TRANSMISSION OF HEAT THROUGH SCALED BOILER TUBES

BY

HARRY FRED GODEKE
AND
ARTHUR ALDRICH HALE

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

HARRY FRED GODEKE and ARTHUR ALDRICH HALE

ENTITLED TRANSMISSION OF HEAT THROUGH SCALED BOILER TUBES

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

TRANSMISSION OF HEAT THROUGH SCALED BOILER TUBES.

The general outline to be followed in the presentation of this thesis will be arranged in the following order:

A-- INTRODUCTION.
- (a)- Object.
- (b)- Previous work on the same subject.
- (c)- General method of proceedure.

B-- APPARATUS.
- (a)- Description.
- (b)- Plates.

C-- MANNER OF CONDUCTING TESTS.

D-- TABLES.

E-- CALCULATIONS.

F-- CONCLUSIONS AND REMARKS.

TRANSMISSION OF HEAT THROUGH SCALED BOILER TUBES.

A-- INTRODUCTION.

(a) OBJECT.-- The object of this thesis is to determine the relative efficiency of scaled boiler tubes for conducting heat, as compared with clean boiler tubes, under the same conditions.

The following tests were made upon locomotive boiler flues; however, the same principles hold true for all classes of boiler tubes.

(b) PREVIOUS WORK.-- Three theses have previously been submitted on this subject; one by Messrs. Armstrong and Herwig, class of '99; one by Mr. F.L.McCume, class of '01; and one by Messrs. Miskimen and Stone, class of '04.

The work of Messrs. Armstrong and Herwig was divided into two parts; the first consisted of testing a locomotive, both before and after the tubes had been cleaned. This part we strongly recommend, as here the tubes are tested under actual conditions. There is, however, one disadvantage in this method in that the tubes are not coated alike, owing to their various positions in the boiler; hence, the effect of the different thicknesses of scale can not be ascertained.

Not being entirely satisfied with this work, Messrs. Armstrong and Herwig next took up the matter of testing tubes singly and in groups. They experimented on different forms of apparatus but did not meet with much success.

Mr. McCune took up the subject where yhey left off. He improved their apparatus until it became practically the same as used in the work here reported; some alterations being made by Messrs. Miskimen and Stone and some by the writers. This apparatus will be described in detail under "B".

(c) GENERAL METHOD.-- The method pursued in the experimental workof this thesis was as follows:

The hot gases passed from the combustion chamber, through the tube. A portion of the heat was transmitted through the

walls of this tube, into the water, which entered the boiler at the exhaust end, flowed through in the direction opposite that of the furnace gases, and was discharged from the head end of the boiler, into a weighing tank.

In conducting these tests the following observations were made:

1. Furnace temperature.
2. Temperature of escaping gases.
3. Temperature of water entering the boiler.
4. Temperature of water leaving the boiler.
5. Amount of water passing through the boiler in a specified time.

This series of readings were taken, first, with a clean tube and then with a scaled tube. The furnace temperature and the temperature of the water leaving the boiler were kept as near constant as possible, and the amount of heat transmitted by the scaled tube was compared with that transmitted by the clean tube. For the details of the method pursued see "C".

B-- APPARATUS.

The main parts of the apparatus used were as follows:

1. Water chamber or boiler.
2. Combustion Chamber.
3. Burner.
4. Constant pressure water tank.
5. Constant pressure air and gas tanks.
6. Weighing tank with platform scales.
7. Pyrometer and thermometers.

(1) BOILER.-- The body of the boiler, marked "A" in plan view, Plate 1, is of 10" wrought iron pipe, with a standard flange on each end. These flanges have an outside diameter of 16", and are drilled with 8 holes, on a 14" circle. On each is bolted a plate of the same diameter and thickness as the flange, and which has a 2 1/2" hole in the center, into

which the tube is packed. Rubber gaskets are placed between the heads and flanges, and thus when the tobes are packed into the heads with asbestos wicking, the boiler is water tight. Water enters, from the water tank, at the top of the exhaust emd of the boiler, as shown in Plate 1, and passes out from the top, near the furnace end, into the weighing tank. The boiler is covered with hair-felt, so as to prevent radiation. Thermometers are inserted into the pipes, so as to get the temperatures of the water, just as it enters and leaves the boiler.

(2) COMBUSTION CHAMBER.-- The combustion chamber, "C", Plate 1, is a piece of 6" wrought iron pipe, 22" long, and attached directly to the front end of the boiler. To fasten it to the head a 6" flange was screwed onto the pipe and four 5/8" cap screws secured it to the head. Onto the other end of the pipe were secured a coupling and a standard plug. Drilled into the center of the plug is a 1 1/2" hole, through which the burner "B" projects into the combustion chamber. Into one side of the combustion chamber is projected a piece of 1" pipe, capped at the end, for protecting the pyrometer tube. Into the other side, near the opposite end, was screwed a short piece of 1/2" pipe, to aid the combustion, when starting. This pipe was plugged when the flame was thoroughly settled. The entire combustion chamber was wrapped with asbestos.

(3) BURNER.-- The burner is shown in section in Plate "3". It consists of a 1 1/4" cast iron "T", in one end of which is a pipe 18" long, and in the other end, a plug. The plug is bored to admit a 3/8" gas pipe and also tapped at right angles to the pipe for a 3/16" set screw, which holds the pipe at any desired point. Illuminating gas is admitted through the 3/8" pipe and compressed air is admitted through the bottom of the "T", and into the surrounding pipe. The two form a mixture and burn at the end of the tube. Flexible 3/4" tubing is placed between the burner and the tank connections, in order that the burner may be easily removed from the combustion chamber for lighting.

(4) WATER TANK.-- The constant pressure water tank, shown in Plate 1, is simply a galvanized tank 15" in diameter and having two pipe connections near the bottom. It is suspended from the ceiling by wires. Water flows into the top from the service pipe, connected to the main as shown in Plate 1. One of the pipes at the bottom leads to the boiler, the other being an overflow pipe. Where the overflow enters the tank, an elbow and a vertical pipe 16" high are attached, so the water must stand 18" deep in the tank before any overflow occurs. Thus as long as the overflow is kept running slightly, there is a constant head in the tank.

(5) AIR AND GAS TANKS.-- A section of one of the constant pressure tanks, used for air and gas, is shown on Plate 2. The tanks are identical except that the gas tank has 1" pipes and the air tank 3/4" pipes. Each consists of a stationary tank, to hold water, which is connected to the supply main and has an inlet and outlet pipe "A" and "B" respectively, coming up nearly level with the top of the tank as shown. In the tank is a central axis of 3/8" gas-pipe, which is stayed at the lower end by the metal cone and wires. This tank is about half filled with water and an inverted tank placed in it. The inverted tank has through its center a 3/4" pipe, which slides over the small pipe of the water tank, thus keeping the two central and allowing the inverted tank to move freely. It is kept floaying by the pressure of the gas between it and the water, so the pressure delivered at the burner can be regulated by placing different weights on top of the floating tank. No weight is needed on top of the gas tank, the weight of the tank alone being sufficient to furnish the necessary amount of gas. As long as the tank with the given weight is sustained, the pressure of the out going gas is practically constant.

(6) WEIGHING TANK.-- The weighing tank is shown in Plate 1. It is made of galvanized iron, holds about 1000 lbs. of water and has an outlet, near the bottom, controlled by a gate valve. It is mounted upon a pair of standard platform scales.

(7) PYROMETER.-- The temperatures of escaping gases and of entering and leaving water were taken with mercury thermometers, reading up to 1000 and 220 degrees Fahrenheit respectively.

To determine the furnace temperature the Le Chatelier pyrometer was used, and while it was rather inconvenient to handle on account of the broken porcelain tube, (which was broken last year, and which we used by packing the end with asbestos wicking), and the delicacy of the needle, it gave very accurate results.

The principle involved in the construction of the instrument is the conversion of heat into an electric current and the determination of the degree of heat by means of the galvanometer, equipped with suitable scales. The conversion is affected as follows:

Two wires, one of absolutely pure platinum and the other consisting of the same metal alloyed with 10% rhodium, are fused together at one of the ends, into a small ball. This junction of the two wires generates a slight electric current when heated, and such currents have been found to be proportional to the heat applied.

To prevent injury to the wires from abrasion, corroding gas, etc., they are enclosed in porcelain tubes; a small tube open at both ends, insulating the two wires, and a large one closed at one end covering the whole. It was the end of this tube that was broken off. For diagram see Fig.2, Plate 4.

The galvanometer used is of the D'Arsonval type and is especially adapted to the measureing of thermal currents. The current is transmitted to an armature wound in quadrangular shape through a fine wire of hard metal which does not oxydize. A small spring of the same metal acts as negative. The galvanometer is shown in Fig.1, Plate 4.

A strong permanent magnet with iron pole shoes constitutes a magnetic field, and an iron cylinder in the center concentrates the magnetic lines of force.

The pointer moves over two scales, one of which denotes the Electro Motive Force of the current in micro-volts, which makes it possible to check readings on the instrument,

while the other scale gives direct readings in Centigrade degrees.

On the base of the instrument is a small lever, which, when thrown over, secures the armature, thus avoiding the breaking of the delicate suspension wire while in transit.

Adjusting screws and spirit level allow the instrument to be placed readily in the horizontal plane.

The binding posts (B-B) are shown on Plate 4, Fig. 7. The one marked (+) should be connected to the platinum-rhodium wire and the one marked (−), to the platinum wire. The platinum wire is the softer of the two.

The temperature of the air surrounding the conducting wires should be about 32°F., to give absolutely correct readings; however, our room was about 65° F. but we made no correction for it as the scale on the instrument could not be read closely enough to warrant such a correction.

C-- MANNER OF CONDUCTING TESTS.

The method of running these tests was as follows:

The apparatus was placed in readiness with the tube packed in, the burner removed from the combustion chamber for lighting and the pyrometer and the thermometers in their proper places. The first step was to turn on the water so there would be no chance of getting the apparatus hot while still dry. The flow of water was regulated so as to give about 750 lbs. per hour. The gas and air tanks were filled. The cock regulating the flow of gas from the tank was opened to a definite position. This position was determined by marks on the stem. The gas was then lighted and the valve regulating the flow of gas into the tank was opened so as to keep the floating tank at a constant height. The air was then turned on, the cock controlling the flow of air from the tank was opened to a position fixed also by marks, which position was nearly wide open. The air tank was also maintained at a constant height by the valve at the entrance to the tank. When the flame became settled the burner was inserted into the combustion chamber.

The apparatus was allowed to heat up to constant condit-

ions, which took about an hour. Readings were then taken, as before specified, every ten minutes, for a period of one hour. Three tests were made upon each tube, all conditions being kept as nearly constant as possible.

The furnace temperature was kept at about 1750°F.or 1800°F.. The position of the burner in the combustion chamber was kept constant, the temperature being regulated by the gas cock.

The temperature of the leaving water was kept between 100°F. and 105°F., this being regulated by the amount of flow.

From the entire number of tubes tested, the results of 11 are chosen as being reliable; the remainder were thrown out for reasons mentioned under "F".

On each tube received was a tag upon which was a number which referred to an accompanying letter giving information as follows:

1. The road and division from which it came.
2. Time in actual service.
3. Number of engine from which it was taken.

After testing the tubes the thickness of scale was measured and samples of the scales were sent to the Chemistry Department for analysis.

All data, including chemical analysis, are contained in the tables of results which follow.

E-- CALCULATIONS.

In making these tests we tried to approach actual conditions as near as possible. In order to do this it was necessary that we should pass through the tubes the maximum amount of heated gases, likewise that they should be as hot as possible.

While we did not evaporate the water, as is done in a steam boiler, owing to the small amount that we would be able to evaporate, we felt that passing through the boiler a large amount of water and discharging it at a temperature considerable below the boiling point, gives much more accurate results, than using a small amount of water and trying

to evaporate it.

The methods of calculating the different items given in the tables is shown here:

(a) CALCULATIONS OF AIR AND GAS PASSING THROUGH THE BURNER.-- In order to measure the amount of gas and air, flowing through the burner, we raised the tanks to their maximum height, closed the inlet valves, then opened the cocks leading to the burner, and noted the time necessary for the tanks to fall a specified distance. By measureing the circumference of the tanks, the area of cross section could be calculated. Multiplying this by the drop in the specified time, we obtained the volume of gas or air passed into the burner in that time. The cross section of the tanks (both tanks alike), shows an area of 442.5 sq.in.. For the air tank to fall 7 in. required 12 sec. and for the gas tank to fall 12 in. it took 70 sec.. This gives a volume of 8.676 cu.ft. of air and 3.634 cu.ft. of gas used per minute.

(b) MERHOD OF CZLCULATING TO COMPARE RESULTS OF TESTS.

Temperature of leaving water = t_1

Temperature of entering water = t_2

Rise in temperature = $t_1 - t_2$

Weight of water passed through boiler = W

B.T.U. transmitted by tube = $W \times (t_1 - t_2)$

Temperature of furnace gases = T_1

Temperature of exhaust gases = T_2

Mean temperature of gases = $\frac{T_1 + T_2}{2}$

Mean temperature of water = $\frac{t_1 + t_2}{2}$

Range of temperature = $\frac{T_1 + T_2}{2} - \frac{t + t}{2}$ = R

B.T.U. per degree range of temperature = $\frac{\text{B.T.U.}}{R}$

*$\frac{\text{B.T.U. (clean tube)}}{\text{Range (clean tube)}} - \frac{\text{B.T.U. (scaled tube)}}{\text{Range (scaled tube)}}$ = Loss.

Loss $\div \frac{\text{B.T.U. (clean tube)}}{\text{Range (clean tube)}}$ = % loss.

*Thomas Preston, in Preston's Heat, pp.629, is authority for the statement that the heat transmitted through the tubes varies directly as the range.

F-- CONCLUSIONS AND REMARKS.

Fromthe inspection of the results it is plain to be seen that boiler tubes covered with scale are uneconomical, or that scale is injurious.

We do not believe that the thickness of the scale has as much effect as does the character or composition of the scale. However, for the same kind of scale we believe that the loss would vary as the thickness. The thickness of the scale upon the tubes that we had was very uneven, so that the effective thickness was hard to determine. We were unable to use half of the tubes sent to us, because of the scale being knocked off in places. The tubes came wrapped in burlap, and while some of them were bad before shipping, others showed the results of bad handling. For this reason we should suggest that in the future, in case these tests are continued, the tubes should be coated with scale at the University. This would enable scale to be distributed over the tubes uniformly. By this means also a comparison can be made for different thicknesses of scale, as scale of uniform character can be produced. We have not decided whether it would be best to coat the tubes by means of heating them in a strong solution, thereby burning on the scale, or by making a paste and painting it on with a brush. The latter method will be the more easily done if the scale willonly adhere to the tubes. We should suggest that the tubes be coated with a thin scale and tested, then another coat put on and again tested, and so on until the desired results are obtained.

To obtain the results shown in the last table we have taken the average of the results obtained from each tube, but in case where two were nearly alike and one considerably different, we have dropped the one.

The matter of testing a locomotive, both before and after the tubes had been cleaned, appealed very strongly to us, but we were unable to get the locomotive to test, hence all of our tests were made on the apparatus shown in the plates.

There were several difficulties which we encountered some of which were as follows:

In the first place we had trouble in lighting our burner. We thought that a blue flame would give the maximum heat, but could not keep it burning, for, as soon as we put the burner into the combustion chamber, the flame would begin puffing and go out. We tried putting a piece of heavy sheet iron, twisted through an angle of 180°, into the end of the burner, but it only made matters worse. Finally we discovered that a quiet yellow flame, burning inside the end of the burner gave the most satisfactory conditions. We also found that with the burner projected clear into the furnace and about 10" of the 3/8" pipe inside the burner, we were able to obtain the most heat.

We tried throttling the flow of the gases at the exhaust end of the tube but soon found this to be a failure.

We took no account of the heating surface in contact with the hot gases. The tubes were all of the same size (1 3/4"), and therefore all had the same area of heating surface, and so long as this remained true, our object, which was to determine the relative efficiency of the scaled tube as compared with the plain tube, was not affected.

At first we intended to run three tests on each tube, varying the furnace temperature at each test; the object of this being to determine whether or not the effect of the scale would be different for various conditions. Later, however, we decided that, by confining ourselves to one range of temperature, and making three tests at this temperature, we should obtain more substantial results. We would recommend that in case this thesis be continued, it should be taken up for a different range of temperature than the one taken by us, so that this point of argument might be settled.

We have divided our tests into two classes. The first group, containing all tests up to number 21, are not considered by us to be of any value. The remainder, however, we believe to be reliable tests. We intended to re-run the first group but did not have time enough.

In starting our work we were unable to get any sheet asbestos to place between the burner and the boiler. The

best insulation that we were able to find was some gas engine packing. This soon burned out and left the head of the boiler exposed to the direct flame of the burner. The more this packing became burned out, the more became the heat transmitted to the water. Finally we secured some 1/4" asbestos board and placed that between our combustion chamber and boiler. Tests from number 21 on were made under these conditions. It may be that still more packing than this would have been advisable, but this seemed to give very good results.

We were also bothered, especially in the early season, by poor gas. We found it impossible, by burning the same amount of gas ans air at different imes, to obtain the same amount of heat. As the air was the greater factor in the amount of hot gases passing through the tube, we governed the heat by regulating the gas cock, rather than the air cock; a very small turn of this cock giving us considerable of a change in temperature.

It is also necessary, in order to maintain a constant temperature, that the inverted tanks remain at a definite position throughout the test, especially the gas tank, as the pressure varies with the position of the tank. As before stated, the conditions throughout should be as near constant as possible; especially is this true of the temperature of the water. The boiler holds about 260 lbs. of water. Should the temperature of the leaving water register one degree more at the end of the test than at the beginning, there are 260 B.T.U. of heat in the boiler, that have been taken from the tube, for which no credit is given.

We should also suggest that a new porcelain tube be obtained for the pyrometer as the broken tube gives very much trouble. It is impossible to pack it to any advantage.

From the data which we have obtained we conclude:

1. That there is a positive loss due to scale.

2. That this loss ranges from about 1.3% to about 8% for common thicknesses of scale.

3. That this loss is not so great as it has often been reported to be.

4. That the loss depends both upon the thickness and composition of the scale.

TEST No. 1.

March 4, 1905.

Tube No. 1. Plain.

Time.	Degrees in Temperature.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
10:30	1481	672	59	96.5
10:40	1499	675	61.5	97
10:50	1512	675	61	98
11:00	1487	675	63	99
11:10	1499	674	65	101
11:20	1517	673	62	100
11:30	1510	675	59	99
Average	1500.7	674.1	61.5	98.6

Water passing through boiler 722 lbs.
Mean temperature of gases 1087.4
Mean temperature of water in boiler 80
Difference 1007.4
Rise in temperature of water 37.1
B.T.U. given up to water 26786
B.T.U. transmitted per degree range of temperature 26.589

TEST No. 2.

March 6, 1905.

Tube No. 1.

Time.	Degrees in temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
10:25	1598	670	59	102
10:35	1613	676	59	102
10:45	1625	675	59.5	100
10:55	1637	670	59	101.5
11:05	1655	675	59	103
11:15	1658	674	59	105
11:25	1664	677	59	105
Average	1635.7	673.9	59.1	102.6

Water passing through boiler 628 Lbs.
Mean temperature of gases 1154.8
Mean temperature of water in boiler 80.8
Difference 1074
Rise in temperature of water 43.5
B.T.U. given up to water 27318
B.T.U. transmitted per degree range of temperature 25.436

TEST No. 3.

March 6, 1905.

Tube No. 1.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:40	1670	672	59	99
11:50	1673	674	59	96
12:00	1678	675	59	96
12:10	1685	674	59	96
12:20	1685	676	59	96
12:30	1688	676	59	96
12:40	1688	676	59	96
Average	1681	674.7	59	96.4

Water passing through boiler 780 lbs.
Mean temperature of gases 1177.8
Mean temperature of water in boiler 77.7
Difference 1100.1
Rise in temperature of water 37.4
B.T.U. given up to water 29172
B.T.U. transmitted per degree range of temperature 26.517

TEST No. 4.

March 7, 1905.

Tube No. 1.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
2:30	1616	980	58.5	102
2:40	1604	985	58.5	102.5
2:50	1598	980	58.8	103
3:00	1607	987	58.8	99
3:10	1598	985	58.7	96
3:20	1595	980	58.7	95
3:30	1592	980	59	95
Average	1601.4	982.4	58.7	98.9

Water passing through boiler 776 lbs.
Mean temperature of gases 1291.9
Mean temperature of water in boiler 78.8
Difference 1213.1
Rise in temperature of water 40.2
B.T.U. given up to water 31195
B.T.U. transmitted per degree range of temperature 25.715

TEST No. 5.

March 11, 1905.

Engine No.533. Tube No.2.

Road- Big Four. Mean thickness of scale .057 in.

Running between Character of scale- Soft and

Indianapolis & Springfield, O. porous.

Time in use 10 mo.

CHEMICAL ANALYSIS.

Constituents.	$Si\ O_2$	$Fe_2\ O_3$ $Al_2\ O_3$	$Ca\ SO_4$	$Ca\ CO_3$	Ca O
Amount in %-	8.03	2.60	14.44	45.29	

Constituents.	$Mg\ CO_3$	Mg O	Moist.	Org.Mat. and Alk.	
Amount in %.		18.13	0.68	10.83	

Time.	Degrees in temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
9:45	1649	668	58.5	102
9:55	1643	674	58.5	101
10:05	1652	671	58.5	101
10:15	1665	670	58.5	100
10:25	1661	675	58.5	100
10:35	1670	670	58.5	100
10:45	1658	674	58.5	100
Average	1636.9	671.7	58.5	100.6

Water passed through boiler 693 lbs.

Mean temperature of gases 1164.3

Mean temperature of water in boiler 79.5

Difference 1084.8

Rise in temperature of water 42.1

B.T.U. given up to water 29175

B.T.U. transmitted per degree range of temperature 26.895

TEST No. 6.

March 18, 1905.

Tube No. 2.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:20	1733	718	62	102.5
11:30	1736	720	62	103
11:40	1736	727	62	104
11:50	1736	734	62	105
12:00	1736	733	62	106
12:10	1736	731	62	105
12:20	1739	735	61.5	107
Average	1736	728.3	61.9	104.6

Water passed through boiler 668 lbs.
Mean temperature of gases 1232.1
Mean temperature of water 83.2
Difference 1148.9
Rise in temperature of water 42.7
B.T.U. given up to water 28524
B.T.U. transmitted per degree range of temperature 24.827

TEST No. 7.

March 25, 1905.

Tube No. 2.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
10:50	1693	745	59	101
11:00	1693	750	59	102
11:10	1693	757	59	101
11:20	1693	762	59	101
11:30	1706	765	59	101
11:40	1706	765	59	101
11:50	1706	766	59	101
Average	1698.6	758.6	59	101.1

Water passed through boiler 700 lbs.
Mean temperature of gases 1228.6
Mean temperature of water in boiler 80
Difference 1148.6
Rise in temperature of water 42.1
B.T.U. given up to water 29470
B.T.U. transmitted per degree range of temperature 25.657

TEST No. 8.

March 25, 1905.

Tube No. 2.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
12:00	1710	760	59	101
12:10	1710	765	59	101
12:20	1710	765	59	101
12:30	1706	765	59	101
12:40	1710	768	59	101
12:50	1710	769	59	101
1:00	1706	766	59	101
Average	1708.9	765.4	59	101

Water passed through boiler 677 lbs.
Mean temperature of gases 1237.1
Mean temperature of water in boiler 80
Difference 1157.1
Rise in temperature of water 42
B.T.U. given up to water 28434
B.T.U. transmitted per degree range of temperature 24.573

TEST No. 9.

March 27, 1905.

Engine No.136. Tube No.3.

Road- I.C. Mean thickness of scale .065 in.

Division- Chicago Terminal. Character of scale- Medium.

Time in use 18 mo.

5.05 acs 1/31/07

CHEMICAL ANALYSIS.

Constituents.	SiO_2	Fe_2O_3 Al_2O_3	$CaSO_4$	$CaCO_3$	CaO
Amount in %.	7.09	2.30	17.16	19.45	

Constituents.	$MgCO_3$	MgO	Moist.	Org.Mat. and Alk.	
Amount in %.	.77	34.10	.58	15.80	

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:30	1688	680	60	104
11.40	1690	683	60	103
11:50	1693	675	60	102
12:00	1693	667	60	101
12:10	1693	685	60	101
12:20	1697	677	60	100
12:30	1698	675	60	100
Average	1693.1	677.4	60	101.6

Water passed through boiler 773 lbs.

Mean temperature of gases 1185.2

Mean temperature of water in boiler 80.8

Difference 1104.4

Rise in temperature of water 41.6

B.T.U. given up to water 32147

B.T.U. transmitted per degree range in temperature 29.117

TEST No. 10.

March 27, 1905.

Tube No. 3.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:05	1706	680	60	101
1:15	1706	670	60	100
1:25	1708	678	60	100
1:35	1706	675	60	101
1:45	1706	672	60	102
1:55	1706	670	60	101
2:05	1704	675	60	101
Average	1706	674.3	60	100.9

Water passed through boiler 748 lbs.
Mean temperature of gases 1190.1
Mean temperature of water in boiler 80.4
Difference 1109.7
Rise in temperature in water 40.9
B.T.U. given up to water 30593
B.T.U. transmitted per degree range of temperature 27.569

TEST No. 11.

March 27, 1903.

Tube No. 3.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
2:15	1702	727	60	101
2:25	1702	735	60	102
2:35	1720	750	60	102
2:45	1720	735	60	98
2:55	1727	730	60	102
3:05	1735	737	60	97
3:15	1730	742	60	98
Average	1789.4	736.6	60	100

Water passed through boiler 772 lb.

Mean temperature of gases 1228

Mean temperature of water in boiler 80

Difference 1148

Rise in temperature of water 40

B.T.U. given up to water 30880

B.T.U. transmitted per degree range of temperature 26.899

TEST No. 12.

March 28, 1905.

Engine No.802. Tube No.4.

Road- I.C. Mean thickness of scale .047 in.

Running between Character of scale- Hard.

Centralia & Mounds.

Time in use 8 mo.

CHEMICAL ANALYSIS.

Constituents.	$Si\ O_2$	$Fe_2\ O_3$ $Al_2\ O_3$	$Ca\ SO_4$	$Ca\ CO_3$	Ca O
Amount in %.	6.92	3.57	21.57	3.61	25.61

Constituents.	$Mg\ CO_3$	Mg O	Moist.	Org.Mat. and Alk.	
Amount in %.		1.85	0.56-	36.31	

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
2:20	1688	703	61	104
2:30	1690	710	60	104
2:40	1698	700	60.6	104
2:50	1693	692	60.8	104
3:00	1698	698	60.3	105
3:10	1695	690	61	103
3:20	1697	693	60.3	104
Average	1694.1	698	60.6	104

Water passed through boiler 747 lbs.

Mean temperature of gases 1196

Mean temperature of water in boiler 82.3

Difference 1113.7

Rise in temperature of water 43.4

B.T.U. given up to water 32420

B.T.U. transmitted per degree range of temperature 29.11

TEST No. 13.

March 28, 1905.

Tube No. 4.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
3:25	1698	697	60.5	103.5
3:35	1704	698	61	102.5
3:45	1700	693	60	102.5
3:55	1700	692	60	102
4:05	1702	693	60	102
4:15	1702	695	60	102
4:25	1702	692	60	102
Average	1701.1	694.3	60.2	102.4

Water passed through boiler 784 lbs.
Mean temperature of gases 1297.7
Mean temperature of water in boiler 81.3
Difference 1216.4
Rise in temperature of water 42.2
B.T.U. given up to water 33085
B.T.U. transmitted per degree range of temperature 27.199

TEST No. 14.

March 28, 1905.

Tube No. 4.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
4:30	1706	691	60	102.5
4:40	1703	698	60	102
4:50	1700	703	60	102.5
5:00	1700	702	60	101.5
5:10	1701	711	60	102
5:20	1708	705	60	103
5:30	1708	703	60	103.3
Average	1703.7	701.9	60	102.4

Water passed through boiler 780 lbs.
Mean temperature of gases 1202.8
Mean temperature of water in boiler 81.2
Difference 1121.6
Rise in temperature of water 42.4
B.T.U. given up to water 33072
B.T.U. transmitted per degree range of temperature 29.486

TEST No. 15.

March 31, 1905.

Engine No.722. Tube No.5.
Road- I.C. Mean thickness of scale .08 in.
Division- Chicago Terminal. Character of scale- Soft & Red.
Time in use 8 mo.

CHEMICAL ANALYSIS.

Constituents.	$Si\ O_2$	$Fe_2\ O_3$ $Al_2\ O_3$	$Ca\ SO_4$	$Ca\ CO_3$	$Ca\ O$
Amount in %.	10.48	11.95	4.37	55.24	5.50

Constituents.	$Mg\ CO_3$	$Mg\ O$	Moist.	Org.Mat. and Alk.	
Amount in %.		3.17	1.55	7.74	

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
10:10	1737	775	61	103
10:20	1742	775	61	103.5
10:30	1751	775	61	103.5
10:40	1751	795	61	104
10:50	1740	795	61	104
11:00	1740	800	61	104.5
11:10	1740	800	61	104.5
Average	1743	787.9	61	103.9

Water passing through boiler 732 lbs.
Mean temperature of gases 1265.4
Mean temperature of water in boiler 82.4
Difference 1183
Rise in temperature of water 42.9
B.T.U. given up to water 31493
B.T.U. transmitted per degree range of temperature 26.545

TEST No. 16.

March 31, 1905.

Tube No. 5.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:25	1737	795	61	107
11:35	1728	796	61	106
11:45	1728	802	61	106.5
11:55	1724	807	61	106.5
12:05	1724	802	61	105
12:15	1726	809	61	107.5
12:25	1733	809	61	106
Average	1728.6	802.9	61	106.4

Water passed through boiler 722 lbs.
Mean temperature of gases 1265.7
Mean temperature of water in boiler 83.7
Difference 1182
Rise in temperature in water 45.4
B.T.U. given up to water 32779
B.T.U. transmitted per degree rise of temperature 27.732

TEST No. 17.

March 31, 1905.

Tube No. 5.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
12:55	1751	800	61,5	101.5
1:05	1755	800	61.5	102
1:15	1765	808	61.5	102
1:25	1760	808	61.5	102
1:35	1763	798	62.5	102.5
1:45	1765	806	62	101.5
1:55	1765	815	62.5	102.5
Average	1760.6	805	61.9	102

Water passed through boiler 781 lbs.
Mean temperature of gases 1282.8
Mean temperature of water in boiler 81.9
Difference 1200.9
Rise in temperature of water 40.1
B.T.U. given up to water 31318
B.T.U. transmitted per degree range of temperature 26.079

TEST No. 18.

April 3, 1905.

Engine No.1420. Tube No.6.

Road- I.C. Mean thickness of scale .075 in.

Division- Chicago Terminal. Character of scale- Hard.

Time in use 2 yrs.

CHEMICAL ANALYSIS.

Constituents.	SiO_2	Fe_2O_3 Al_2O_3	$CaSO_4$	$CaCO_3$	CaO
Amount in %.	10.56	4.89	43.26	9.57	

Constituents.	$MgCO_3$	MgO	Moist.	Org.Mat. And Alk.	
Amount in %.		24.38	0.82	6.52	

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:40	1782	745	60	99
11:50	1787	741	60	101.5
12:00	1796	751	60	102.5
12:10	1796	760	60	102
12:20	1796	780	60	102
12:30	1790	775	60	102
12:40	1796	780	60	102
Average	1791.9	761.7	60	101.6

Water passed through boiler 699 lbs.

Mean temperature of gases 1276.8

Mean temperature of water in boiler 80.8

Difference 1196

Rise in temperature of water 41.6

B.T.U. given up to water 29078

B.T.U. transmitted per degree range of temperature 24 313

TEST No. 19.

April 3, 1905.

Tube No. 6.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:25	1760	817	61	102
1:35	1769	790	60	101
1:45	1769	805	60	101.5
1:55	1772	803	60	102
2:05	1772	805	60	102.5
2:15	1773	808	60	102.5
2:25	1778	805	60	103
Average	1770.4	804.7	60.1	102.1

Water passed through the boiler 767 lbs.

Mean temperature of gases 1287.5

Mean temperature of water in boiler 81.1

Difference 1206.4

Rise in temperature of water 42

B.T.U. given up to water 32214

B.T.U. transmitted per degree range of temperature 26.703

TEST No. 20.

April 3, 1905.

Tube No. 6.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
2:50	1757	810	60.5	99.5
3:00	1757	817	61	101
3:10	1751	795	61	102.5
3:20	1757	792	61	103
3:30	1760	785	61	102
3:40	1760	785	60	102
3:50	1760	785	60.5	101.5
Average	1757.4	795.6	60.7	101.6

Water passed through boiler 761 lbs.

Mean temperature of gases 1276.5

Mean temperature of water in boiler 81.1

Difference 1195.4

B.T.U. given up to water 31125

B.T.U. transmitted per degree range of temperature 26.037

TEST No. 21.

April 15, 1905.

Tube No. 7. Plain.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
10:50	1783	798	65	101
11:00	1787	795	64.5	101
11:10	1782	788	64	102
11:20	1796	795	64.5	102
11:30	1796	805	64.5	103
11:40	1805	798	64.2	103
11:50	1796	779	64.5	103
Average	1792.1	794	64.5	102.1

Water passed through boiler 782 lbs.
Mean temperature of gases 1293
Mean temperature of water in boiler 83.3
Difference 1219.7
Rise in temperature of water 37.6
B.T.U. given up to water 29403
B.T.U. transmitted per degree range ot temperature 24.107

TEST No. 22.

April 15, 1905.

Tube No. 7.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:55	1800	780	64.5	104
12:05	1796	780	64.5	104
12:15	1796	788	64.3	105
12:25	1793	780	64.2	104
12:35	1780	780	64	101
12:45	1796	800	64	103
12:55	1814	800	64	104.5
Average	1796.4	786.9	64.2	103.6

Water passed through boiler 754 lbs.
Mean temperature of gases 1291.6
Mean temperature of water in boiler 83.9
Difference 1207.7
Rise in temperature of water 39.4
B.T.U. given up to water 29708
B.T.U. transmitted per degree range of temperature 24.598

TEST No. 23.

April 15, 1905.

Tube No. 7.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:05	1814	780	63.7	101
1:15	1794	775	63.5	101
1:25	1814	804	63.3	104
1:35	1800	780	63.2	100
1:45	1809	789	63.1	102
1:55	1800	780	63	100.5
2:05	1823	777	63	101.5
Average	1807.7	783.6	63.3	101.4

Water passing through boiler 776 lbs.
Mean temperature of gases 1295.6
Mean temperature of water in boiler 82.3
Difference 1213.3
Rise in temperature of water 38.1
B.T.U. given up to water 29566
B.T.U. transmitted per degree range of temperature 24.368

TEST No. 24.

April 5, 1905.

Engine No.533. Tube No.8.

Road- Big Four. Mean thickness of scale .033 in.

Running between Character of scale- Soft.

Indianapolis & Springfield, O.

Time in use 10 mo.

CHEMICAL ANALYSIS.

Constituents.	SiO_2	Fe_2O_3 Al_2O_3	$CaSO_4$	$CaCO_3$	CaO
Amount in %.	6.61	1.34	0.62	74.26	

Constituents.	$MgCO_3$	MgO	Moist.	Org. Mat. and Alk.	
Amount in %.	0.15	10.87	0.68	5.47	

Time.	Degrees in Temperature. F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
12:45	1792	735	59.5	102.5
12:55	1787	734	59.5	102
1:05	1787	740	59.7	102.5
1:15	1787	743	59.5	102.5
1:25	1787	747	59.8	103
1:35	1787	740	60	103
1:45	1787	738	60	103.5
Average	1787.7	739.6	59.7	102.7

Water passed through boiler 641 lbs.

Mean temperature of gases 1263.6

Mean temperature of water in boiler 81.2

Difference 1182.4

Rise in temperature of water 43

B.T.U. given up to water 27563

B.T.U. transmitted per degree range in temperature 23.311

Loss due to scale 1.046 B.T.U.

Loss in per cent 4.3

TEST No. 25.

April 3, 1905.

Tube No. 8.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:55	1787	742	60	105
2:05	1787	750	60.5	107
2:15	1785	742	60	103.5
2.25	1789	740	60	101
2:35	1805	745	60	100
2:45	1789	740	60	99.5
2:55	1789	742	60	101
Average	1790.1	743	60.1	102.4

Water passing through boiler 660 lbs.
Mean temperature of gases 1266.5
Mean temperature of water in boiler 81.2
Difference 1185.3
Rise in temperature of water 42.3
B.T.U. given up to water 27918
B.T.U. transmitted per degree range of temperature 23.554
Loss due to scale 0.803 B.T.U.
Loss in per cent 4.3 3.29

TEST No. 26.

April 5, 1905.

Tube No. 8.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
3:00	1792	750	60	101
3:10	1805	746	60	101
3:20	1810	749	60	102
3:30	1818	745	60	102
3:40	1809	737	60.3	102
3:50	1800	735	60	102
4:00	1798	740	60.2	102
Average	1804.6	743.1	60.1	101.7

Water passed through boiler 656 lbs.
Mean temperature of gases 1273.8
Mean temperature of water in boiler 80.9
Difference 1192.9
Rise in temperature of water 41.6
B.T.U. given up to water 27290
B.T.U. transmitted per degree range of temperature 22.877
Loss due to scale 1.45 B.T.U.
Loss in per cent 5.96

TEST No. 27.

April 7, 1905.

Engine No.233. Tube No.9.

Road- Big Four. Mean thickness of scale .089 in.

Running between Character of scale- Very soft.

Cincinnati & Delaware, O.

Time in use 14 mo.

CHEMICAL ANALYSIS.

Constituents.	$Si\ O_2$	$Fe_2\ O_3$ $Al_2\ O_3$	$Ca\ SO_4$	$Ca\ CO_3$	Ca O
Amount in %.	8.44	2.52	12.59	56.80	

Constituents.	$Mg\ CO_3$	Mg O	Moist.	Org.Mat. and Alk.	
Amount in %.	0.33	11.43	0.87	7.02	

Time.	Degrees in Temperature.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
5:40	1757	787	60	102
5:50	1758	793	60	103
6:00	1755	791	59.7	100
6:10	1748	790	59.5	99
6:20	1748	790	60	101
6:30	1745	790	60	101.5
6:40	1755	799	60	101
Average	1752.3	791.4	59.9	101.1

Water passed through boiler 683 lbs.

Mean temperature of gases 1271.8

Mean temperature of water in boiler 80.5

Difference 1191.3

Rise in temperature of water 41.2

B.T.U. given up to water 28140

B.T.U. transmitted per degree range of temperature 23.621

Loss due to scale 0.736 B.T.U.

Loss in per cent 3.02

TEST No. 28.

April 7, 1905.

Tube No. 9.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
6.50	1756	798	60	100
7:00	1754	805	60	100
7:10	1754	805	60	100.5
7:20	1751	803	60	100.5
7:30	1751	802	60	101
7:40	1748	800	60	101.5
7:50	1754	788	60	101
Average	1752.6	800.1	60	100.6

Water passed through boiler 682 lbs.
Mean temperature of gases 1276.3
Mean temperature of water in boiler 80.3
Difference 1196
Rise in temperature of water 40.6
B.T.U. given up to water 27689
B.T.U. transmitted per degree range of temperature 23.151
Loss due to scale 1.206 B.T.U.
Loss in per cent 4.95

TEST No. 29.

April 7, 1905.

Tube No. 9.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
8:00	1751	784	60	100.5
8:10	1748	781	60	101
8:20	1753	787	60	100.5
8:30	1769	800	59.5	101
8:40	1769	798	59.5	101.5
8:50	1773	800	59.5	100
9:00	1778	804	59.5	100
Average	1763	793.4	59.7	100.6

Water passed through boiler 695 lbs.
Mean temperature of gases 1278.2
Mean temperature of water in boiler 80.1
Difference 1198.1
Rise in temperature of water 40.9
B.T.U. given up to water 28426
B.T.U. transmitted per degree range of temperature 23.726
Loss due to scale 0.631 B.T.U.
Loss in per cent 2.56

TEST No. 30.

April 7, 1905.

Engine No.1424. Tube No.10.

Road- I.C. Mean thickness of scale .07 in.

Division- Chicago Terminal. Character of scale- Soft.

Time in use 10 mo.

CHEMICAL ANALYSIS.

Constituents.	SiO_2	Fe_2O_3 Al_2O_3	$CaSO_4$	$CaCO_3$	CaO
Amount in %.	3.33	1.43	5.82	67.99	1.64

Constituents.	$MgCO_3$	MgO	Moist.	Org.Mat. and Alk.	
Amount in %.		11.11	0.48	8.20	

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:20	1778	791	59.2	101
11:30	1758	779	59	100.5
11:40	1769	788	59.7	104
11:50	1773	787	59.4	105
12:00	1769	780	59	97
12:10	1769	782	58.5	100.5
12:20	1787	797	58.5	101
Average	1771.9	786.3	59.	101.2

Water passed through boiler 674 lbs.

Mean temperature of gases 1279.1

Mean temperature of water in boiler 80.1

Difference 1199

Rise in temperature of water 42.3

B.T.U. given up to water 28510

B.T.U. transmitted per degree range of temperature 23.778

Loss due to scale 0.579 B.T.U.

Loss in per cent 2.38

TEST No. 31.

April 8, 1905.

Tube No. 10.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
12:30	1778	783	58.3	100
12:40	1769	775	58.2	101
12:50	1782	790	58.8	102
1:00	1787	792	59.2	104
1:10	1787	790	59.2	103
1:20	1787	790	59	101
1:30	1787	793	59	99.5
Average	1782.4	787.6	58.8	101.8

Water passed through boiler 663 lbs.
Mean temperature of gases 1285
Mean temperature of water in boiler 80.3
Difference 1204.7
Rise in temperature of water 43
B.T.U. given up to water 28509
B.T.U. transmitted per degree range of temperature 23.665
Loss due to scale 0.692 B.T.U.
Loss in per cent 2.84

TEST No. 32.

April 8, 1905.

Tube No. 10.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:35	1787	790	59	100.5
1:45	1778	786	59	100.5
1:55	1778	790	59	101
2:05	1785	790	59	101.5
2:15	1787	795	59	102
2:25	1783	795	59.2	102
2:35	1783	795	59.2	102
Average	1783	791.6	59.1	101.4

Water passed through boiler 671 lbs.
Mean temperature of gases 1287.3
Mean temperature of water in boiler 80.2
Difference 1207.1
Rise in temperature of water 42.3
B.T.U. given up to water 28383
B.T.U. transmitted per degree range of temperature 23.513
Loss due to scale 0.844 B.T.U.
Loss in per cent 3.47

TEST No. 33.

April 10, 1905.

Engine No.233 Tube No.11.

Road- Big Four. Mean thickness of scale .042 in.

Running between Character of scale- Very soft.

Cincinnati & Delaware, O.

Time in use 14 mo.

CHEMICAL ANALYSIS.

Constituents.	$Si\ O_2$	$Fe_2\ O_3$ $Al_2\ O_3$	$Ca\ SO_4$	$Ca\ CO_3$	Ca O
Amount in %.	7.09	2.30	14.87	58.18	

Constituents.	$Mg\ CO_3$	Mg O	Moist.	Org.Mat. and Alk.	
Amount in %.	2.22	8.26	0.75	6.33	

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:00	1766	798	66.7	101.5
11.10	1769	802	66.7	102.5
11.20	1771	802	66.9	102
11.30	1771	802	67	102
11.40	1782	807	67	102
11:50	1760	795	67.2	103
12:00	1774	800	67	103
Average	1770.4	800.9	66.9	102.3

Water passed through boiler 724 lbs.

Mean temperature of gases 1285.6

Mean temperature of water in boiler 84.6

Difference 1201

Rise in temperature of water 35.4

B.T.U. given up to water 25630

B.T.U. transmitted per degree range of temperature 21.341

Loss due to scale 3.016 B.T.U.

Loss in per cent 12.39

TEST No. 34.

April 10, 1905.

Tube No. 11.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
12:05	1782	807	67	104
12:15	1778	805	67.2	104
12:25	1765	805	67.2	103.5
12:35	1768	803	67.2	104
12:45	1780	803	67.2	103
12:55	1780	804	67	103
1:05	1780	805	67	100
Average	1776.1	804.6	67.1	103.1

Water passed through boiler 767 lbs.
Mean temperature of gases 1290.3
Mean temperature of water in boiler 85.1
Difference 1205.2
Rise in temperature of water 36
B.T.U. given up to water 27612
B.T.U. transmitted per degree range of temperature 22.911
Loss due to scale 1.446 B.T.U.
Loss in per cent 5.95

TEST No. 35.

April 10, 1905.

Tube No. 11.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:15	1760	790	67	100
1:25	1778	795	67	100.5
1:35	1787	802	67	101.5
1:45	1785	805	67	103
1:55	1796	810	67	105
2:05	1796	810	67	106
2:15	1794	810	67	101
Average	1785.1	803.1	67	102.4

Water passed through boiler 753 lbs.
Mean temperature of gases 1294.1
Mean temperature of water in boiler 84.7
Difference 1209.4
Rise in temperature of water 35.4
B.T.U. given up to water 26656
B.T.U. transmitted per degree range of temperature 22.041
Loss due to scale 2.316 B.T.U.
Loss in per cent 9.54

TEST No. 36.

April 11, 1905.

Engine No.140 Tube No.12.

Road- I.C. Mean thickness of scale .07 in.

Division- Chicago Dist. Character of scale- Hard.

Time in use 21 mo.

CHEMICAL ANALYSIS.

Constituents.	SiO_2	Fe_2O_3 Al_2O_3	$CaSO_4$	$CaCO_3$	CaO
Amount in %.	27.72	9.53	12.11	10.05	0.24

Constituents.	$MgCO_3$	MgO	Moist.	Org.Mat. and Alk.	
Amount in %.		29.90	1.07	9.38	

Time.	Degrees in temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:30	1760	795	64.7	102
1:40	1773	808	64.7	103
1:50	1773	795	65.5	103
2:00	1755	788	68	105
2:10	1757	793	65	106
2:20	1772	807	64	103
2:30	1778	805	64.5	102.5
Average	1766.9	798.7	65.2	103.5

Water passed through boiler 694 lbs.

Mean temperature of gases 1282.8

Mean temperature of water in boiler 84.3

Difference 1198.5

Rise in temperature of water 38.3

B.T.U. given up to water 26580

B.T.U. transmitted per degree range of temperature 22.178

Loss due to scale 2.179 B.T.U.

Loss in per cent 8.95

TEST No. 37.

April 11. 1905.

Tube No. 12.

Time.	Degrees in Temperature. F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
2:35	1778	808	64.7	103.5
2:45	1773	805	64.7	100.5
2:55	1765	800	65	101
3:05	1769	805	65	102
3:15	1769	804	64.2	102
3:25	1790	804	64.1	102.5
3:35	1787	800	64	103
Average	1775.9	803.7	64.5	102.1

Water passed through boiler 747 lbs.
Mean temperature of gases 1289.8
Mean temperature of water in boiler 83.3
Difference 1206.5
Rise in temperature of water 37.6
B.T.U. given up to water 28087
B.T.U. transmitted per degree range of temperature 23.280
Loss due to scale 1.077 B.T.U.
Loss in per cent 4.43

TEST No. 38.

April 11, 1905.

Tube No. 12.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
3:40	1787	801	64	103
3:50	1760	780	64	101.5
4:00	1800	805	64	102
4:10	1787	790	64.2	102
4:20	1792	787	64.1	102
4:30	1782	780	64	102
4:40	1784	785	64	102.5
Average	1784.6	789.7	64	102.1

Water passed through boiler 721 lbs.
Mean temperature of gases 1287.1
Mean temperature of water in boiler 83
Difference 1204.1
Rise in temperature of water 38.1
B.T.U. given up to water 27470
B.T.U. transmitted per degree range of temperature 22.814
Loss due to scale 1.543 B.T.U.
Loss in per cent 6.35

TEST No. 39.

April 12, 1905.

Engine No.303. Tube No. 13.
Road- I.C. Mean thickness of scale .02 in.
Division- Chicago Dist. Character of scale- Hard.
Time in use 18 mo.

CHEMICAL ANALYSIS.

Constituents.	$Si\ O_2$	$Fe_2\ O_3$ $Al_2\ O_3$	$Ca\ SO_4$	$Ca\ CO_3$	$Ca\ O$
Amount in %.	9.54	10.38	8.41	9.67	3.87

Constituents.	$Mg\ CO_3$	$Mg\ O$	Moist.	Org.Mat. and Alk.	
Amount in %.		39.09	0.71	18.33	

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:50	1760	745	60.5	101
12:00	1765	743	60	101.5
12:10	1773	737	60.4	101.5
12:20	1778	742	60.3	101.5
12:30	1770	728	60	101.5
12:40	1755	738	60	102
12:50	1760	748	60	101
Average	1765.9	740.1	60.2	101.4

Water passed through boiler 679 lbs.
Mean temperature of gases 1253
Mean temperature of water in boiler 80.8
Difference 1172.2
Rise in temperature of water 41.2
B.T.U. given up to water 27975
B.T.U. transmitted per degree range of temperature 23.865
Loss due to scale 0.492 B.T.U.
Loss in per cent 2.02

TEST No. 40.

April 12, 1905.

Tube No. 13.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:00	1755	755	60.7	102
1:10	1760	745	60.7	104
1:20	1767	738	60.7	103
1:30	1758	750	60.7	103
1:40	1746	752	60.7	104
1:50	1746	752	60.7	102
2:00	1746	745	60.9	102
Average	1754	748.1	60.7	102.9

Water passed through boiler 668 lbs.
Mean temperature of gases 1251
Mean temperature of water in boiler 81.8
Difference 1169.2
Rise in temperature of water 42.2
B.T.U. given up to water 28190
B.T.U. transmitted per degree range of temperature 24.110
Loss due to scale 0.246 B.T.U.
Loss in per cent 1.01

TEST No. 41.

April 12, 1905.

Tube No. 13.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
2:05	1742	745	61	102
2:15	1744	735	61	101
2:25	1751	728	61	101
2:35	1748	735	61	101.5
2:45	1749	737	61.2	101.5
2:55	1746	738	61.5	102
3:05	1746	735	61.7	101.5
Average	1746.6	736.1	61.2	101.5

Water passed through boiler 695 lbs.
Mean temperature of gases 1241.3
Mean temperature of water in boiler 81.3
Difference 1160
Rise of temperature of water 40.3
B.T.U. given up to water 28009
B.T.U. transmitted per degree range of temperature 24.146
Loss due to scale 0.211 B.T.U.
Loss in per cent 0.87

TEST No. 42.

April 17, 1905.

Engine No.1004. Tube No. 14.

Road- I.C. Mean thickness of scale .038 in.

Division- Fulton District. Character of scale- Medium.

Time in use 21 mo.

CHEMICAL ANALYSIS.

Constituents.	SiO_2	Fe_2O_3 Al_2O_3	$CaSO_4$	$CaCO_3$	CaO
Amount in %.	16.87	4.73	2.22	40.30	6.06

Constituents.	$MgCO_3$	MgO	Moist.	Org.Mat. and Alk.	
Amount in %.		19.25	0.83	9.74	

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:10	1787	790	58.5	102
11:20	1781	810	58.5	103
11:30	1781	813	58.5	103
11:40	1785	810	58.5	103
11:50	1787	806	58.5	102
12:00	1792	805	58.5	102
12:10	1798	800	58.5	102
Average	1787.3	804.9	58.5	102.4

Water passed through boiler 670 lbs.

Mean temperature of gases 1296.1

Mean temperature of water in boiler 80.4

Difference 1215.7

Rise in temperature of water 43.9

B.T.U. given up to water 29413

B.T.U. transmitted per degree range of temperature 24.194

Loss due to scale 0.163 B.T.U.

Loss in per cent 0.67

TEST No. 43.

April 17, 1905.

Tube No. 14.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
12:20	1796	808	58.5	102
12:30	1796	807	58.5	102.5
12:40	1804	807	58.5	102
12:50	1809	805	58.5	102
1:00	1805	812	58.5	102
1:10	1810	810	58.5	102
1:20	1814	805	58.5	102
Average	1804.9	807.7	58.5	102.1

Water passed through boiler 657 lbs.
Mean temperature of gases 1306.3
Mean temperature of water in boiler 80.3
Difference 1226
Rise in temperature of water 43.6
B.T.U. given up to water 28645
B.T.U. transmitted per degree range of temperature 23.365
Loss due to scale 0.992 B.T.U.
Loss in per cent 4.07

TEST No. 44.

April 17, 1905.

Tube No. 14.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:40	1796	795	58.7	104
1:50	1787	805	58.7	103.5
2:00	1800	810	58.7	105
2.10	1794	803	58.7	102
2:20	1787	800	59	99
2:30	1785	803	59	103
2:40	1796	805	59	104
Average	1792.1	803.3	58.8	102.9

Water passed through boiler 645 lbs.
Mean temperature of gases 1297.7
Mean temperature of water in boiler 80.8
Difference 1216.9
Rise in temperature of water 44.1
B.T.U. given up to water 28445
B.T.U. transmitted per degree range of temperature 23.375
Loss due to scale 0.982 B.T.U.
Loss in per cent 4.03

TEST No. 45.

April 21, 1905.

Tube No. 4.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
9:30	1814	740	61.7	102
9:40	1814	745	62	102
9:50	1814	735	62.2	102
10:00	1814	735	62.5	102.5
10:10	1823	727	62.5	103
10:20	1823	730	62.3	105
10:30	1810	720	62.5	101.5
Average	1816 ✓	733.1 ✓	62.2 ✓	102.6 ✓

Water passed through boiler 699 lbs.
Mean temperature of gases 1274.5
Mean temperature of water in boiler 82.4
Difference 1192.1
Rise in temperature of water 40.4
B.T.U. given up to water 28340
B.T.U. transmitted per degree range of temperature 23.689
Loss due to scale 0.668 B.T.U.
Loss in per cent 2.75

TEST No. 46.

April 21, 1905.

Tube No. 4.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
10:40	1812	715	62.8	100.5
10:50	1830	721	63	102.5
11:00	1805	725	63	104
11:10	1796	715	63.1	103
11:20	1787	713	63.2	103
11:30	1835	710	63.3	100
11:40	1800	705	63.3	101
Average	1809.3 ✓	714.9 ✓	63.2 ✓	102 ✓

Water passed through boiler 707 lbs.
Mean temperature of gases 1262.1
Mean temperature of water in boiler 82.6
Difference 1179.5
Rise in temperature of water 38.8
B.T.U. given up to water 27432
B.T.U. transmitted per degree range of temperature 23.257
Loss due to scale 1.10 B.T.U.
Loss in per cent 4.53

TEST No. 47.

April 21, 1905.

Tube No. 4.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
11:50	1814	710	63.5	102.5
12:00	1778	700	63.5	102
12:10	1780	700	63.5	101
12:20	1814	712	63.3	103
12:30	1820	705	63.3	104
12:40	1810	700	63	102.5
12:50	1823	706	62.8	102
Average	1805.6	704.7	63.3	102.4

Water passed through boiler 692 lbs.
Mean temperature of gases 1255.1
Mean temperature of water in boiler 82.8
Difference 1172.3
Rise in temperature of water 39.1
B.T.U. given up to water 27057
B.T.U. transmitted per degree range of temperature 23.080
Loss due to scale 1.277 B.T.U.
Loss in per cent 5.25

TEST No. 48.

April 18, 1905.

Tube No. 3.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
2:05	1796	864	62.2	103.5
2:15	1778	870	62.2	103.5
2:25	1783	876	62.3	103.5
2:35	1778	872	62.5	103.5
2:45	1787	873	62.5	103.5
2:55	1783	878	62.5	104.5
3:05	1778	874	62.6	103.5
Average	1783.3 ✓	872.7 ✓	62.4 ✓	103.6 ✓

Water passed through boiler 717 lbs.

Mean temperature of gases 1228

Mean temperature of water in boiler 83

Difference 1245

Rise in temperature of water 41.2

B.T.U. given up to water 29540

B.T.U. transmitted per degree range of temperature 23.727

Loss due to scale 0.630 B.T.U.

Loss in per cent 2.59

TEST No. 49.

April 18, 1903.

Tube No. 3.

Time.	Degrees in Temperature. F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
3:10	1783	876	62.5	101.5
3:20	1785	878	62.5	101.7
3:30	1783	882	62.5	104
3:40	1783	882	62.5	103
3:50	1781	873	62.3	101.5
4:00	1774	874	62.2	101.5
4:10	1778	880	62.1	101.5
Average	1781	873.6	62.4	102.1

Water passed through boiler 753 lbs.
Mean temperature of gases 1329.8
Mean temperature of water in boiler 82.2
Difference 1247.6
Rise in temperature of water 39.7
B.T.U. given up to water 29894
B.T.U. transmitted per degree range of temperature 23.961
Loss due to scale 0.396 B.T.U.
Loss in per cent 1.63

TEST No. 50.

April 18, 1903.

Tube No. 3.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
4:20	1800	862	62	100
4:30	1796	874	62	100.5
4:40	1805	850	62	101
4:50	1800	856	62	96
5:00	1796	872	62	97.5
5:10	1794	872	62	99.5
5:20	1792	883	62	100
Average	1797.6 ✓	867 ✓	62 ✓	99.2 ✓

Water passed through boiler 800 lbs.
Mean temperature of gases 1332.3
Mean temperature of water in boiler 80.6
Difference 1251.7
Rise in temperature of water 37.2
B.T.U. given up to water 29760
B.T.U. transmitted per degree range of temperature 23.775
Loss due to scale 0.581 B.T.U.
Loss in per cent 2.39

TEST No. 51.

April 19, 1905.

Engine No. 1012. Tube No. 15.

Road- I.C. Mean thickness of scale .033 in.

Division- Chicago Dist. Character of scale- Very hard.

Time in use 12 mo.

CHEMICAL ANALYSIS.

Constituents.	$Si\ O_2$	$Fe_2\ O_3$ $Al_2\ O_3$	$Ca\ SO_4$	$Ca\ CO_3$	Ca O
Amount in %.	24.03	12.69	1.46	31.37	0.35

Constituents.	$Mg\ CO_3$	Mg O	Moist.	Org.Mat. and Alk.	
Amount in %		20.91	1.45	7.74	

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
1:05	1794	750	61	104
1:15	1805	765	61	101
1:25	1810	750	61	101
1:35	1805	750	61	100
1:45	1805	765	61	101
1:55	1805	770	61.2	103.5
2:05	1805	765	61.5	104
Average	1804.1 ✓	759.3 ✓	61.1 ✓	102.1 ✓

Water passed through boiler 688 lbs.

Mean temperature of gases 1281.7

Mean temperature of water in boiler 81.6

Difference 1200.1

Rise in temperature of water 41

B.T.U. given up to water 28208

B.T.U. transmitted per degree range of temperature 23.505

Loss due to scale 0.852 B.T.U.

Loss in per cent 3.5

TEST No. 52.

April 19, 1905.

Tube No. 15.

Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
12:00	1808	714	60.5	101
12:10	1816	722	60.6	100
12:20	1810	717	60.6	98
12:30	1800	738	60.9	100
12:40	1810	755	61	102
12:50	1814	750	61	103
1:00	1800	755	61	102
Average	1808.3	735.9	60.8	100.9

Water passing through boiler 701 lbs.
Mean temperature of gases 1272.1
Mean temperature of water in boiler 80.8
Difference 1191.3
Rise in temperature of water 40.1
B.T.U. given up to water 28110
B.T.U. transmitted per degree range of temperature 23.596
Loss due to scale 0.761 B.T.U.
Loss in per cent 3.13

TEST No. 53.

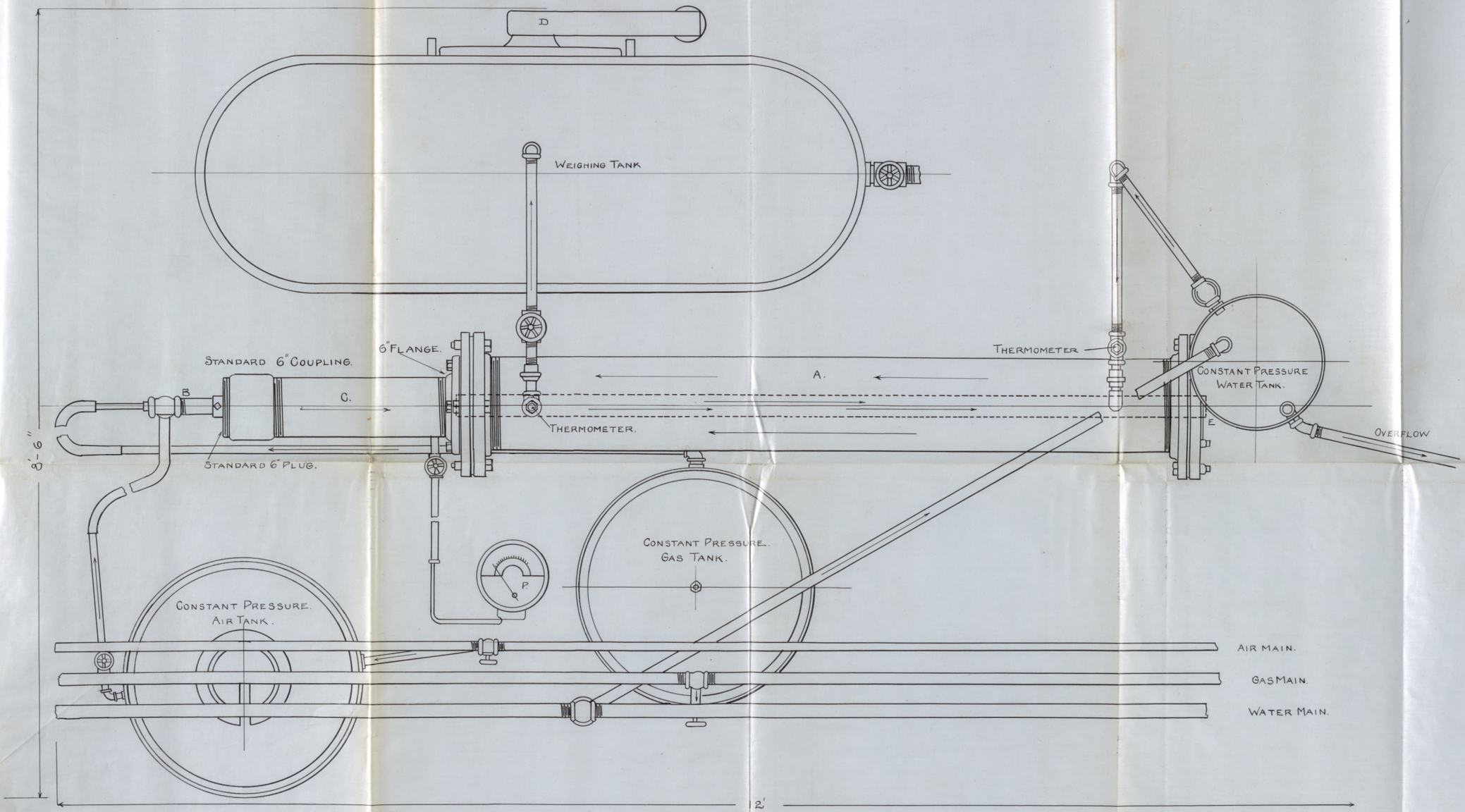
April 19, 1905.

Tube No. 13.

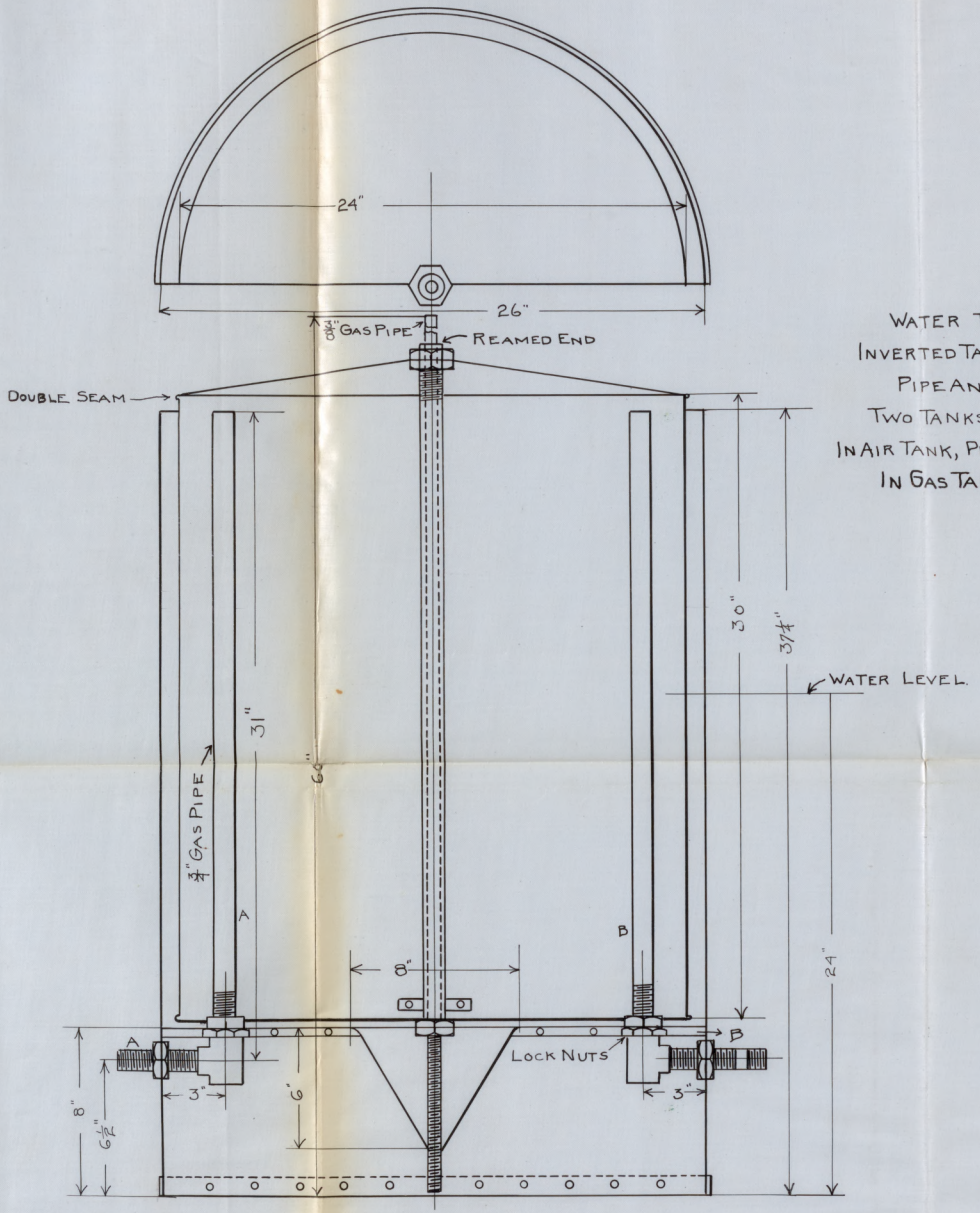
Time.	Degrees in Temperature.F.			
	Furnace Gases.	Escaping Gases.	Entering Water.	Leaving Water.
2:10	1805	748	61.5	104
2:20	1805	745	61.5	100
2:30	1805	745	61.7	103
2:40	1810	745	62	104
2:50	1814	745	62	102
3:00	1818	772	62	103
3:10	1805	755	62	104
Average	1808.9	750.1	61.8	102.9

Water passed through boiler 703 lbs.
Mean temperature of gases 1279.5
Mean temperature of water in boiler 82.3
Difference 1197.2
Rise in temperature of water 41.1
B.T.U. given up to water 28893
B.T.U. transmitted per degree range of temperature 24.134
Loss due to scale 0.223 B.T.U.
Loss in per cent 0.92

Tube No.	Thickness of Scale in inches.	Av. Loss due to Scale in per cent.
3	.065	2.20
4	.047	4.17
8	.033	3.80
9	.089	3.52
10	.070	2.90
11	.042	7.75
12	.070	5.45
13	.020	1.30
14	.038	4.05
15	.033	3.50

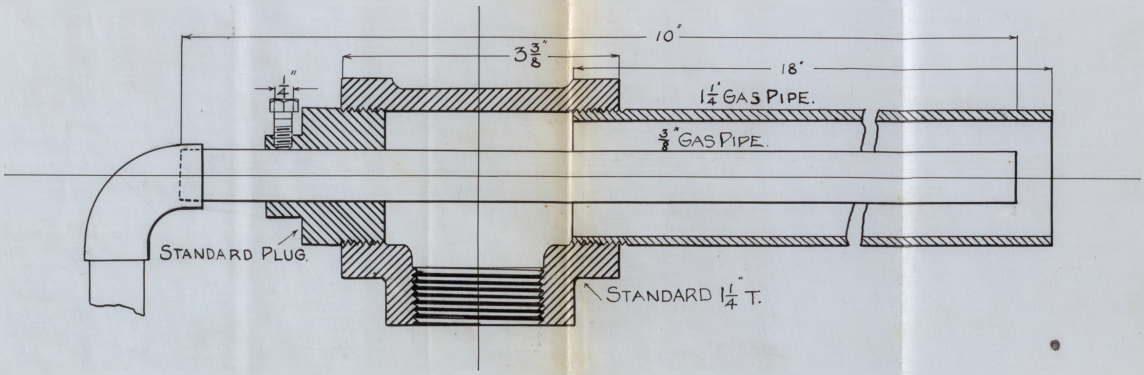


PLAN VIEW OF APPARATUS
FOR
DETERMINATION OF HEAT TRANSMISSION
THROUGH SCALED BOILER TUBES.
M.E. DEPT. UNIV. OF ILL.
SCALE $\frac{1}{8}$" = 1" MAY - 1905.
THESIS DRAWING
PLATE I.
H. J Godeke and A. A. Hale.



Water Tank Of No. 20 Galvanized Iron.
Inverted Tank Of No 26 Galvanized Iron
Pipe And Lock Nuts Galvanized.
Two Tanks Used, Water And Gas.
In Air Tank, Pipes A, And B Are 3/4 Inch, As Shown.
In Gas Tank, Pipes A And B Are 1 Inch.

Section
Of
Constant Pressure Tank.
M. E. Dept. Univ. Of Ill.
Scale 1" = 1". May, - 1905 -
Thesis Drawing
Plate II
H. J. Godeke and A. A. Hall.

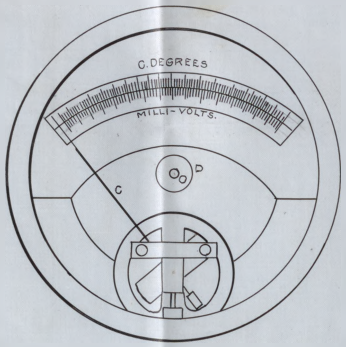


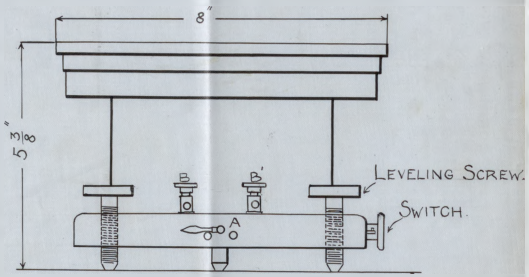
SECTION
OF
GAS BURNER

M.E. DEPT. UNIV. OF ILL.
FULL SIZE. MAY 1905.
THESIS DRAWING.
PLATE III

H. J. Gondeby and A. A. Hale

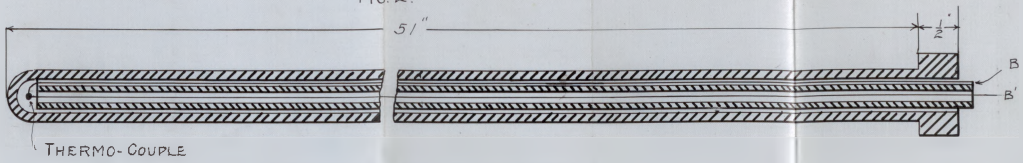
Fig. 1.





GALVANOMETER
HALF SIZE.

Fig. 2.



PORCELAIN PROTECTION TUBES.
FULL SIZE.

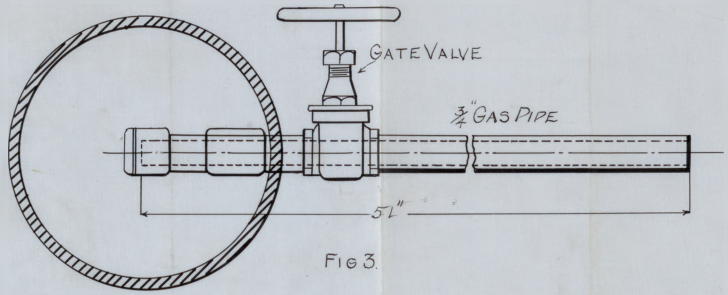


Fig 3.

COMBUSTION CHAMBER.

DETAILS
OF
PYROMETER AND CONNECTIONS.
M. E. DEPT. UNIV. OF ILL.
SCALE 1/2" = 1' 1 MAY – 1905
THESIS DRAWING
PLATE IV.
H. J. Godeke and A. A. Hall