	.993	2	76	111	....	154
12 m	274	120	390	314	.994	2	77	110	725	157
12.15 p. m	275	122	390	316	.995	3	77	114	....	158
12.30 p. m	275	122	390	316	.995	2.5	78	110	725	160
12.45 p. m	272	118	390	316	.995	2.5	78	113	....	160
1 p. m	275	120	390	316	.995	2	80	120	740	161
1.15 p. m	275	118	390	316	.995	2.5	79	120	....	160
1.30 p. m	275	120	390	316	.995	3	79	122	745	166
1.45 p. m	275	121	390	316	.995	3	80	126	....	168
2 p. m	275	120	390	316	.995	2.5	80	128	748	170
2.15 p. m	275	122	390	316	.995	2.5	78	130	....	170
2.30 p. m	276	122	390	316	.995	2.5	80	134	760	172
2.45 p. m	275	120	390	316	.995	2.5	80	135	....	173
3 p. m	275	120	390	318	.996	3	79	142	777	174
3.15 p. m	276	120	390	320	.997	3.5	79	138	....	175
3.30 p. m	276	120	390	320	.997	2.5	79	138	790	178
3.45 p. m	276	122	390	320	.997	2.5	79	135	....	176
4 p. m	276	120	390	320	.997	2.5	79	136	800	178
4.15 p. m	276	120	390	320	.997	2.5	79	133	....	178
Average	274	119.7	....	....	.995	....	77.6	120	747	161

State of weather, thin fleecy clouds.
Barometer at noon, 30.10 inches.
Kind of fuel, Beaumont oil.
Revolutions of Root blower, 246.7 per minute.
Draft openings into furnace, 642 square inches.

No. 8.—*Test of oil fuel in a Hohenstein*

[Three hours duration with

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.			
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.	Air from Root blower.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
11 a. m	277	120	384	298	0.987	1.5	80	110	....	132
11.15 a. m	278	120	384	298	.987	2	80	112	918	133
11.30 a. m	278	120	384	298	.987	2.5	80	112	....	133
11.45 a. m	278	128	385	298	.986	2	81	113	927	134
12 m	277	120	385	302	.989	2.5	81	113	....	134
12.15 p. m	278	118	386	306	.991	2.5	81	114	1,200	136
12.30 p. m	277	118	386	306	.991	2	82	115	....	136
12.45 p. m	277	118	386	306	.991	3	82	116	1,027	136
1 p. m	277	116	386	306	.991	2.5	82	117	....	138
1.15 p. m	278	118	386	302	.988	2	83	117	1,015	138
1.30 p. m	278	118	386	298	.986	2	83	117	....	138
1.45 p. m	277	114	386	302	.988	3	83	117	1,015	138
2 p. m	278	115	386	302	.988	2.5	84	118	....	138
Average	277.5	119	....	....	.988	....	82	115	1,017	136

State of weather, smoky; occasional clouds.
Barometer at noon, 30.08 inches.
Kind of fuel, Beaumont oil.
Revolutions of fan blower, 506.
Revolutions of Root blower, 248.
Draft openings into furnace, 642 square inches.

water-tube marine boiler, August 15, 1902.

the Root blower working at its maximum capacity.]

Air from Root blower, pressure per square inch.	Draft pressures in inches of water.					Flue gases.			Oil.		Water.	
	Furnace.	Combustion chamber.	Tube chamber.	Above tubes, below drums.	Base of stack.	CO_2.	O.	CO.	Burned per hour.	Total weight burned.	Fed per hour.	Total weight fed.
Lbs.						%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
4.63	−0.10	−0.15	−0.20	−0.35	−0.50				0	0	0	0
4.63	− .10	− .15	− .20	− .35	− .53	10.2	6.9	0.1				
4.63	− .10	− .13	− .18	− .35	− .52							
4.63	− .10	− .12	− .20	− .35	− .53	9.9	6.6	.5				
4.63	− .10	− .13	− .20	− .35	− .52				1,501	1,501	17,226	17,226
4.63	− .10	− .12	− .20	− .35	− .53	10	6.6	.2				
4.63	− .10	− .13	− .20	− .35	− .52							
4.63	− .10	− .12	− .20	− .35	− .53	10.2	6.4	.4				
4.63	0	− .13	− .20	− .35	− .52				1,477	2,978	17,383	34,609
4.63	0	− .12	− .20	− .35	− .53	9.7	6.6	.5				
4.63	− .10	− .13	− .20	− .35	− .52							
4.63	− .10	− .12	− .20	− .35	− .53	10	6.8	.2				
4.63	− .08	− .10	− .20	− .35	− .52				1,465	4,443	17,002	51,611
4.63	− .10	− .10	− .20	− .35	− .53	10.3	6.6	.1				
4.63	− .10	− .13	− .23	− .38	− .55							
4.63	− .10	− .12	− .20	− .37	− .55	9.8	7.1	.1				
4.63	− .10	− .13	− .20	− .38	− .55				1,566	6,009	17,639	69,250
4.63	− .10	− .12	− .20	− .37	− .58	9.8	7	.5				
4.75	− .10	− .13	− .23	− .38	− .57							
4.75	− .10	− .12	− .22	− .37	− .58	10.3	6.4	.3				
4.75	− .10	− .13	− .23	− .38	− .57				1,558	7.567	18,073	87,323
4.75	− .10	− .15	− .22	− .37	− .58	10.7	6.3	.2				
4.75	− .10	− .15	− .23	− .38	− .57							
4.75	− .10	− .15	− .22	− .37	− .58	10.4	6.4	.2				
4.75	− .10	− .15	− .23	− .38	− .57				1,522	9,089	17,673	104,996
4.66	− .09	− .13	− .21	− .36	− .54	10.1	6.64	.275	1,515		17,499	

The smoke varied from 0 to 1, averaging about 0.4 by Ringelmann charts.
Temperature near middle of furnace, 2,200° F.
Temperature of gases just after turning edge of first baffle, 2,090° F.
Toward the close of the test the temperature over the platform in the fire room reached 220° F., a serious objection to this method of forcing combustion.

water-tube marine boiler, August 20, 1902.

forced draft, using air burners.]

Air from Root blower, pressure per square inch.	Draft pressures in inches of water.					Flue gases.			Oil.		Water.	
	Fire room.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Burned per hour.	Total weight burned.	Fed per hour.	Total weight fed.
Lbs.						%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
4.68	Estimated from revolutions of fan.	3.2	2.3	1.8	−0.4				0	0	0	0
4.68		3.2	2.3	1.8	− .5	7.2	10.5	0.3				
4.68		3.3	2.3	1.8	− .5							
4.68		3.4	2.3	1.8	− .5	6.9	11.1	.3				
4.68		3.5	2.3	1.8	− .5				3,143	3,143	29,672	29,672
4.68		3.5	2.3	1.9	− .5	8.6	8.3	.2				
4.68		3.5	2.3	1.9	− .5							
4.68		3.5	2.3	1.9	− .5	8.1	9.4	0.0				
4.68		3.5	2.3	1.9	− .6				3,454	6,597	31,469	61,141
4.68		3.5	2.3	1.9	− .6	8.2	9.5	.3				
4.68		3.5	2.3	1.9	− .6							
4.68		3.5	2.3	1.9	− .6	8.2	9.2	.2				
4.68		3.5	2.3	1.9	− .6				3,312	9,909	32,244	93,385
4,68	3.75	3.4	2.3	1.86	−.53	7.87	9.66	.22	3,303		31,128	

Very thick black smoke throughout the test.
From 12.15 p. m. to end of test, continuous flaming in stack.
After test was over, 42 pounds of carbon were removed from furnace.

No. 9.—*Test of oil fuel in a Hohenstein*

[Six hours duration with natural

Time.	Steam pressure by gauge.	Temperature of feed water.	Colorimeter.			Height of water in gauge glass.	Temperature.			
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Oil in weighing tank.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
1.30 p. m	275	122	388	302	0.988	2.5	76	96	....	460
1.45 p. m	275	120	386	304	.989	2.75	77	95	....	....
2 p. m	275	119	386	306	.991	2.75	77	98	72.5	440
2.15 p. m	275	120	386	308	.992	2.5	77	98	....	....
2.30 p. m	274	134	386	308	.992	2.5	78	98	....	....
2.45 p. m	275	125	386	308	.992	2.5	79	99	....	....
3 p. m	275	130	386	308	.992	2.75	79	100	72	....
3.15 p. m	275	137	386	308	.992	2.75	77	99	....	....
3.30 p. m	275	140	386	308	.992	2.5	78	98	....	....
3.45 p. m	275	138	386	308	.992	2.75	77	99	....	....
4 p. m	275	137	386	303	.989	2.75	77	99	72	....
4.15 p. m	275	130	386	303	.989	3	77	100	....	....
4.30 p. m	275	136	386	303	.989	2.5	78	100	....	....
4.45 p. m	276	124	386	306	.991	2.5	76	99	....	450
5 p. m	275	118	384	306	.991	2.5	74	100	72	....
5.15 p. m	275	130	386	308	.992	2.75	74	99	....	445
5.30 p. m	275	120	386	308	.992	2.5	74	99	....	....
5.45 p. m	275	130	386	306	.991	2.5	74	98	....	....
6 p. m	275	130	386	306	.991	2.5	73	99	72	....
6.15 p. m	275	130	384	306	.991	2.5	72	98	....	....
6.30 p. m	275	120	384	306	.991	2.5	70	97	....	....
6.45 p. m	275	122	384	306	.991	2.5	70	96	....	....
7 p. m	275	122	384	306	.391	2.5	70	94	71	....
7.15 p. m	275	124	384	306	.991	2.5	70	94	....	....
7.30 p. m	275	120	386	306	.991	2.5	68	92	....	....
Average	275	127	....	....	.991	....	75	98	72	449

State of weather, partly cloudy.
Barometer at noon, 30.16 inches.
Kind of fuel, Beaumont oil.
Draft opening into furnace, 180 square inches.
Pressure in oil-pipe air chamber, 20.3 pounds.
Temperatcre over fire-room platform, average, 165° F, maximum 170° F.

water-tube marine boiler, September 12, 1902.

draft, using "Hayes" steam burners].

Pressure of steam used in spraying oil.	Draft pressures in inches of water.				Flue gases.			Oil burned.		Steam used by burners.		Feed water	
	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Per hour.	Total.	Per hour.	Total.	Per hour.	Total.
Lbs.					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
30	−0.20	−0.20	−0.20	−0.32	5.6	12.7	0.2	0	0	0	0	0	0
30	− .20	− .20	− .20	− .38	......	......	......	......	......	......	......	......	......
32	− .18	− .20	− .20	− .35	4.8	13.7	.3	......	......	......	......	......	......
32	− .19	− .20	− .22	− .33	......	......	......	......	......	......	......	......	......
32	− .20	− .20	− .20	− .32	......	......	......	572	572	456	456	6,702	6,702
33	− .18	− .20	− .22	− .38	......	......	......	......	......	......	......	......	......
33	− .21	− .20	− .20	− .38	......	......	......	......	......	......	......	......	......
32	− .20	− .20	− .20	− .38	......	......	......	......	......	......	......	......	......
32	− .20	− .20	− .20	− .38	......	......	......	601	1,173	402	858	7,311	14,013
32	− .20	− .20	− .20	− .35	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .20	− .35	......	......	......	......	......	......	......	......	......
31	− .20	− .20	− .20	− .35	......	......	......	......	......	......	......	......	......
32	− .20	− .20	− .20	− .38	......	......	......	602	1,775	553	1,311	7,241	21,254
32	− .20	− .20	− .20	− .40	6	12.8	.3	......	......	......	......	......	......
32	− .20	− .20	− .20	− .38	......	......	......	......	......	......	......	......	......
32	− .20	− .20	− .20	− .38	5.6	13	.3	......	......	......	......	......	......
32	− .21	− .21	− .21	− .40	......	......	......	590	2,365	459	1,770	7,480	28,734
32	− .22	− .21	− .21	− .40	......	......	......	......	......	......	......	......	......
32	− .22	− .21	− .21	− .40	......	......	......	......	......	......	......	......	......
32	− .22	− .21	− .21	− .40	......	......	......	......	......	......	......	......	......
32	− .22	− .21	− .21	− .40	......	......	......	639	3,004	295	2,065	7,691	36,425
32	− .22	− .21	− .21	− .41	......	......	......	......	......	......	......	......	......
32	− .22	− .21	− .21	− .41	......	......	......	......	......	......	......	......	......
32	− .22	− .21	− .21	− .41	......	......	......	......	......	......	......	......	......
32	− .22	− .21	− .21	− .41	......	......	......	596	3,600	459	2,524	7,336	43,761
32	−.205	−.204	−.205	− .38	5.5	13.05	.27	600	......	421	......	7,294	......

10.30 a. m. Started fires. The boilers were under steam yesterday and the water is already quite warm.

12.30 to 1.30 p. m. Data taken during this period shows about the same evaporative capacity as during the succeeding six hours. The smoke ranged from ½ to 1. Average ¾, by Ringelmann charts. A few ounces of carbon was deposited near the right-hand burner orifice. The burners made comparatively little noise, probably not more than a quarter as much as the compressed-air burners used in the preceding eight tests; but on the other hand, the flames were longer, reaching well into the tube chamber.

No. 10.—*Test of oil fuel in a Heohenstein water*

[Eight hours duration with natural

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.			
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Oil in weighing tank.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
10.30 a. m	275	118	380	308	0.994	2.75	62	90		
10.45 a. m	275	120	380	308	.994	2.75	63	91		600
11 a. m	275	118	380	308	.994	2.75	64	90	68	
11.15 a. m	275	118	380	308	.994	2.50	64	90		
11.30 a. m	275	115	380	308	.994	2.50	66	91		
11.45 a. m	275	118	380	309	.995	2.50	66	92		605
12 m	275	116	380	310	.995	2.50	67	99	68	
12.15 p. m	275	115	380	310	.995	3	67	99		
12.30 p. m	275	118	382	310	.995	2.50	68	100		
12.45 p. m	275	110	380	310	.995	2.50	68	101		600
1 p. m	275	112	380	310	.995	2.50	69	100	68	
1.15 p. m	275	118	380	310	.995	2.50	70	100		
1.30 p. m	275	120	380	310	.995	2.50	71	100		
1.45 p. m	275	120	384	310	.994	3	71	95		605
2 p. m	275	120	384	310	.994	3	71	98	68	
2.15 p. m	275	118	384	310	.994	3	70	98		
2.30 p. m	270	118	384	310	.994	2.50	70	96		
2.45 p. m	275	118	384	310	.994	2.50	70	96		580
3 p. m	275	120	384	310	.994	2.50	70	94	68	
3.15 p. m	275	122	384	310	.994	2.50	71	100		
3.30 p. m	275	120	384	310	.994	2.50	71	100		
3.45 p. m	275	120	384	310	.994	2.50	70	98		575
4 p. m	275	122	384	310	.994	3	70	94	68	
4.15 p. m	275	118	384	310	.994	2.50	70	98		
4.30 p. m	274	118	384	310	.994	2.50	70	102		
4.45 p. m	274	118	380	310	.995	2.50	70	110		595
5 p. m	275	118	380	310	.995	2.50	70	106	68	
5.15 p. m	275	120	380	310	.995	2.50	70	104		
5.30 p. m	274	120	380	310	.995	2.50	70	104		
5.45 p. m	274	120	380	310	.995	2.50	70	100		610
6 p. m	274	120	380	310	.995	2.50	70	100	69	
6.15 p. m	274	118	380	310	.995	2.50	70	104		
6.30 p. m	275	120	360	308	1.001	2.75	70	99		
Average	274.6	118.3			.995		69	98	68.1	596

State of weather, thin clouds.
Barometer at noon, 30.20 inches.
Kind of fuel, Beaumont oil.
Draft opening into furnace, 500 square inches.
Pressure in oil pipe air chamber, 20 pounds.
Temperature over fire-room platform, average 177° F., maximum 184° F.
Temperature of superheated steam for burners, 444.4° F.

tube marine boiler, September 19, 1902.

draft, using steam burners.]

Pressure of steam used in spraying oil.	Draft pressures, in inches of water.				Flue gases.			Oil burned.		Steam used by burners.		Feed water.	
	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Per hour.	Total.	Per hour.	Total.	Per hour.	Total.
Lbs.					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
28	−0.20	−0.15	−0.20	−0.60	......	......	......	0	0	0	0	0	0
29	− .18	− .18	− .20	− .60	7	10.6	0	......	......	......	......	......	......
30	− .20	− .20	− .20	− .60	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	983	983	475	475	11,181	11,181
29	− .20	− .20	− .30	− .60	7.1	11.1	0	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
31	− .20	− .20	− .30	− .60	......	......	......	968	1,951	365	840	11,143	22,324
30	− .20	− .20	− .30	− .60	7	11.2	.1	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	934	2,885	423	1,263	11,222	33,546
30	− .20	− .20	− .30	− .60	7	11.1	0	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	915	3,800	326	1,589	10,551	44,097
28	− .20	− .20	− .30	− .60	6.6	11.2	0	......	......	......	......	......	......
28	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
28	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
28	− .20	− .20	− .30	− .60	......	......	......	851	4,651	399	1,988	10,287	54,384
28	− .20	− .20	− .30	− .60	6.6	11.8	0	......	......	......	......	......	......
28	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .30	− .60	......	......	......	......	......	......	......	......	......
30	− .20	− .20	− .30	− .55	......	......	......	826	5,477	479	2,467	9,733	64,117
32	− .22	− .22	− .25	− .60	7.4	10.8	0	......	......	......	......	......	......
32	− .22	− .22	− .25	− .60	......	......	......	......	......	......	......	......	......
32	− .22	− .22	− .25	− .60	......	......	......	......	......	......	......	......	......
32	− .22	− .22	− .25	− .60	......	......	......	970	6,447	452	2,919	11,071	75,188
32	− .21	− .21	− .25	− .58	7.2	10.6	0	......	......	......	......	......	......
32	− .21	− .20	− .25	− .58	......	......	......	......	......	......	......	......	......
31	− .20	− .20	− .28	− .58	......	......	......	......	......	......	......	......	......
29	− .20	− .20	− .28	− .58	......	......	......	913	7,360	493	3,412	10,603	85,791
29.9	− .202	− .201	− .281	− .596	6.99	11.05	.013	920	......	427	......	10,724	......

The angular setting of the side burners is changed so as to direct their flames more toward the center of the furnace. Heretofore the side walls of the furnace have absorbed an undue amount of heat as shown by their glow after extinguishing the burners.

Curved sheet-iron deflectors have been placed in what were formerly the ash pit openings, so as to direct the entering air upward at an angle against the flames.

The smoke averages about ¼, the maximum being ½, by Ringelmann charts.

A disk of carbon 9 inches in diameter was deposited on the back wall opposite the center burners.

The burners make much less noise than those made by the same builders using air.

No. 11.—*Test of oil fuel in a Hohenstein water*

[Eight hours duration with natural

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.			
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Oil in weighing tank.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9 a. m	270	118	380	306	0.993	3	66	93	....	....
9.15 a. m	276	118	384	308	.993	3	70	94	....	....
9.30 a. m	271	120	380	308	.994	3	72	96	68	635
9.45 a. m	273	120	382	308	.993	3	74	98	....	....
10 a. m	269	120	380	308	.994	2	76	100	....	....
10.15 a. m	273	120	384	310	.994	2.5	78	100	....	....
10.30 a. m	277	118	384	310	.994	2.5	80	104	68	640
10.45 a. m	277	118	384	310	.994	2.5	80	106	....	....
11 a. m	276	120	384	310	.994	2.5	80	106	....	....
11.15 a. m	277	120	380	310	.995	2.5	80	106	....	....
11.30 a. m	275	118	380	310	.995	2.5	80	104	68	645
11.45 a. m	276	120	384	310	.994	2.5	80	106	....	....
12 m	276	120	384	310	.994	2.5	80	104	....	....
12.15 p. m	273	120	380	310	.995	2.5	80	106	....	....
12.30 p. m	276	120	380	310	.995	2.5	80	106	68	630
12.45 p. m	277	122	380	310	.995	2.5	80	106	....	....
1 p. m	277	124	382	310	.994	2.5	80	108	....	....
1.15 p. m	275	120	383	310	.994	2.5	78	108	....	....
1.30 p. m	276	122	383	310	.994	2.5	76	110	68	620
1.45 p. m	278	122	383	310	.994	2.5	76	110	....	....
2 p. m	274	124	383	310	.994	2.5	76	110	....	....
2.15 p. m	275	122	383	310	.994	3	76	108	....	....
2.30 p. m	275	122	380	310	.995	2.75	76	108	68	615
2.45 p. m	277	122	380	310	.995	2.75	78	108	....	....
3 p. m	275	120	380	310	.995	3	78	108	....	....
3.15 p. m	278	120	380	310	.995	2.5	78	98	....	....
3.30 p. m	277	120	380	310	.995	2.5	78	108	68	620
3.45 p. m	277	120	380	310	.995	2.5	78	110	....	....
4 p. m	273	120	380	310	.995	2.5	78	110	....	....
4.15 p. m	277	120	380	310	.895	2.5	78	112	....	....
4.30 p. m	274	118	380	310	.995	2.5	78	112	68	620
4.45 p. m	276	120	380	310	.995	2.5	78	111	....	....
5 p. m	276	118	380	310	.995	3	78	110	....	....
Average	275.2	120.2	....	....	.994	....	77	106	68	628

State of weather, thin clouds.
Barometer at noon, 30.18 inches.
Kind of fuel, Beaumont oil.
Draft opening into furnace, 500 square inches.
Pressure in oil pipe air chamber, 30 pounds.
Temperature over fire room platform, average 182° F., maximum 188° F.

tube marine boiler, September 20, 1902.

draft, using steam burners.]

Pressure of steam used in spraying oil.	Draft pressures, in inches of water.				Flue gases.			Oil burned.		Steam used by burners.		Feed water.	
	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Per hour.	Total.	Per hour.	Total.	Per hour.	Total.
Lbs.					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
60	−0.14	−0.20	−0.27	−0.53	......	......	......	0	0	0	0	0	0
60	− .14	− .20	− .27	− .54	......	......	......	......	......	......	......	......	......
60	− .14	− .20	− .29	− .50	7.4	10.6	0.1	......	......	......	......	......	......
60	− .14	− .18	− .25	− .52	......	......	......	......	......	......	......	......	......
62	− .14	− .19	− .26	− .52	......	......	......	1,040	1,040	578	578	12,117	12,117
62	− .14	− .19	− .28	− .52	......	......	......	......	......	......	......	......	......
62	− .14	− .18	− .27	− .52	7.6	10	.3	......	......	......	......	......	......
61	− .14	− .19	− .26	− .50	......	......	......	......	......	......	......	......	......
61	− .14	− .19	− .29	− .52	......	......	......	1,087	2,127	523	1,101	12,391	24,508
62	− .14	− .20	− .28	− .53	......	......	......	......	......	......	......	......	......
62	− .14	− .20	− .28	− .53	7.6	10.8	0	......	......	......	......	......	......
62	− .14	− .20	− .25	− .53	......	......	......	......	......	......	......	......	......
62	− .14	− .20	− .28	− .53	......	......	......	1,056	3,183	526	1,627	12,550	37,058
64	− .14	− .20	− .28	− .53	......	......	......	......	......	......	......	......	......
65	− .14	− .20	− .28	− .53	......	......	......	......	......	......	......	......	......
64	− .14	− .20	− .28	− .53	......	......	......	......	......	......	......	......	......
62	− .14	− .20	− .28	− .53	......	......	......	1,037	4,220	554	2,181	12,072	49,130
62	− .14	− .20	− .28	− .53	......	......	......	......	......	......	......	......	......
61	− .14	− .20	− .28	− .53	7.8	10.2	0	......	......	......	......	......	......
61	− .14	− .20	− .28	− .53	......	......	......	......	......	......	......	......	......
61	− .14	− .20	− .28	− .53	......	......	......	1,022	5,242	558	2,739	12,082	61,212
60	− .14	− .20	− .25	− .53	......	......	......	......	......	......	......	......	......
60	− .14	− .20	− .25	− .53	7.1	11.1	.2	......	......	......	......	......	......
60	− .14	− .20	− .25	− .53	......	......	......	......	......	......	......	......	......
60	− .14	− .20	− .25	− .53	......	......	......	991	6,233	472	3,211	11,771	72,983
60	− .14	− .20	− .27	− .53	......	......	......	......	......	......	......	......	......
60	− .14	− .20	− .27	− .53	7.0	11.2	0	......	......	......	......	......	......
60	− .14	− .19	− .28	− .54	......	......	......	......	......	......	......	......	......
60	− .14	− .20	− .28	− .55	......	......	......	1,013	7,246	593	3,804	11,635	84,618
61	− .14	− .20	− .28	− .55	......	......	......	......	......	......	......	......	......
62	− .14	− .19	− .29	− .54	7.8	10.7	0	......	......	......	......	......	......
62	− .13	− .19	− .28	− .53	......	......	......	......	......	......	......	......	......
62	− .14	− .20	− .28	− .53	......	......	......	1,011	8,257	448	4,252	11,838	96,456
61.4	− .140	− .197	− .279	− .529	7.47	10.66	.086	1,032	......	532	......	12,057	......

Temperature of superheated steam for burners, 408.2° F.
The angular setting of the burners and the deflectors for the entering air are the same as yesterday. (See Test No. 10.)
The smoke averages ¼, the maximum being ½, by Ringelmann charts.
The deposit of carbon was slight and fairly uniform across the back wall of the furnace.

No. 12.—*Test of oil fuel in a Hohenstein water*

[Eight hours duration with natural

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.			
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Oil in weighing tank.	Gases at base of stack.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9 a. m	277	118	380	310	0.995	2.5	70	99	....	....
9.15 a. m	276	120	382	310	.995	2.5	72	102	....	....
9.30 a. m	276	120	380	310	.995	2.5	72	100	68	665
9.45 a. m	278	120	380	310	.995	3	72	99	....	....
10 a. m	277	118	380	310	.995	3	73	100	....	....
10.15 a. m	277	120	380	310	.995	2.5	73	100	....	....
10.30 a. m	278	120	380	310	.995	2.5	73	100	68	660
10.45 a. m	278	120	380	310	.995	3	74	100	....	....
11 a. m	277	118	380	310	.995	2.75	74	100	....	....
11.15 a. m	277	120	380	310	.995	3	74	98	....	....
11.30 a. m	275	120	380	310	.995	2.5	74	102	69	655
11.45 a. m	275	120	380	310	.995	2.25	75	104	....	....
12 m	275	120	380	310	.995	2.75	76	104	....	....
12.15 p. m	276	118	380	310	.995	2.75	78	102	....	....
12.30 p. m	275	118	380	310	.995	2.5	78	104	68	660
12.45 p. m	278	120	380	310	.995	3	79	106	....	....
1 p. m	278	120	380	310	.995	2.5	78	104	....	....
1.15 p. m	275	120	380	310	.995	3	80	104	....	....
1.30 p. m	275	120	380	310	.995	3	80	104	68	665
1.45 p. m	276	120	380	310	.995	4	80	105	....	....
2 p. m	273	120	378	310	.996	2.75	82	104	....	....
2.15 p. m	275	120	380	310	.995	2.5	82	105	....	....
2.30 p. m	275	120	380	310	.995	2	82	106	68	650
2.45 p. m	275	120	380	310	.995	2	82	104	....	....
3 p. m	273	120	380	310	.995	2.25	80	105	....	....
3.15 p. m	275	120	380	310	.995	2.5	80	108	....	....
3.30 p. m	275	118	380	310	.995	2.75	80	106	68	670
3.45 p. m	273	118	380	310	.995	2.5	80	106	....	....
4 p. m	275	120	380	310	.995	2.5	80	106	....	....
4.15 p. m	272	120	380	310	.995	3	80	105	....	....
4.30 p. m	275	120	380	310	.995	3	80	106	68	660
4.45 p. m	275	120	380	310	.995	2.5	79	106	....	....
5 p. m	277	120	380	310	.995	2.5	78	110	....	....
Average	275.7	119.6	....	....	.995	....	77	103	68.1	661

State of weather, partly cloudy.
Barometer at noon, 30.05 inches.
Kind of fuel, Beaumont oil.
Draft opening into furnace, 500 square inches.
Pressure in oil pipe air chamber, 45 pounds.
Temperature over fire-room platform, average 192° F., maximum 200° F.

tube marine boiler, September 22, 1902.

draft, using steam burners.]

Pressure of steam used in spraying oil.	Draft pressures, in inches of water.				Flue gases.			Oil burned.		Steam used by burners.		Feed water.	
	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Per hour.	Total.	Per hour.	Total.	Per hour.	Total.
Lbs.					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
90	−0.14	−0.15	−0.22	−0.52	......	......	......	0	0	0	0	0	0
90	− .14	− .13	− .22	− .53	......	......	......	......	......	......	......	......	......
90	− .14	− .14	− .21	− .53	8.6	9	0.2	......	......	......	......	......	......
90	− .14	− .13	− .21	− .52	......	......	......	......	......	......	......	......	......
90	− .14	− .15	− .21	− .53	......	......	......	1,157	1,157	635	635	13,375	13,375
92	− .14	− .17	− .21	− .54	......	......	......	......	......	......	......	......	......
92	− .14	− .16	− .22	− .53	9	8.7	.3	......	......	......	......	......	......
91	− .14	− .16	− .21	− .53	......	......	......	......	......	......	......	......	......
92	− .14	− .16	− .21	− .53	......	......	......	1,147	2,304	740	1,375	13,425	26,800
93	− .14	− .16	− .21	− .53	......	......	......	......	......	......	......	......	......
93	− .14	− .16	− .21	− .53	8.5	9.3	.2	......	......	......	......	......	......
93	− .14	− .16	− .21	− .53	......	......	......	......	......	......	......	......	......
93	− .15	− .16	− .21	− .53	......	......	......	1,115	3,419	747	2,122	13,109	39,909
90	− .15	− .17	− .21	− .53	......	......	......	......	......	......	......	......	......
90	− .14	− .17	− .21	− .53	8.2	9.5	0	......	......	......	......	......	......
92	− .14	− .17	− .21	− .53	......	......	......	......	......	......	......	......	......
91	− .14	− .17	− .21	− .53	......	......	......	1,112	4,531	509	2,631	13,112	53,021
91	− .14	− .17	− .21	− .53	......	......	......	......	......	......	......	......	......
90	− .14	− .17	− .21	− .53	8.5	9.5	0	......	......	......	......	......	......
90	− .14	− .17	− .21	− .53	......	......	......	......	......	......	......	......	......
90	− .14	− .17	− .21	− .53	......	......	......	1,125	5,656	710	3,341	13,433	66,454
90	− .14	− .17	− .21	− .53	......	......	......	......	......	......	......	......	......
90	− .14	− .17	− .21	− .53	7.5	10.1	.2	......	......	......	......	......	......
90	− .14	− .17	− .21	− .53	......	......	......	......	......	......	......	......	......
90	− .14	− .18	− .21	− .53	......	......	......	1,066	6,722	821	4,162	12,548	79,002
90	− .14	− .17	− ,21	− .53	......	......	......	......	......	......	......	......	......
90	− .14	− .17	− .21	− .54	8.6	8.6	0	......	......	......	......	......	......
91	− .14	− .17	− .21	− .53	......	......	......	......	......	......	......	......	......
92	− .14	− .17	− .21	− .53	......	......	......	1,167	7,889	538	4,700	13,810	92,812
91	− .15	− .18	− .21	− .53	......	......	......	......	......	......	......	......	......
89	− .15	− .18	− .21	− .53	8.6	9.6	.2	......	......	......	......	......	......
88	− .15	− .17	− .21	− .53	......	......	......	......	......	......	......	......	......
89	− .15	− .17	− .21	− .53	......	......	......	1,085	8,974	605	5,305	12,735	105,547
91	− .142	− .164	− .211	− .530	8.44	9.29	.014	1,122	......	663	......	13,193	......

Temperature of superheated steam for burners, 401° F.
Setting of burners and deflectors unchanged. (See Test No. 10.)
The smoke averages 3/8, the maximum being 1/2, by Ringelmann charts.
No increase in the deposit of carbon.
Blew down boiler. Much mud in the water; also considerable soot among the tubes and on the baffles.

No. 13.—*Test of oil fuel in a Hohenstein*

[Eight hours duration with natural draft,

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.					
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.	Air from Root blower.	Superheated steam for burners.	Oil in weighing tank.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
10 a. m	275	114	380	310	0.995	2.5	76	95	....	110	356	....
10.15 a. m	275	116	380	310	.995	3	76	95	....	112	360	....
10.30 a. m	275	116	382	312	.996	2.5	78	94	605	112	360	72
10.45 a. m	283	122	382	312	.996	3	80	92	....	112	362	....
11 a. m	278	126	382	312	.996	3.5	80	97	....	112	350	....
11.15 a. m	279	122	382	312	.996	3.25	82	98	....	111	352	....
11.30 a. m	276	130	378	312	.997	2.5	82	96	600	112	352	72
11.45 a. m	279	128	380	312	.996	3.25	78	102	....	112	352	....
12 m	279	126	380	312	.996	2.5	78	98	....	112	356	....
12.15 p. m	279	118	380	312	.996	3	78	98	....	113	358	....
12.30 p. m	279	120	380	312	.996	2.5	78	98	600	113	358	72
12.45 p. m	279	120	380	312	.996	2.75	80	100	....	114	380	....
1 p. m	279	128	380	312	.996	2.75	80	100	....	114	380	....
1.15 p. m	279	124	380	310	.995	2.75	80	100	....	114	380	....
1.30 p. m	278	120	378	312	.997	2.5	82	100	570	115	386	72
1.45 p. m	277	120	378	312	.997	2.5	80	99	....	115	382	....
2 p. m	277	124	378	312	.997	2.5	82	98	....	116	380	....
2.15 p. m	277	122	376	310	.997	2.5	90	99	....	116	380	....
2.30 p. m	278	120	376	310	.997	2.5	90	100	565	116	380	72
2.45 p. m	278	120	378	310	.996	2.5	90	102	....	116	382	....
3 p. m	278	120	378	312	.997	2.75	92	102	....	116	384	....
3.15 p. m	277	120	378	310	.996	2.5	84	103	....	116	384	....
3.30 p. m	279	120	378	310	.996	2.5	82	103	560	116	384	72
3.45 p. m	278	120	378	310	.996	2.75	80	102	....	116	386	....
4 p. m	279	124	378	312	.997	2.75	80	104	....	116	386	....
4.15 p. m	279	122	380	310	.995	2.75	80	102	....	115	388	....
4.30 p. m	279	128	380	310	.995	3	79	100	580	115	386	72
4.45 p. m	278	120	376	310	.997	2.75	78	102	....	114	382	....
5 p. m	277	126	378	310	.996	2.5	78	104	....	113	380	....
5.15 p. m	279	120	378	310	.996	3	78	99	....	114	385	....
5.30 p. m	279	128	378	310	.996	2.75	76	100	540	114	388	73
5.45 p. m	279	118	378	310	.996	3	74	98	....	116	396	....
6 p. m	279	120	378	310	.996	2	74	99	....	114	398	....
Average.	278.2	121.9	....	....	.996	....	80.4	99.4	578	114	375	72.1

State of weather, fair.
Barometer at noon, 29.92 inches.
Kind of fuel, Beaumont oil.
Revolutions of Root blower, 215 per minute.
Draft opening into furnace in square inches, average, 165; maximum, 204; minimum, 114.
Temperature over fire-room platform, maximum, 182° F.; average, 179° F.
Pressure in oil system at air chamber, 20 pounds.
Very little smoke; at times none.

water-tube marine boiler, September 27, 1902.

using "Reed" air and steam burners.]

Pressures per square inch.		Draft pressure in inches of water.				Flue gases.			Oil burned.		Steam used by burners.		Feed water	
Air from Root blower.	Steam for burners.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Per hour.	Total.	Per hour.	Total.	Per hour.	Total.
Lbs.	*Lbs.*					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1.61	90	−0.15	−0.15	−0.20	−0.45	......	......	......	0	0	0	0	0	0
1.61	93	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.61	93	− .15	− .15	− .20	− .45	8.7	8.7	0	......	......	......	......	......	......
1.58	95	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.61	93	− .15	− .15	− .20	− .45	......	......	......	1,051	1,051	967	967	12,943	12,943
1.46	94	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.61	95	− .15	− .15	− .20	− .45	7.5	10.3	.2	......	......	......	......	......	......
1.61	95	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.46	95	− .15	− .15	− .20	− .45	......	......	......	972	2,023	984	1,951	11,778	24,721
1.61	92	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.61	92	− .15	− .15	− .20	− .45	8.0	9.6	0	......	......	......	......	......	......
1.61	92	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.61	92	− .15	− .15	− .20	− .45	......	......	......	1,006	3,029	1,042	2,993	12,239	36,960
1.61	91	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.46	92	− .15	− .15	− .20	− .45	8.2	9.4	0	......	......	......	......	......	......
1.46	91	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.46	91	− .15	− .15	− .20	− .45	......	......	......	1,002	4,031	696	3,689	12,078	49,038
1.46	90	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.46	90	− .15	− .15	− .20	− .45	7.8	9.8	0	......	......	......	......	......	......
1.46	90	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.46	90	− .15	− .15	− .20	− .45	......	......	......	970	5,001	626	4,315	11,936	60,974
1.46	90	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.46	92	− .15	− .15	− .20	− .45	7.4	11	.2	......	......	......	......	......	......
1.46	91	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.46	90	− .15	− .15	− .20	− .45	......	......	......	920	5,921	596	4,911	11,348	72,322
1.46	91	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.46	91	− .15	− .15	− .20	− .45	7	9.2	.2	......	......	......	......	......	......
1.46	90	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.46	92	− .15	− .15	− .20	− .45	......	......	......	907	6,828	490	5,401	11,145	83,467
1.46	92	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.36	92	− .15	− .15	− .20	− .45	7	10.8	0	......	......	......	......	......	......
1.46	90	− .15	− .15	− .20	− .45	......	......	......	......	......	......	......	......	......
1.34	90	− .15	− .15	− .20	− .45	......	......	......	864	7,692	455	5,856	11,928	95,395
1.51	92	− .15	− .15	− .20	− .45	7.70	9.85	.075	962	......	732	......	11,924	......

The front wall of the furnace has been rebuilt and now has openings 8 inches in diameter for the burners. This provides an annular opening for the admission of atmospheric air around each burner.

September 26: A preliminary run of 9 hours was made with a bridge wall built across the furnace 9 inches from the back wall and up to within 9 inches of the lower row of tubes. The wall was hollow and had perforations in front, its object being to introduce heated air at the back of the furnace. The front of the wall was in the form of 4 steps, each 8 inches high. The wall proved to be too high, choking the draft. In preparation for the trial of September 27, the top step was removed; also, to reduce loss by downward radiation of heat, inclined sheets of asbestos were laid on the lowest step of the bridge wall, the sheets extending to the front of the furnace.

September 27: At the end of the test there was a deposit of carbon about 9 inches in diameter on the bridge wall opposite the right burners. The perforations in the bridge wall were partially choked with slag melted out of the brickwork.

No. 14.—*Test of oil fuel in a Hohenstein*

[Eight hours duration with natural draft,

Time.	Steam pressure by gauge.	Temperature of feed water.	Calorimeter.			Height of water in gauge glass.	Temperature.					
			Higher temperature.	Lower temperature.	Quality of steam.		Outside air.	Air in fire room.	Gases at base of stack.	Air from Root blower.	Superheated steam for burners.	Oil in weighing tank.
	Lbs.	*Deg. F.*	*Deg. F.*	*Deg. F.*		*Ins.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
9.15 a. m	279	120	380	312	0.996	2.5	76	98	....	112	400	....
9.30 a. m	279	120	380	313	.997	2.5	78	101	685	111	390	74
9.45 a. m	279	120	376	314	.999	3	79	102	....	112	404	....
10 a. m	279	112	380	312	.996	2	80	105	....	113	410	....
10.15 a. m	279	122	380	313	.997	2.5	82	106	....	114	386	....
10.30 a. m	279	126	380	312	.996	2.5	82	104	645	114	360	74
10.45 a. m	279	120	380	314	.997	2.75	82	108	....	114	354	....
11 a. m	279	120	378	314	.998	2.5	82	108	....	114	368	....
11.15 a. m	279	120	380	314	.997	2.5	84	109	....	115	370	....
11.30 a. m	279	120	380	314	.998	2.5	86	110	660	115	370	74
11.45 a. m	279	120	380	314	.997	3	86	111	....	116	363	....
12 m	279	120	380	314	.998	2.5	84	110	....	116	364	....
12.15 p. m	278	124	376	314	.999	2.5	84	112	....	117	430	....
12.30 p. m	279	120	376	314	.999	3	84	110	645	116	456	74
12.45 p. m	278	124	376	314	.999	2.5	84	111	....	117	476	....
1 p. m	279	120	376	314	.999	2.5	84	111	....	118	480	....
1.15 p. m	279	120	376	314	.999	2.75	85	112	....	118	484	....
1.30 p. m	279	124	376	314	.999	2.5	84	114	600	118	476	74
1.45 p. m	279	124	376	314	.999	2.5	84	113	....	118	480	....
2 p. m	279	120	376	314	.999	2.5	84	114	....	119	460	....
2.15 p. m	279	120	376	314	.999	3	92	114	....	120	460	....
2.30 p. m	279	124	376	314	.999	3	90	115	630	120	454	74
2.45 p. m	279	120	376	314	.999	2.75	90	118	....	120	450	....
3 p. m	279	120	376	314	.999	2.5	92	118	....	120	430	....
3.15 p. m	279	122	376	314	.999	2.5	92	118	....	120	420	....
3.30 p. m	278	120	376	314	.999	2	93	114	655	120	420	74
3.45 p. m	278	120	376	314	.999	2.5	96	116	....	121	420	....
4 p. m	279	120	378	316	.999	2.25	96	116	....	122	410	....
4.15 p. m	279	122	378	316	.999	2.5	92	114	....	122	380	....
4.30 p. m	279	120	378	316	.999	2.5	86	116	640	122	390	74
4.45 p. m	279	120	378	316	.999	3	83	116	....	122	408	....
5 p. m	279	124	378	316	.999	3	82	116	....	122	406	....
5.15 p. m	279	120	378	316	.999	2.5	80	118	....	122	402	....
Average.	278.9	120.8	....	....	.998	....	85.4	111.5	645	117.5	416	74

State of weather, clear.
Barometer at noon, 29.96 inches.
Kind of fuel, Beaumont oil.
Revolutions of Root blower, 239 per minute, of which 52 were required by burner in auxiliary boiler.
Draft openings into furnace, 664 square inches until 10.30 a. m., then 408 square inches.
Temperature over fire room platform, maximum 196° F., average 187° F.
Pressure in oil system at air chamber, 20 pounds.
Average smoke, ¼; maximum, ½ by Ringelmann charts.

water-tube marine boiler, September 29, 1902.

using "Reed" air and steam burners.]

Pressures per square inch.		Draft pressure in inches of water.				Flue gases.			Oil burned.		Steam used by burners.		Feed water.	
Air from Root blower.	Steam for burners.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	CO_2.	O.	CO.	Per hour.	Total.	Per hour.	Total.	Per hour.	Total.
Lbs.	*Lbs.*					%	%	%	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1.46	90	−0.05	−0.1	−0.2	−0.5	......	......	......	0	0	0	0	0	0
1.46	88	− .05	− .1	− .2	− .5	8.3	9.7	0	......	......	......	......	......	......
1.34	92	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.46	93	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.41	93	− .1	− .1	− .2	− .5	......	......	......	1,143	1,143	808	808	13,572	13,572
1.41	92	− .1	− .1	− .2	− .5	8.3	8.5	0	......	......	......	......	......	......
1.46	90	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.46	90	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.46	90	− .1	− .1	− .2	− .5	......	......	......	1,194	2,337	670	1,478	14,376	27,948
1.46	90	− .1	− .1	− .2	− .5	8.6	8.8	0	......	......	......	......	......	......
1.41	90	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.46	90	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.21	93	− .1	− .1	− .2	− .5	......	......	......	1,133	3,470	684	2,162	13,971	41,919
1.21	94	− .1	− .1	− .2	− .5	8.5	9.4	.1	......	......	......	......	......	......
1.21	92	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.21	86	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.21	88	− .1	− .1	− .2	− .5	......	......	......	1,145	4,615	281	2,443	14,108	56,027
1.46	88	− .1	− .1	− .2	− .5	8.4	9	0	......	......	......	......	......	......
1.46	87	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.46	87	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.46	87	− .1	− .1	− .2	− .5	......	......	......	1,157	5,772	370	2,813	14,192	70,219
1.46	87	− .1	− .1	− .2	− .5	8.4	9.4	.2	......	......	......	......	......	......
1.21	88	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.21	86	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.21	86	− .1	− .1	− .2	− .5	......	......	......	1,133	6,905	332	3,145	13,640	83,859
1.21	87	− .1	− .1	− .2	− .5	8.6	8.9	0	......	......	......	......	......	......
1.21	86	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.34	88	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.46	90	− .1	− .1	− .2	− .5	......	......	......	1,196	8,101	633	3,778	14,284	98,143
1.46	90	− .1	− .1	− .2	− .5	9.1	8.6	.1	......	......	......	......	......	......
1.46	90	.1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.46	91	− .1	− .1	− .2	− .5	......	......	......	......	......	......	......	......	......
1.34	90	− .1	− .1	− .2	− .5	......	......	......	1,115	9,216	680	4,458	13,972	112,115
1.37	89	− .097	− .10	− .20	− .50	8.53	9.04	.05	1,152	......	557	......	14,014	......

Before beginning this test another step of 8 inches was removed from the top of the bridge wall, and brick uptakes were built in the furnace so as to lead the air from the old ash pit openings vertically upward to the burners.

During the test the quantity of steam used in the burners was the least permissible, i. e., a further reduction would result in the production of smoke.

At the end of the test there was a deposit of carbon 10 inches in diameter on the bridge wall opposite the right burners and one 8 inches in diameter in front of the middle burners. The openings in the bridge wall were filled with slag.

Summary of tests of Hohenstein marine

Number of trial.	Date of trial, 1902.	Duration of trial (hours).	Kind of fuel.	Oil burner used.	State of weather.	Height of barometer at noon.
1	2	3	4	5	6	7
1	June 11	6	Beaumont oil	O. C. B. W. (air)	Bright sunny day	30.02
2	June 12	4	do	do	do	30
3	June 26	8	do	do	do	29.70
4	June 27	3	do	do	Bright sun, few clouds.	29.94
5	Aug. 2	5	do	do	Bright sunny day	30.13
6	Aug. 4–9	116	do	do	(See log)	29.89
7	Aug. 15	6	do	do	Thin fleecy clouds	30.10
8	Aug. 20	3	do	do	Smoky occasional clouds.	30.08
9	Sept. 12	6	do	Hayes (steam)	Partly cloudy	30.16
10	Sept. 19	8	do	O. C. B. W. (steam)	Thin clouds	30.20
11	Sept. 20	8	do	do	do	30.18
12	Sept. 22	8	do	do	Partly cloudy	30.05
13	Sept. 27	8	do	Reed (air and steam).	Fair	29.92
14	Sept. 29	8	do	do	Clear	29.96

Summary of test of Hohenstein marine

Number of trial.	Approximate fire room air pressure (inches of water).	Oil.		Steam.		Water.				Economic results.	
		Weight of oil used during test (pounds).	Weight of steam consumed directly or indirectly in spraying oil, in the latter case assuming 34½ evaporation units per hour per indicated horsepower.	Quality of steam.	Percentage of moisture in steam, 100−100×(**24**).	Total weight of water fed to boiler, pounds (corrected for inequality of water level and steam pressure at beginning and end of test).	Equivalent weight of water evaporated into dry steam (pounds), (**26**)×(**24**).	Factor of evaporation, $(H-h)\div 965.7$.	Equivalent weight of water evaporated into dry steam from and at 212° F. (pounds), (**27**)×(**28**).	Feed water per pound of oil (pounds), (**26**)÷(**22**).	Equivalent evaporation from and at 212° F. per pound of oil (pounds), (**29**)÷(**22**).
1	10	22	23	24	25	26	27	28	29	30	31
1	1.3	10,584	2,820	0.983	1.7	117,976	115,960	1.159	134,400	11.15	12.70
2	2.3	9,180	3,770	.980	2	96,928	94,980	1.177	111,800	10.56	12.18
3	0	6,122	827	.984	1.6	78,000	76,740	1.151	88,330	12.74	14.43
4	3.3	8,602	2,550	.981	1.9	88,604	86,915	1.161	100,900	10.30	11.73
5	0	4,668	1,153	.986	1.4	58,529	57,700	1.151	66,380	12.54	14.22
6	0	96,517	18,240	.985	1.5	1,192,482	1,174,500	1.160	1,363,000	12.36	14.12
7	0	9,089	7,800	.995	.5	104,631	104,100	1.160	120,780	11.52	13.29
8	3.75	9,909	3,950	.988	1.2	92,997	91,870	1.161	106,690	9.39	10.77
9	0	3,600	2,524	.991	.9	43,761	43,367	1.153	50,000	12.16	13.89
10	0	7,360	3,412	.995	.5	85,791	85,350	1.162	99,170	11.65	13.47
11	0	8,257	4,252	.994	.6	96,469	95,880	1.160	111,190	11.68	13.45
12	0	8,974	5,305	.995	.5	105,547	105,020	1.160	121,840	11.77	13.58
13	0	7,692	8,166	.996	.4	95,605	95,310	1.158	110,370	12.43	14.35
14	0	9,216	6,838	.998	.2	112,115	111,890	1.159	129,570	12.17	14.06

water-tube boiler, burning oil.

Average pressures.								Average temperature (Deg. F.).					
		Draft pressure in inches of water.											
Steam pressure by gauge; corrected for water level (pounds per square inch).	Pressure of medium used for spraying oil (pounds per square inch).	Fire room.	Furnace.	Combustion chamber.	Tube chamber.	Base of stack.	Revolutions of fan blower per minute.	External air.	Air in fire room.	Medium used in spraying oil.	Chimney gases.	Feed water entering boiler.	Steam at gauge pressure (**8**), from steam tables.
8	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
273.5	3.20	1.27	0.78	0.642	0.25	−0.49	327	85.4	121	(?)	704.6	120.7	413.7
273.5	4.62	2.31	1.55	1.38	.83	− .50	423	86	121.5	(?)	779	103.2	413.7
273.5	.78	0	−.15	−.19	− .25	− .35	0	79	106	102.5	503.6	128.5	413.7
273.5	3.37	3.25	2.60	2.02	1.25	− .41	483	81	108	122	854	119	413.7
273.5	1.41	0	−.15	−.20	− .28	− .40	0	87	112	120	557	129	413.7
271.5	1.31	0	−.17	−.23	− .30	− .46	0	79	112	113.5	585	119.4	413.1
272.5	4.66	0	−.09	−.13	− .21	− .54	0	77.6	120	161	747	119.7	413.4
276	4.68	3.75	3.40	2.30	1.86	− .53	506	82	115	136	1,017	119	414.5
273.5	32	0	−.20	−.20	− .20	− .38	0	75	98	(?)	449	127	413.7
273.1	29.9	0	−.20	−.20	− .28	− .60	0	69	98	444.4	596	118 3	413.6
273.7	61.4	0	−.14	−.20	− .28	− .53	0	77	106	408.2	628	120.2	413.8
274.2	91	0	−.14	−.16	− .21	− .53	0	77	103	401	661	119.6	414.0
276.7	92	0	−.15	−.15	− .20	− .45	0	80.4	99.4	375	578	121.9	414.8
277.4	89	0	−.097	−.10	− .20	− .50	0	85.4	111.5	416	645	120.8	415.0

water-tube boiler, burning oil.

Economic results.			Fuel per hour.				Water per hour.				
Pounds of steam used in spraying oil per pound of oil, (**23**) ÷ (**22**).	Steam used in spraying oil (per cent of total steam generated), (**23**) ÷ (**26**) × 100.	Cubic feet of free air used in spraying oil per pound of oil sprayed.	Oil per hour (pounds), (**22**) ÷ (**3**).	Oil per hour per horizontal square foot of furnace (pounds), (**35**) ÷ 50.14.	Oil per hour per square foot of heating surface (pounds), (**35**) ÷ 21.30.	Steam consumed in spraying oil (pounds per hour), (**23**) ÷ (**3**).	Feed water per hour (pounds), (**26**) ÷ (**3**).	Water per hour corrected for quality of steam (pounds), (**27**) ÷ (**3**).	Equivalent evaporation from and at 212° F. per hour (pounds), (**29**) ÷ (**3**).	Equivalent evaporation from and at 212° F. per hour per horizontal square foot of furnace (pounds), (**41**) ÷ 50.14.	Equivalent evaporation from and at 212° F. per hour per square foot of heating surface (pounds), (**41**) ÷ 21.30.
32	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**
0.303	2.39	34.3	1,764	35.15	0.83	535	19,663	19,327	22,400	447	10.5
.474	3.89	37.4	2,295	45.8	1.08	1,088	24,232	23,745	27,975	558	13.1
.153	1.06	62.8	765	15.25	.36	117.5	9,750	9,593	11,041	220	5.18
.337	2.88	36.7	2,867	57.2	1.35	967	29,535	28,972	33,633	671	15.8
.280	1.97	70	933.6	18.6	.44	262	11,706	11,540	13,276	265	6.23
.216	1.53	55.4	832	16.6	.39	179.5	10,280	10,125	11,750	234	5.52
.990	7.45	78.3	1,515	30.2	.71	1,501	17,447	17,360	20,137	402	9.45
.458	4.25	36	3,303	65.9	1.55	1,511	31,001	30,629	35,560	709	16.7
.701	5.77	0	600	11.97	.28	421	7,294	7,228	8,333	166	3.91
.464	3.98	0	920	18.34	.43	427	10,724	10,669	12,396	247	5.82
.515	4.41	0	1,032	20.57	.48	532	12,057	11,985	13,899	277	6.52
.591	5.03	0	1,122	22.35	.53	663	13,193	13,128	15,230	303	7.15
1.062	8.54	81.4	962	19.15	.45	1,021	11,951	11,914	13,796	275	6.48
.742	6.09	78	1,152	22.95	.54	855	14,014	13,986	16,196	323	7.60

Summary of test of Hohenstein marine

Number of trial.	Approximate fire room air pressure (inches of water).	Chimney gas analysis.				Pounds of dry chimney gas per pound of carbon. [11(**44**) + 8(**45**) + 7(**46**) + 7(**47**)] ÷ [3(**44**) + 3(**46**)].	Percentage of carbon in oil by chemical analysis.	Pounds of dry chimney gas per pound of oil, (**48**) × (**49**).	Heat balance, or distribution of the heating value of the oil. In British thermal units.		
		Carbonic acid, CO_2 (per cent).	Oxygen, O (per cent).	Carbonic oxide, CO (per cent).	Nitrogen, N (per cent by difference).				Heat absorbed by the boiler. (**31**) × 965.7.	Loss due to superheating steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.
1	**10**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**
1	1.3	6.97	8.77	1.50	82.76	28.99	83.26	24.1	12,250	0	1,440
2	2.3	6.96	9.20	1.20	82.64	30.11	83.26	25.1	11,760	0	1,480
3	0	7.24	10.2	.425	82.135	32.15	83.26	26.8	13,930	0	1,350
4	3.3	7.50	10.4	.3	81.80	31.64	83.26	26.4	11,320	0	1,540
5	0	7.70	10	.13	82.17	31.54	83.26	26.3	13,720	0	1,370
6	0	7.68	10.25	.06	82.01	31.91	83.26	26.6	13,620	0	1,390
7	0	10.1	6.64	.275	82.985	24	83.26	20	12,830	0	1,470
8	3.75	7.87	9.66	.22	82.25	30.54	83.26	25.4	10,400	0	1,620
9	0	5.5	13.05	.27	81.18	42.47	83.26	35.4	13,413	58	1,366
10	0	6.99	11.05	.013	81.95	35.16	83.26	29.3	13,008	77	1,445
11	0	7.47	10.66	.086	81.78	32.64	83.26	27.2	12,989	79	1,458
12	0	8.44	9.29	.014	82.26	29.29	83.26	24.4	13,114	93	1,479
13	0	7.70	9.85	.075	82.37	31.70	83.26	26.4	13,857	125	1,431
14	0	8.53	9.04	.05	82.38	28.85	83.26	24	13,578	112	1,465

water-tube boiler, burning oil.

Heat balance, or distribution of the heating value of the oil.										Efficiency.	
In British thermal units.				In percentages of the total heating value of the oil.							
Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc., by difference.	Heat value of one pound of oil, calculated from chemical analysis.	Heat absorbed by boiler.	Loss due to superheating steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.	Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc.	Of boiler (per cent), $[(51) \div (57)] \times 100 = (58)$.	Of boiler and furnace (per cent), $(64) \times \left[1 - \frac{(33)}{100}\right]$.
54	55	56	57	58	59	60	61	62	63	64	65
3,375	1,495	921	19,481	62.8	0	7.4	17.3	7.7	4.8	62.8	61.3
3,925	1,242	1,074	19,481	60.3	0	7.6	20.1	6.4	5.6	60.3	58
2,565	469	1,167	19,481	71.5	0	6.9	13.2	2.4	6	71.5	70.7
4,720	326	1,575	19,481	58.1	0	7.9	24.2	1.7	8.1	58.1	56.4
2,800	141	1,450	19,481	70.4	0	7	14.4	.7	7.5	70.4	69
3,020	66	1,385	19,481	69.9	0	7.1	15.5	.3	7.2	69.9	68.8
2,945	224	2,012	19,481	65.8	0	7.5	15.1	1.2	10.4	65.8	60.9
5,480	230	1,751	19,481	53.4	0	8.3	28.1	1.2	9	53.4	51.1
2,990	395	1,259	19,481	68.9	.3	6.9	15.4	2	6.5	68.9	64.9
3,500	16	1,435	19,481	66.7	.4	7.4	18	.1	7.4	66.7	64.1
3,410	97	1,448	19,481	66.7	.4	7.5	17.5	.5	7.4	66.7	63.8
3,270	14	1,511	19,481	67.3	.5	7.6	16.8	.1	7.7	67.3	63.9
3,000	82	986	19,481	71.1	.6	7.4	15.4	.4	5.1	71.1	65
3,070	49	1,207	19,481	69.7	.6	7.5	15.7	.3	6.2	69.7	65.4