BOILER EXPERIMENTS.

An account of some experiments made in 1873, at the Washington Navy Yard, on the 8 feet diameter cylindrical boiler used with compound engines in several steamers of the United States Navy.

By Chief Engineer ISHERWOOD, U. S. Navy.

As it is necessary in war steamers that the entire machinery be placed below their water line, the height of their boilers in small vessels is, consequently, greatly restricted, and, in many such vessels of the United States Navy, 8 feet were all that could be obtained. When the boilers were to furnish high pressure steam for a compound engine, their shells had to be cylindrical and of this diameter, and it was difficult in so small a circle to obtain a satisfactory arrangement of the furnace and tubes. The plan of boiler finally adopted, is the one shown in the sketch accompanying this paper, and three experiments were made with it at the Washington Navy Yard by Chief Engineers Loring and Baker, of the United States Navy, to determine the effect upon its absolute and economic vaporizations produced by the two modifications of the tube surface and calorimeter hereinafter described. These experiments are the only ones ever made on the evaporative efficiency of boilers of this type with the given proportions, and as several steamers of the United States Navy are fitted with them, it is of interest, in view of a comparison of the cost of the horse-power developed by their engines in pounds of coal consumed per hour, to know the weight of water vaporized per pound of coal.

An important practical evil of boilers of this small diameter at once developed when they were put in use, namely an incorrigible tendency to "prime" or "foam," which required the throttle valve to be nearly always carried very much closed; and, when only a portion of the boilers of a vessel were employed, the smaller that portion, the closer had the throttle to be closed. A very high pressure was thus required in the boiler to furnish a very moderate one in the cylinder, involving all the undoubted disadvantages of high pressure steam, while none of its presumed advantages could be obtained. The excessive strain on the boiler and the excessive temperature in the fire-room, produced by the high pressure steam, were fully realized; but neither the supposed

benefit of a large measure of expansion for this very high pressure could be had, nor the unquestionable benefit of a relatively small back pressure against the piston, due to a high average total pressure upon it during its stroke.

The tubes were secured in the tube-plates by means of screw ferrules of brass $1\frac{1}{2}$ inches long, on the outer circumference of which a thread was cut fitting into a corresponding thread cut on the inner circumference of the tube. The ferrule at the back end of the tube had a shoulder which fitted against the outside of the tube-plate, the end of the tube fitting against the inside and forming a shoulder there, so that when the ferrule was turned by means of a wrench on the outside, the shoulders of the ferrule and of the tube were compressed against the tube-plate. The ferrule at the front end of the tube, for the thickness of the tube-plate, had a diameter greater than the outside diameter of the tube, and on the circumference of this greater diameter a thread was cut fitting into a corresponding thread cut in the tube-plate: by means of these threads the ferrule was screwed into the tube-plate, while simultaneously it was screwed into the tube by means of the threads previously described cut on the inner circumference of the tube and on the outer circumference of the ferrule where its diameter was least. By unscrewing the ferrules at both ends of a tube, the latter could be drawn out without injury for examination or cleaning; or for convenience in examining, cleaning or repairing the inside of the boiler shell. This was the purpose of the design which, however, signally failed in the application, as after a short subjection to the high temperature of the gases of combustion, the fittings were so warped and altered that the screws became inoperative, and the removal of the tubes involved the destruction of both them and the ferrules. This very expensive, useless and *unpractical* method of securing the tubes in their plates, was originally a French invention and had been tried in the boilers of several French steamers, but its use had long been discontinued before its application to the boilers of any United States Naval steamer.

As regards the experiments, it is regrettable that they were not continued for a longer time than twelve hours each, which is far shorter than desirable for reliable results, although, in their cases, great accuracy of observation was depended on to obviate this objection. That the boiler was not protected with the usual non-conducting covering, is

also to be regretted, though the writer has been able to satisfactorily supply the deficiency from other data.

The original notes of these experiments were furnished by Chief Engineer Baker to the writer, who has made the necessary calculations from them, and arranged both data and results in a tabular form, pre-facing the table with a description of the boiler and of the manner of making the experiments, and following it with some remarks.

BOILER.

The boiler is of the horizontal fire-tube type with nearly all the tubes returned by the sides of the furnace. It is a duplicate of many in use with compound engines on board of U. S. Naval steamers of a small size.

The shell of the boiler is a cylinder of 8 feet diameter and 8 feet 1 inch length, with flat ends. The back end is flush with the end of the shell, but the front end is recessed $4\frac{1}{2}$ inches within the shell. The entire shell is constructed of $\frac{5}{8}$ inch thick plate iron, with the joints butted, single welted, and double riveted. The front end serves for the front tube-plate.

The shell contains a single cylindrical furnace of 54 inches inner diameter and 6 feet $8\frac{1}{2}$ inches extreme length. It contains a grate 4 feet 6 inches wide and 5 feet 4 inches long. The grate-bars are of the ordinary pattern, and are cast in two equal lengths. The grate surface, at the front, coincides with the horizontal diameter of the furnace, sloping downwards 4 inches at the back. The bridge-wall is of cast iron, faced with fire-brick $4\frac{1}{2}$ inches thick on the 9 inches it rises above the back of the grate. The bottom of the ash-pit is $4\frac{1}{2}$ inches above the bottom of the shell. The furnace is constructed of $\frac{1}{2}$ inch thick iron in three equal lengths, and has, at each end of the middle length, a stiffening

Fig. 1.

Longitudinal vertical section through axis of shell, exclusive of uptake.

ring inserted of iron $2\frac{1}{2}$ inches deep, $\frac{1}{2}$ inch thick, and 5 feet outside diameter.

The furnace has two doors placed side by side; each door-opening is semi-circular on top, 20 inches wide and 16 inches high. Each door is perforated with eleven holes of $1\frac{3}{8}$ inches diameter for the admission of air; and the lining plate is perforated with as many $\frac{1}{4}$ inch diameter holes as it will contain, for the distribution of this air above the incandescent coal.

The front of the furnace is of cast iron with a double shell; the outer shell is pierced with seventeen holes of $1\frac{3}{8}$ inches diameter for the admission of air; and the inner shell is pierced with as many $\frac{1}{4}$ inch diameter holes as it will contain, for the distribution of this air above the incandescent coal.

The back smoke connection is 11 inches wide in the clear lengthwise the boiler: it is flat on top, with its sides and bottom concentric with

Fig 2.

Half elevation, with uptake and outer plate of furnace front removed.

Half cross section on A B, Fig. 1.

Fig 3.

Front elevation, exclusive of uptake.

the cylindrical shell of the boiler from which they are separated by a water-space $4\frac{1}{2}$ inches wide including thicknesses of metal. The sides and bottom are, consequently, a segment of a circle 7 feet 3 inches in diameter. The extreme height of the connection in the clear is 5 feet 3 inches. The back of the connection is flat and parallel to the end of the boiler shell from which it is separated by a water-space $5\frac{1}{2}$ inches wide including thicknesses of metal. The connection is stayed to the

boiler shell by socket bolts of one inch diameter spaced every 6 inches. The whole of the connection is of plate iron $\frac{5}{8}$ ths of an inch thick.

The tubes, with the exception of those of the upper row, twenty-one in number, are divided into two equal and symmetrical groups, one of which is returned on each side of the furnace from the back smoke connection to the uptake, completely filling the spandrels between the furnace and the boiler shell. Of these tubes, sixteen (eight on each end) lie below the level of the top of the bridge-wall, and six (three on each side) lie just at the level of that top. The upper row of tubes lie unbroken above the furnace.

The tubes are of brass and seamless, and are secured to their plates by screw ferrules of 2 inches inside diameter. Each tube is $2\frac{1}{2}$ inches 2·3 inches in inside diameter, in outside diameter and 6 feet 4 inches in extreme length to outside of tube-plates. They are one hundred and nineteen in number. The object of the screw ferrules was to allow the tubes to be removed for cleaning without injury, and to be replaced quickly. The distance between the axes of the tubes, horizontally, is $3\frac{1}{2}$ inches; and, vertically, 3·2 inches.

Above the tubes, the flat ends of the boiler shell are stayed together by eighteen rods of $1\frac{1}{4}$ inches in diameter: these rods pass through the flat ends, to which they are secured by collars on the inside and nuts on the outside. The rods average $8\frac{1}{4}$ inches from centre to centre.

The uptake is a separate construction of sheet iron placed against the front end of the boiler, which is nearly covered by it, with the exception of the front of the furnace and ashpit. It has the usual doors, hinged at top and giving access to the tubes for sweeping, etc. The chimney rises from the top of the uptake.

During the experiments, the boiler had no covering of any kind.

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

Diameter of the shell,	.	.	.	.	8 ft.
Extreme length of the shell,	.	.	.	.	8 ft. 1 in.
Number of furnaces,	.	.	.	.	1.
Width of the grate,	.	.	.	.	4 ft. 6 in.
Length of the grate,	.	.	.	.	5 ft. 4 in.
Grate surface,	.	.	.	.	24 sq. ft.
Number of tubes,	.	.	.	.	119.
Outside diameter of tubes,	.	.	.	.	2·5 in.
Inside diameter of tubes,	.	.	.	.	2·3 in.

Inside diameter of ferrules for tubes,	2.0 in.
Length of tubes in the clear between the tube plates,	6 ft. 2 $\frac{3}{4}$ in.
Height of the chimney above the grate surface,	59 ft. 6 in.
Diameter of the chimney connection,	2 ft. 1 $\frac{1}{2}$ in.
Cross area above the bridge-wall for draught,	6.0945 sq. ft.
Cross area through the tubes for draught,	3.4334 sq. ft.
Cross area through the ferrules of the tubes for draught,	2.5962 sq. ft.
Cross area of the chimney connection,	3.5465 sq. ft.
Heating surface in the furnace,	48.6 sq. ft.
Heating surface in the back smoke connection,	64.0 sq. ft.
Heating surface in the tubes, calculated for their inner circumference,	446.4 sq. ft.
Heating surface in the uptake,	14.0 sq. ft.
Total heating surface in the boiler,	573.0 sq. ft.
Square feet of heating surface per square foot of grate surface,	23.875
Square feet of grate surface per square foot of cross area above the bridge-wall,	3.938
Square feet of grate surface per square foot of cross area through the tubes,	6.990
Square feet of grate surface per square foot of cross area through the ferrules,	9.244
Square feet of grate surface per square foot of cross area of chimney connection,	6.767
Water room in boiler to 6 inches above top of tubes,	100 cub. ft.
Steam room in boiler above 6 inches above top of tubes,	75 cub. ft.
Weight of boiler, exclusive of grate-bars and chimney,	22100 pounds.
Weight of grate bars,	1210 pounds.
Weight of water in boiler,	6233 pounds.

MANNER OF MAKING THE EXPERIMENTS.

The experiments were made in the following manner:

A clean anthracite fire of 9 inches thickness having been brought to steady action, with the steam blowing freely from the boiler escape-pipe—the safety-valve having been previously removed from its seat—the water-level in the boiler was adjusted to 6 inches above the top-

of the tubes, and the experiment held to commence. Each experiment continued exactly 12 hours, at which time the fire was thoroughly cleaned and made of the same thickness as at the commencement, with the water-level at the same mark.

During the continuance of each experiment, a tabular record or log was kept, in which was noted, at the end of each hour, the height of the barometer, the temperature of the air in the boiler-room, of the feed-water in the tank, and of the gases of combustion in the uptake, the latter being given by a metallic pyrometer. All the anthracite thrown into the furnace was carefully weighed, and all the refuse of ash, clinker and soot was likewise weighed on the same scales. After the completion of an experiment, the tubes were swept together with the other fire surfaces, so that each experiment was begun with a clean boiler. The boiler being entirely new, its water surfaces were quite clean. The water fed into the boiler was first accurately measured in tank. The steam pressure in the boiler was found to be slightly in excess of the atmospheric pressure. All the experiments were made by the same personnel and in the same manner; the anthracite being burned at the maximum rate of combustion which could be obtained without forcing the fire.

The boiler was without any non-heat-conducting covering whatever, and was situated in the still air of the boiler-house of the Steam Engineering department of the Washington Navy Yard. Every precaution was taken to insure accuracy in the results, and, also, that those from the different experiments might be fairly comparable. These results, and the data from which they were calculated, will be found in the following table.

The experiments were three in number. During the first, made on the 24th of May, 1873, all the tubes were in use. During the second, made on the 21st of May, 1873, the lower twenty-one tubes—ten on one side of the furnace and eleven on the other—were tightly plugged at both ends, so as to prevent the passage through them of any of the hot gases of combustion, thereby reducing the heating surface 13·75 per centum, or from a proportion of 23·8750 square feet to 1·0000 of grate surface, to the proportion of 20·5926 to 1·0000; the calorimeter through the tubes being thereby reduced 17·65 per centum, or from a proportion of 1·0000 square foot to every 9·2443 square feet of grate surface, to the proportion of 1·0000 to 11·2255. During the third experiment, made on the 23d of May, 1873, exactly the same reduc-

tions of heating surface and of calorimeter were made as in the second experiment, but, in this case, they were effected by plugging tightly at both ends the twenty-one tubes composing the upper row—the plugs used in the second experiment having, of course, been removed from the twenty-one lower tubes. The absolute areas and proportions of the grate surface, heating surface, and calorimeter through the tubes, in both the second and third experiments, were precisely the same, the only difference being that the reductions in these particulars from the quantities in the first experiment, were made in the second experiment in tubes *lying below the top of the bridge-wall*, and in the third experiment in tubes *lying above the top of the bridge-wall*.

The first and second experiments, therefore, permit the determination of the effect produced on the absolute and economic vaporizations of the boiler, by the simultaneous reduction of its heating surface and of its calorimeter through the tubes, its grate surface remaining constant, and all its heating surface lying above the top of its bridge-wall.

In the third experiment, 15·94 per centum of the heating surface, and 21·43 per centum of the calorimeter through the tubes, lay *below* the top of the bridge-wall, therefore, experiments second and third permit the determination of the effect produced on the absolute and economic vaporizations of the boiler by this distribution; the grate surface, heating surface, and calorimeters through the tubes being exactly the same in both experiments, the only difference being in the arrangement of the heating surface and calorimeter through the tubes relatively to the top of the bridge-wall. In the second experiment, all the calorimeter through the tubes was above that top; while, in the third experiment, only 78·57 per centum of the calorimeter was above that top. The grate surface and the calorimeter above the bridge-wall remained constant throughout, and the latter was so much larger than the calorimeter through the tubes that it exercised no influence on the results.

As the boiler, during all the experiments, had no covering to diminish the loss of heat by radiation from the external surfaces; and as boilers on which experiments are made, almost always have very efficient coverings for that purpose; it became necessary, in order that the results from this boiler may be comparable with those from other boilers, to ascertain the vaporizative value of the difference of the heat radiated in still air from the naked boiler and from the same boiler

under the same conditions when covered with the usual protector of hair felt $1\frac{1}{2}$ inches thick. This has been effected by means of the constants in a table constructed from experiments made for this object by the writer, and published on page 161 of the March number of the JOURNAL for 1878. In that table, the number of Fahrenheit units of heat lost per hour per square foot of boiler plate per degree Fahrenheit difference of temperature between that of the steam upon one side of the metal, and that of the still air upon the opposite side, is 2.9330672 when the metal is naked, and 0.2507097 when the metal is covered with $1\frac{1}{2}$ inches thickness of hair felt. The difference, 2.6823575 Fahrenheit units of heat, has been assumed, in the case of this boiler, to have been lost per hour per square foot of the 204 square feet of its exposed external surface, per degree Fahrenheit of difference of temperature between the temperature of the steam inside and that of the still air in the fire-room outside of the boiler. From these data and the latent heat of the steam, the vaporizations in the table due to the loss of heat by external radiation, have been calculated; and these vaporizations have been added to those given by the direct tank measurement, in order to obtain the normal vaporizations. As the experimental boiler was in the same room with other and much larger boilers in use, the temperature of the air in that room has been taken as the proper temperature for the calculation, instead of the temperature of the external air.

RESULTS.

If the atmospheric conditions governing the force of the draught, could be considered constant during the experiments, then the rate of combustion of the gasifiable portion of the anthracite was reduced, comparing experiments first and second $\left(\frac{4148 - 3625 \times 100}{4148} = \right) 12.61$ per centum for a reduction of 21.43 per centum in the calorimeter through the tubes; that is to say, for a reduction from the proportion of 1.0000 square foot of calorimeter to 9.2443 square feet of grate, to the proportion of 1.0000 to 11.2255: all of the calorimeter in both cases being above the top of the bridge wall. Under these circumstances, the absolute vaporization was reduced

$$\left(\frac{36744.067 - 31919.145 \times 100}{36744.067} = \right) 13.13 \text{ per centum,}$$

the economic vaporization remaining sensibly unaffected notwithstanding

ing the reduction of 13·75 per centum in the heating surface. But had the absolute vaporizations been made the same in both experiments, by a proper reduction in the rate of combustion during the first experiment, the economic vaporization would certainly have been at least 6 or 7 per centum better in that experiment with all the tubes in use, than in the second experiment with a considerable portion of them plugged.

In the third experiment, the rate of combustion was sensibly the same as in the second experiment, but the absolute and the economic vaporizations were less. The first fell off

$$\left(\frac{31919 \cdot 145 - 30103 \cdot 678 \times 100}{31919 \cdot 145} = \right) 5 \cdot 69 \text{ per centum,}$$

and the last, correspondingly,

$$\left(\frac{10 \cdot 202 - 9 \cdot 680 \times 100}{10 \cdot 202} = \right) 5 \cdot 12 \text{ per centum.}$$

If the absolute vaporization in the third experiment had, by means of a higher rate of combustion, been made equal to the absolute vaporization in the second experiment, then this difference of 5·12 per centum in the economic vaporization would have been considerably increased.

With regard to the temperature of the gases of combustion in the uptake during the different experiments, and comparing the first and second experiments, there is a difference of (867·5—814·2=) 53·3 degrees Fahrenheit in that temperature. The rate of combustion in the second experiment was 12·61 per centum less than in the first, but the heating surface was 13·75 per centum less also. Comparing, now, that temperature in the second and third experiments, in which the heating surface and the calorimeter were exactly the same, and the rate of combustion almost exactly the same, the temperature of the gases of combustion in the uptake was (814·2—785·0 =) 29·2 degrees Fahrenheit less in the third than in the second experiment, although 15·94 per centum of the heating surface in the former was less efficient than in the latter, owing to its position below the top of the grate bars. The effect of lessening the calorimeter is to lessen the air supply proportionally to weight of coal consumed, and it may easily be lessened to an extent that will materially affect the completeness of the combustion. Now, as the quantity of heat from a given weight of coal and, consequently, the temperature of the gases of combustion produced, are lessened in proportion to the incompleteness of the combustion, too

BOILER EXPERIMENTS.

BY CHIEF ENGINEER ISHERWOOD, U. S. I

TABLE CONTAINING THE DATA AND RESULTS OF THREE EXPERIMENTS MADE ON A SINGLE FURNACE
NAVY-YARD, BY CHIEF ENGINEERS LORING AND BAKER, U. S. NAVY, WITH ANTHRACITE CO
TO ASCERTAIN THE EFFECT PRODUCED ON THE ECONOMICAL AND POTENTIAL VAPORIZATION
ROW OF TUBES (21 TUBES), LEAVING ALL THE OTHER TUBES IN USE; AND THEN PLUGG
LEAVING ALL THE OTHER TUBES IN USE, THE UPPER ROW HAVING BEEN U
24 SQUARE FEET. HEIGHT OF CHIMNEY ABOVE GRATE SUR

Date of Experiment,

BOILER.

Number of square feet of heating surface in use,
Number of square feet of heating surface in use, per square foot of grate surface,
Number of square feet of cross area for draught above the bridge-wall,
Number of square feet of grate surface per square foot of cross area above the bridge-wall
Number of square feet of cross area for draught through the ferrules of the tubes,
Number of square feet of grate surface per square foot of cross area through the ferrules

TOTAL
QUANTITIES.

Duration of experiment, in consecutive hours,
Number of cubic feet of water vaporized according to tank measurement,
Number of pounds of water vaporized according to tank measurement,
Number of pounds of water that would have been vaporized had the difference between
the quantities of heat radiated from the boiler when naked and when clad with
14 inches thick felt been so utilized,
Total number of cubic feet of water vaporized in the felt-clad boiler,
Total number of pounds of water vaporized in the felt-clad boiler,
Total number of pounds of anthracite consumed,
Total number of pounds of refuse from the anthracite in ash, clinker and soot,
Total number of pounds of combustible or gasifiable portion of the anthracite consumed
Per centum of the anthracite in refuse of ash, clinker and soot,

RATE OF
COMBUSTION.

Pounds of anthracite consumed per hour,
Pounds of combustible consumed per hour,
Pounds of anthracite consumed per hour per square foot of grate surface,
Pounds of combustible consumed per hour per square foot of grate surface,
Pounds of anthracite consumed per hour per square foot of heating surface,
Pounds of combustible consumed per hour per square foot of heating surface,

PRESSURES.

Height of the barometer in inches of mercury, corrected for temperature,
Steam pressure in boiler in pounds per square inch above zero,

TEMPER-
ATURES.

Temperature in degrees Fahrenheit of the air in the boiler-room,
Temperature in degrees Fahrenheit of the feed-water,
Temperature in degrees Fahrenheit of the gases of combustion in the boiler-uptake,

VAPOR-
IZATION.

Economic. Absolute.

Total number of pounds of water that would have been vaporized in the felted boiler
had the temperature of the feed-water been 100 degrees Fahrenheit, and had it
been vaporized under the standard pressure of 29.92 inches of mercury,
Total number of pounds of water that would have been vaporized in the felted boiler
had the temperature of the feed-water been 212 degrees Fahrenheit, and had it
been vaporized under the standard pressure of 29.92 inches of mercury.

Pounds of water vaporized from 100 degrees Fahrenheit by one pound of anthracite,
Pounds of water vaporized from 100 degrees Fahrenheit by one pound of combustible
Pounds of water vaporized from 212 degrees Fahrenheit by one pound of anthracite,
Pounds of water vaporized from 212 degrees Fahrenheit by one pound of combustible

BOILER EXPERIMENTS.

OF ENGINEER ISHERWOOD, U. S. NAVY.

EXPERIMENTS MADE ON A SINGLE FURNACE CYLINDRICAL MARINE BOILER AT THE WASHINGTON YARD, U. S. NAVY, WITH ANTHRACITE CONSUMED AT THE MAXIMUM RATE OF COMBUSTION, WITH THE UPPER ROW OF TUBES PLUGGED AT BOTH ENDS, FIRST, THE UPPER ROW OF TUBES IN USE; AND THEN PLUGGING AT BOTH ENDS THE LOWER 21 TUBES, THE LOWER ROW OF TUBES IN USE, THE UPPER ROW HAVING BEEN UNPLUGGED. (GRATE SURFACE, 1,000 SQUARE FEET; HEIGHT OF CHIMNEY ABOVE GRATE SURFACE, 59½ FEET.)

	<i>All the tubes in use.</i>	<i>The lower 21 tubes plugged at both ends; all the other tubes in use.</i>	<i>The upper row of tubes (21 in num- ber) plugged at both ends; all the other tubes in use.</i>
	24TH MAY, 1873.	21ST MAY, 1873.	23D MAY, 1873.
Grate surface, per square foot of grate surface,	573·0000	494·2228	494·2228
Height above the bridge-wall,	23·8750	20·5926	20·5926
Area of cross area above the bridge-wall,	6·0945	6·0945	6·0945
Area through the ferrules of the tubes,	3·9380	3·9380	3·9380
Area of cross area through the ferrules,	2·5962	2·1380	2·1380
	9·2443	11·2255	11·2255
Weight of anthracite consumed, according to tank measurement,	12·	12·	12·
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	575·247	495·060	468·191
	35862·000	30858·000	29190·000
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	882·067	1061·145	913·678
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	589·396	512·084	482·846
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	36744·067	31919·145	30103·678
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	4568·	4050·	4098·
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	420·	425·	486·
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	4148·	3625·	3612·
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	9·194	10·494	11·859
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	380·667	337·500	341·500
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	345·667	302·083	301·000
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	15·861	14·002	14·229
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	14·402	12·587	12·542
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	0·664	0·683	0·691
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	0·605	0·611	0·609
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	29·40	30·04	29·48
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	14·60	15·00	14·73
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	81·4	57·1	77·4
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	58·0	60·0	57·0
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	867·5	814·2	785·0
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	38173·352	33114·130	31306·454
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	42633·551	36983·206	34964·320
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	8·357	8·176	7·639
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	9·203	9·135	8·667
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	9·333	9·132	8·532
Weight of anthracite consumed, when the boiler was naked and when clad with felt,	10·278	10·202	9·680

small a calorimeter may simultaneously cause both a lessened economic vaporization and a lower temperature of the gases of combustion in the uptake, although, generally, the latter would indicate a greater economic vaporization. The calorimeter through the tubes, which was small in the first experiment, being only the $\frac{1}{9.2443}$ of the grate, was reduced in the second experiment to the $\frac{1}{11.2255}$ of the grate, and, if only that portion of the calorimeter which is above the top of the bridge wall is effective, it was still further reduced in the third experiment to the $\frac{1}{14.2857}$ of the grate. Each of these reductions was probably attended by a more and more incomplete oxidation of the constituents of the coal, owing to a more and more insufficient air supply relatively to the weight of coal consumed. Thus the less and less temperatures of the gases of combustion in the second and third experiments may have been due solely to their very small calorimeters.

These results show that, with a boiler of this type and of the proportions in the first experiment, both the absolute and economic vaporizations are injuriously affected to a marked degree by a reduction in the heating surface of 13.75 per centum, accompanied by a reduction of 21.43 per centum in the calorimeter through the tubes, the proportion of the original heating surface to the grate surface (23.8750 to 1.0000), and of the original calorimeter through the tubes to the grate surface (1.0000 to 9.2443), being so small that further reductions in either are attended by lessened results. Also, that, other things being equal, both the absolute and economic vaporizations are injuriously affected, and to a marked degree, by placing any considerable portion of the heating surface, and of the calorimeter through the tubes, below the level of the top of the bridge-wall.

Snow Illumination.—During a recent snow-storm, in the early afternoon, an interesting experiment was tried in Paris. At the moment when the sky was darkened by snow, the electric lamps were lighted in the square of the Théâtre Français. The reflection of the light from the snow-flakes immediately dispelled the darkness and produced a very pleasing effect. It is proposed to try a similar experiment in misty weather, and if the light can penetrate even to the distance of 20 metres (65.6 ft.), Jablochkoff lamps will be established at points where the passing is most frequent.—*Les Mondes*. C.