TEST OF A 400 H. P. GAS PRODUCER

OF

ARMOUR & CO. CHICAGO, ILLINOIS

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ARMOUR INSTITUTE OF TECHNOLOGY

1909

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TEST

OF

A 400 H. P. GAS PRODUCER

AT

ARMOUR & CO., CHICAGO, ILL.

A THESIS

PRESENTED BY

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&

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Preface.

The subject of " A Test of a 400 H.P. Gas Producer" is herein presented in five parts.

Part 1:- A brief outline of the underlying principles of a gas producer and the reactions which bring about the change from solid to gaseous fuel.

Part 2:- A description of the plant and the apparatus used in making the test.

Part 3:- The actual test of this particular plant together with the data obtained, and the results.

Part 4:- A brief discussion of the various items which enter into the cost of generating gas in a gas producer, and the total cost of this particular gas.

Part 5:- Conclusions and Bibliography.

Index

-Index -

-Index -

Index -

Test Of A 400 H.P. Gas Producer.

Part 1.

A brief outline of the underlying principles of a gas producer and the reactions which bring about the change from solid to gaseous fuel.

Test Of A 400 H.P. Gas Producer.

The question of fuel is such a large factor in the maintenance of industrial prosperity that there is an increasing demand for closer approximation in daily practice to theoretical efficiency.

There are three classes of fuel; coal, which is the most plentiful; oil, which has the maximum energy; and gas, which can be used in the most ideal manner. Natural gas has been a boon, and at the same time a drawback to producer gas, in so far that the discovery of natural gas and its application to industrial purposes has been the means of teaching the public the many and various purposes to which the gas can be put. Again in the natural gas belts this gas is so cheap that man's gas producers cannot compete with natures producers.

Any fuel, other than natural gas, must be first gasified before heat will be evolved. Whether the resulting gases are combustible, or not, depends upon the nature of the fuel and the means of gasification. The products of complete combustion of ordinary fuels are, carbon dioxide (CO_2) and water (H_2O).

Test Of A 400 H.P. Gas Producer.

The object of direct firing is to effect vaporization,distillation,gasification and complete combustion in one chamber and in close proximity to the fuel bed. Heat is required to vaporize,distill and gasify a fuel,while heat is given up during the combustion of the gases.

The underlying principle of a gas producer is to separate as much as possible,the gasification and the complete combustion of the fuel,for the high temperature resulting from the combustion of the gas may come about in a differant locality to that of the first processes of the heat change.

The following reasons are then apparent as to the advantages of gas producers:-

First - More complete combustion.

Second - Easy control of the air and gas supply, and consequently the combustion.

Third - Higher possible temperatures.

Fourth - Less heat lost up the chimney.

Fifth - No loss of fuel thru the grate.

Sixth - No irregularities of firing.

Seventh - Greater efficiency in the transfer of

heat, due to the higher temperature.
Eighth - It concentrates and lessens labor in handling coal and ash; elliminates the deleterious effects of the ash upon the substance heated and reduces the smoke nuisance to a minimum.

A gas producer, as the name implies, is an apparatus which generates a combustible gas by the incomplete combustion of a solid fuel. Industrially, producer gas is the combustible product of a rather complex series of physical and chemical changes induced in the fuel by the heat arising from its complete combustion. The combustion is termed incomplete not that it leaves part of the fuel unburnt as a residue of carbon or coke, but as being so unburnt that, while completely gasified, the fuel only generates about 30% of its heat, primary combustion, in the producer.

In all cases, carbon is the basic element of the fuel. The heat necessary for the producer reactions and the quantative yield of gas is dependent upon its amount and degree of oxidation. As the chief duty of the gas producer is

to gasify the solid carbonaceous constituent of the fuel, this must become the first consideration. Carbon has the property of combining with oxygen in two ways, thus:

(1) $C + O = CO$.

(2) $C + 2O = CO_2$.

In the first combination 12 parts by weight of carbon combine with 16 parts by weight of oxygen to form 28 parts by weight of carbon monoxide (CO). During this partial oxidation of the carbon, 4451 B.T.U. is developed, for each pound of carbon. The CO thus formed is capable of developing 10159 B.T.U. on the complete oxidation of the carbon according to the equation,

(3) $CO + O = CO_2$.

Under normal conditions of temperature, carbon and oxygen have practically no action upon each other, so that, to bring about combustion, heat must be applied to one or the other, or both, of the constituents. The bringing about of this chemical combination by the application of heat is more dependent upon the intensity of the heat than the quantity, as when the combustion has been

brought about, in however small a degree, the heat developed by the combustion causes the continuation of the combination until one or the other of the constituents is consumed.

Since the air, which usually furnishes the oxygen for combustion contains 3.77 volumes of nitrogen for every volume of oxygen, it is desirable to get at least a part of the oxygen from a source free from nitrogen. Steam is used to furnish this additional oxygen and at the same time enrich the gas by the free hydrogen. Since the breaking up of the steam is a heat absorbing process, its introduction into a gas producer has the property of cooling the fuel column and thus lessens the formation of clinkers.

Assuming at first that all the oxygen for combustion is furnished by the air, then there is in the gaseous mixture,

3.77 volumes of nitrogen = 1349 cu.ft. or 65.3%.

2.00 volumes of carbon monoxide = 715 cu.ft. or 34.7%.

Or 5.77 volumes of the gas = 2064 cu.ft. from 24 pounds of carbon. This follows from the eq-

uation

$2C + O_2 = 2CO$. That is, 2 volumes of carbon combine with one volume of oxygen to form 2 volumes of carbon monoxide. Also 24 pounds of carbon combine with 32 pounds of oxygen to form 56 pounds of carbon monoxide. Therefore 1 lb. C produces (2064 ÷ 24) 86 cu.ft. of gas. This 56 lbs. CO is capable of generating (1059 x 56) 243815 B.T.U. or the gas will have a heat value of (243815 ÷ 2064) 118.1 B.T.U. per cu.ft., and the CO contains (243815 ÷ 715) 341 B.T.U. per cu.ft.

If 10% of the sensible heat in the gas is allowed for radiation, conduction and the heating of the fuel, there still remains (2/3 4451) 2967 B.T.U. per pound of carbon, as sensible heat. This heat will raise the temperature of the gas (2967 ÷ 86 x .019) 1816 Deg.F. The temperature, however, of the fuel bed will be much higher than this and if some agent were introduced to absorb a part of this heat of primary combustion, the temperature will be lowered and clinkering will be minimized. For the purpose of absorbing a part of the heat of primary combustion a mixture of steam and air is used instead of air alone.

Test Of A 400 H.P. Gas Producer.

As the heat transfer in the fuel column is so complex as to prohibit the actual calculation of the theoretical amount of steam used,it will be assumed that 20% of the carbon is oxidized by the decomposition of the steam while 80% is oxidized by the oxygen from the air. It will be assumed that part of the heat lost by radiation has gone to raise the temperature of the water to 212 Deg.F. and evaporate it. Then from the equation,

$H_2O + C = H_2 + CO.$

That is, 18 lbs. of water is decomposed by 12 lbs. carbon,to form 2 lbs.hydrogen and 28 lbs. carbon monoxide. The heat absorbed in decomposing 18 lbs. steam at 212 Deg.F. is (52290 x 2) 104580 B.T.U. Heat developed by the partial oxidation of the carbon = (4451 x 12) 53412 B.T.U..The netdefficiency then = (104580 - 53412) 51168 B.T.U.,or per pound of steam the heat deficiency is (51168 ÷ 18) 2843 B.T.U.. The heat produced per pound of carbon burnt to CO by the oxygen of the air (allowing for radiation,etc.) is 2967 B.T.U.. Therefore the maximum amount of steam which may

be decomposed per pound of carbon burnt by the air is (2843 ÷ 2967).96 lbs. , In practice, however, some of the carbon which is completely oxidized in the lower part of the fuel column, to CO_2, finds its way thru the upper part of the fuel column and into the gas without being reduced to CO, and by so doing, more heat is available to break up steam and make up for the heat deficiency. From the equation,

$$2H_2O + C = 2H_2 + CO_2,$$

we see that the decomposition of 36 lbs. of steam will absorb (52290 x 4) 209160 B.T.U., and the heat developed by the oxidation of the carbon by the oxygen of the steam is (14648 x 12) 175776 B.T.U., and the net heat absorbtion is 209160 - 175776 = 33384 B.T.U., or per pound of steam is (33384 ÷ 36) 928 B.T.U. Therefore the maximum amount of steam which may be decomposed per pound of carbon burnt by the air is (2967 ÷ 928) 3.2 lbs.

Since, in the process where no CO_2 is formed, one-third of the total carbon is oxidized by the steam, it follows that the maximum amount of steam which may be decomposed by the oxidation of the

carbon with air and steam is (.96 ÷ 1.5) .64 lbs. steam; and where the CO_2 is formed the maximum amount of steam is (1.49 ÷ 3.2) 2.15 lbs. steam. (In the first case the steam oxidizes two-thirds, and in the second case one-third of its weight in carbon).

The different reactions may thus be classified:-

1st. No steam used and all the carbon burnt to CO.
2nd. Steam used and all the carbon burnt to CO.
3d. Steam used and all the carbon burnt to CO_2.

In the second reaction the steam oxidizes two-thirds, and in the third, one-third its weight in carbon. Table 1 shows the quality and quantity of the gas by the various combinations of the different reactions.

It is obvious that where the gas of highest heat value is desired, the reactions should follow that of No.2. As this reaction requires a furnace temperature of about 1900 Deg.F., it is hardly practicable to use it, so a combination of reactions No.2, and No.3 is used. However there is a limit to which steam may be used, as the excessive for-

Test Of A 400 H.P. Gas Producer.

TABLE 1

CONSTITUENTS OF THE GAS	REACTION NO. 1			REACTIONS NOS. 1 & 2 COMBINED			REACTIONS NOS. 1 & 3 COMBINED		
	VOLUMES	CU. FT	% BY VOL	VOLUMES	CU. FT	% BY VOL.	VOLUMES	CU. FT.	% BY VOL.
CO FROM AIR	2.00	715.6	34.7	2.00	715.6	25.7	2.00	715.6	23.0
CO FROM STEAM	----	----	----	1.00	357.8	12.9	----	----	----
H FROM STEAM	----	----	----	1.00	357.8	12.9	1.96	701.2	22.5
CO_2 FROM STEAM	----	----	----	----	----	----	0.98	350.6	11.2
N FROM AIR	3.77	1348.8	65.3	3.77	1348.8	48.5	3.77	1348.8	43.3
VOLUME OF GAS PRODUCED	5.77	2064.4	100.	77.6	2780.0	100.	8.70	3116.2	100.
VOLUME OF GAS PER LB. CARBON	86 CUBIC FEET			772 CUBIC FEET			872 CUBIC FEET		
COMBUSTIBLE IN GAS	34.7 %			51.5 %			45.5 %		
CALORIFIC POWER PER CUBIC FOOT	119 B.T.U.			176.9 B.T.U.			156.8 B.T.U.		
STEAM DECOMPOSED PER LB OF CARBON	NONE USED			.64 LB.			2.15 LB.		
AIR REQUIRED PER LB. CARBON	71.2 CUBIC FEET.			47.5 CUBIC FEET.			47.8 CUBIC FEET.		

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Test Of A 400 H.P. Gas Producer.

TABLE 2

GASES BY VOLUME	EXCESS OF STEAM.		
	MODERATE	GREAT	MAXIMUM.
CO_2	5.30 %	8.90 %	15.00 %
CO	23.50	16.40	11.50
CH_4	3.30	2.55	1.90
H	13.14	18.60	24.60
HEAT VALUE PER CU. FT.	151 B.T.U.	135 B.T.U.	129 B.T.U.
TEMPERATURE.	1472°F.	1292°F.	932°F.

JENKIN.

mation of CO_2 greatly lowers the heating value of the gas from the lowering of the furnace temperature. Table 2 shows the effect on the gas of different amounts of steam.

The use of the exhaust gases from gas engines have been used as a cooling agent, but the large per cent of inert nitrogen prohibits its use, for the resulting gas will have a low heat value owing to the large per cent of nitrogen present.

The object of a gas producer is not only to gasify solid fuel, but to wash and cool the gas so that it may be easier transported or used directly in an internal combustion engine. Fig. 1-A is an elevation in section of a typical installation. Referring to Fig. 1-A, the gas is generated in the receptacle A, which consists of either a cast iron or sheet steel shell lined with some refractory earth as firebrick. The air and steam are led in to the bottom of the generator thru a tuyere located in the center of the generator. This tuyere delivers the moisture laden air a few inches below the top of the ash bed, where it has a chance to travel up thru the fuel bed un-

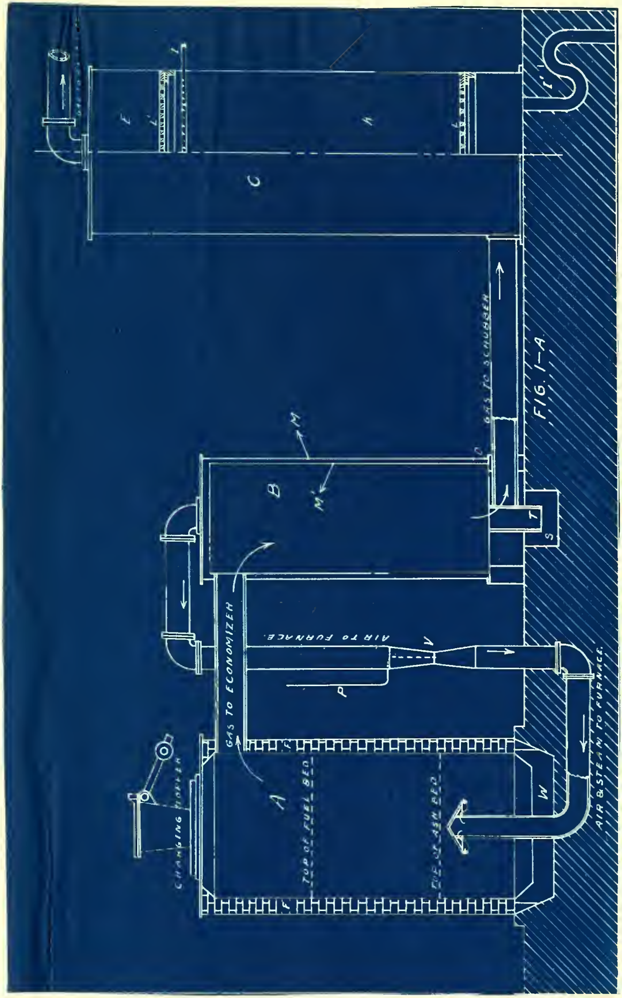

CHARGING HOPPER
TOP OF FUEL BED
TOP OF ASH BED
GAS TO ECONOMIZER
AIR TO FURNACE
AIR & STEAM TO FURNACE
GAS TO SCRUBBER
A
B
C
M
M'
P
V
W
S
T

FIG. 1-A

iformly. Coal is fed into the hopper on top of the producer, and this hopper is so constructed that when it is open at the top to receive coal, it is closed at the bottom to prevent air from leaking in, if it is a suction producer; or the gas leaking out, if it is a pressure producer.

As the gas comes from the fuel bed in the generator it is led to the economizer B. This economizer consists of two concentric steel shells M, & M', so arranged that the gases pass down thru the inner shell while the air for combustion ascends within the annular space between the shells, passing out at the top as shown. Steam is supplied to the air by the pipe P. The steam meets the air at the throat of the venturi tube V, where, in passing downward and expanding, causes the air to be drawn with it. This steam jet causes a slight pressure in the bottom of the generator, and should be just enough to overcome the resistance of the fuel column. The air enters the economizer thru a slide shutter at D. From the economizer the gas passes to the scrubber and in doing so, its course is changed at T which is a short pipe,

water sealed at S. The dust and solid particles in the gas tend to go in the same direction as before, and most of this solid matter is deposited in the water seal S where it is removed. The scrubber consists of a steel tank. The space is filled with coke down thru which water from I trickles. The water meets the upflow of gas and cools it as well as removing the remaining dust and solid matter. The coke is for the purpose of presenting a large wetted surface in contact with the gas. The space E is filled with excelsior soaked with oil. This excelsior removes all the entrained moisture in the gas so that when the gas leaves the scrubber it is cool, but saturated with aqueous vapor at the temperature of the gas. The scrubber water leaves at some point at or around the bottom of the scrubber, as at I'.

When steam is not furnished from some outside source the generator is water jacketed as is the top and the steam thus formed is drawn in with the air. With a producer of this type, instead of there being a pressure in the bottom

of the generator there is a slight suction, and the exhauster, or engine, must draw the gas thru the entire system. A disadvantage of this method lies in the fact that when the operator pokes the fuel bed, air leaks in, not only burning the gas, but diluting it with air which lowers its heating value.

In the case of the producer tested the pressure in the top of the generator is maintained at or near atmospheric pressure, so that the fuel bed could be put in order without in any way lowering the quality of the gas.

Requirements of a producer installation:-
A producer, to be a good one, must be reliable and make a uniform gas under all conditions of load. It must also be able to meet as much as possible, the fluctuations of the load. The producer should be such that it can be quickly started and simple to operate, since the wages paid to operators of gas producers do not induce educated and skilled mechanics to enter this field.

A gas producer should be able to hold fire for at least seventy hours, as from Saturday at noon to Monday morning at six o'clock, without

any attendance and without much fuel being used. After standing for this length of time the producer should be such that good gas can be made twenty-five minutes after starting up.

The one prime factor in the operation of a producer is that it must be economical of fuel. This means that the loss thru the ash-pit must be small, also a large per cent of the heat which would otherwise be wasted should be returned to the fuel bed by preheating the air or evaporating water.

A producer should be so designed that under normal working conditions clinkers will not form. Too high a rate of gassing in a producer, and an insufficient supply of steam will cause clinkersl since with American fuels a temperature above 1500 Deg.F. in the generator will cause clinkers. If coal could be obtained in this country free from a fusible ash, producers could be run at a higher temperature, and consequently at a higher efficiency.

Test Of A 400 H.P. Gas Producer.

Part 2.

A description of the plant, and the apparatus used in making the test.

Test Of A 400 H.P. Gas Producer.

Location of the plant:- The producer gas plant which was tested is installed at the works of Armour & Co.,Union Stock Yards,and furnishes gas in their cooking,soldering,and canning departments. Figs.1,2,& 3, show the general layout of the plant as was installed by Flinn & Dreffein, Engineers,Chicago,Ill. The plant is rated as a 400 H.P. generating unit;that is,the plant is capable of supplying gas to a 400 H.P. producer gas engine,which has a thermal efficiency of 20%.

Operation of the plant:- A producer consists of three essential parts; a generator,in which the coal is gasified,the economizer,which preheats the air,and the scrubber,which cools the gas and at the same time cleanses it.

The coal is elevated to the coal bunkers by the coal conveyer,as shown in Fig.2. From the bunkers the coal gravitates into the weighing hoppers,one over each generator,where it is weighed. From the weighing hoppers it goes to the charging hoppers,which are so arranged that when the hoppers are open at the top they are closed at the bottom,preventing the escape of the gas while

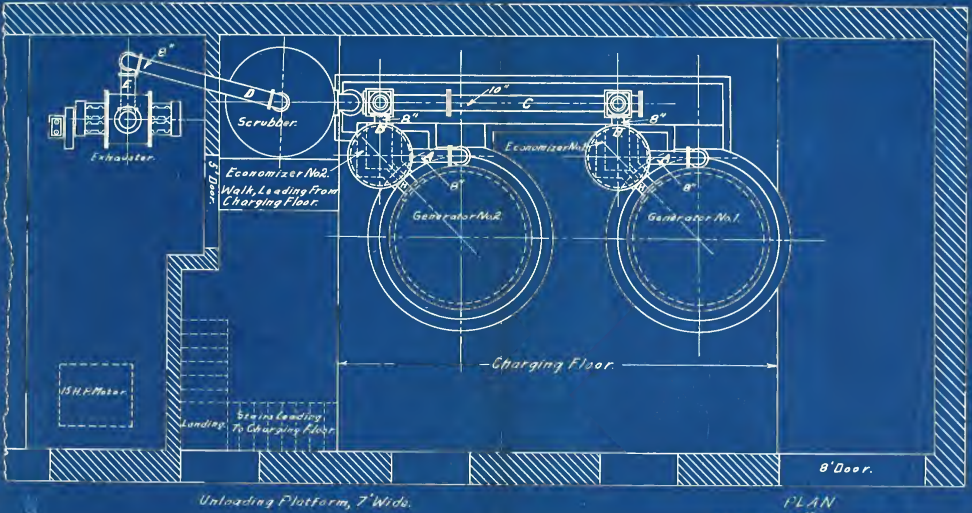


Fig. 1.

PLAN
OF
PRODUCER GAS PLANT
AT
ARMOUR & CO.,
UNION STOCK YARDS,
CHICAGO, ILLS.
SCALE, $\frac{1}{4}$"=1'-0".
JAN. 18th, 1902.

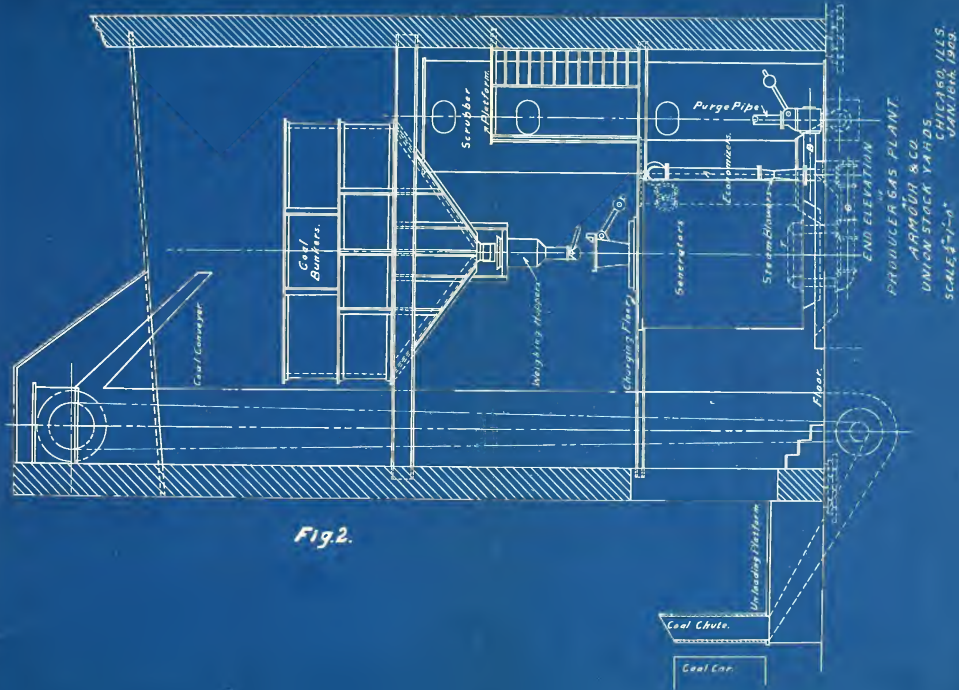

Purge Pipe
Scrubber
Platform
Economizers
Generators
Steam Blowers
Coal Bunkers.
Weighing Hoppers
Charging Floor
Coal Conveyor
Floor.
B
Unloading Platform
Coal Chute.
Coal Car.
END ELEVATION
OF
PRODUCER GAS PLANT.
ARMOUR & CO.
UNION STACK YARDS
CHICAGO, ILLS.
JAN. 16th 1909.
SCALE 1/8" = 1'-0"

Fig. 2.

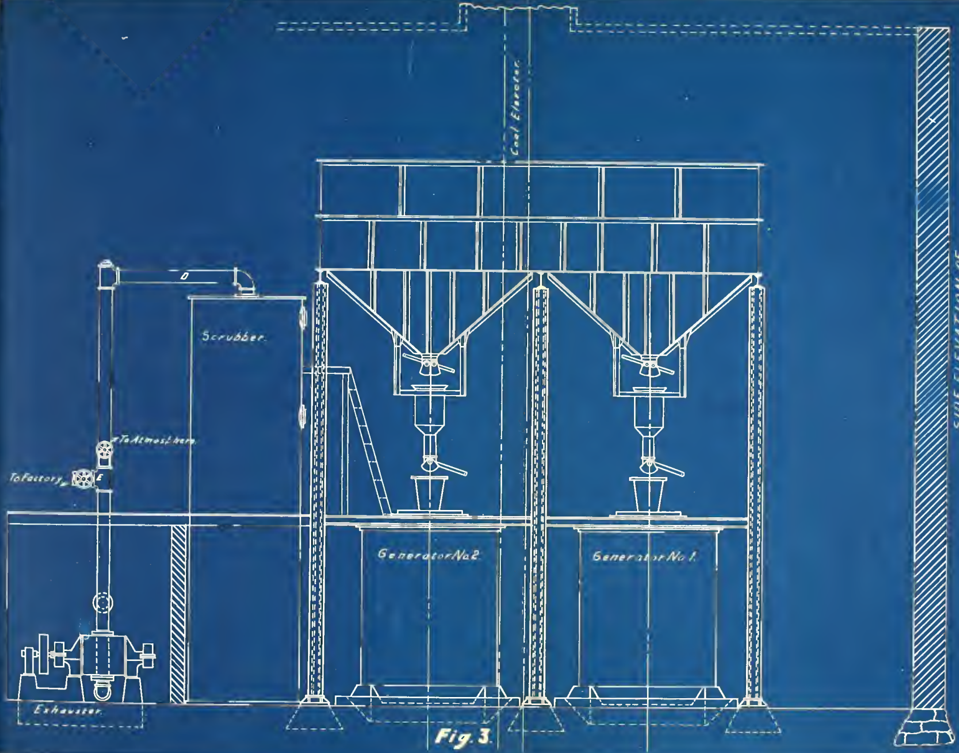

Coal Elevator.
D
Scrubber.
To Atmosphere.
To Factory
E
Generator No 2.
Generator No 1.
Exhauster.
SIDE ELEVATION OF
PRODUCER GAS PLANT
AT
ARMOUR & CO.
UNION STOCK YARDS, CHICAGO, ILLS.
Scale, ¼"=1'-0".
JAN. 18th 1909.

Fig. 3.

Test Of A 400 H.P. Gas Producer.

charging the hoppers with coal. Fires are started in the generators by first filling the producers with ashes so that they just cover the circular tuyere irons (Fig.2). Upon this bed of ashes a wood fire is kindled,the supply of air being furnished by an auxiliary pressure blower. In starting up,the gas valve to the factory mains is closed and the purge pipe valve is opened to the atmosphere. When the wood fire is sufficiently under way,coal is added from the charging hopper until there is an incandescant bed of fuel four to five feet deep. When it is supposed that the gas is of sufficient quality it is tested by lighting a burner,and if found so, the exhauster is started,the factory gas valve opened,the purge pipe valves closed,steam turned into the air,and the producer is started for an indefinite run.

Steam is furnished to the generator from the company's steam power plant at about 140 lbs. pressure which is throttled down to suit the requirements. The steam,on passing thru the venturi-tube is expanded down to a few inches of water pressure. This expansion of the steam creates a suction of air thru the economizer and at the

same time supersaturates the air with moisture.

The generators are two in number, are 13'-0" high above the floor, are 7'-6" external diameter and 6'-0" internal diameter. They are each set in a concrete basin and rest upon four concrete pillars. The bottom of the shell is about 8" from the bottom of the basin, which allows the ashes to be removed without disturbing the gas making process. This concrete basin is about 12" deep and is kept filled with water at all times. The generators are lined with fire brick on the sides and on the top, with the exception of the poke holes and the charging hopper. To prevent undue heating of the hopper casting, the top is water cooled, the overflow being allowed to gravitate to the basin below. The gas leaves the generator thru the 10" pipes H (Fig.1), and enters the economizers, leaving by the 10" pipes B. The gas, on passing thru the economizers, preheats the air.

The economizers consist of two concentric cylindrical shells, with a narrow air space between them. The gas passes down thru the inner shell while the air ascends thru the annular space be-

tween the shells, causing the economizers to operate on the counter-current principle. The preheated air passes thru the 8" pipe A, down thru the steam blower, thru the pipe G (Fig.2) and is finally distributed thru the fuel bed by the tuyere irons T (Fig.2).

The gas passes on its way to the scrubber from the pipes B to the 10"main C, enters the bottom of the scrubber, and leaves from the top thru the 8" pipe D. The exhauster (A Roots positive blower) delivers the gas to the factory mains E under a pressure of about 2.5 lbs. Fig. 2-A shows the general arrangement of the piping to the auxiliary exhauster, and to the main exhauster.

Water enters the scrubber at the top, percolates thru a bed of coke, discharging to the sewer at the bottom. The gas, ascending thru this bed of coke meets the downward flow of water, and is thereby cooled and cleansed. Excelsior in the top compartment of the scrubber removes the entrained moisture, so that the gas is as free from moisture as is possible to make it under ordinary conditions

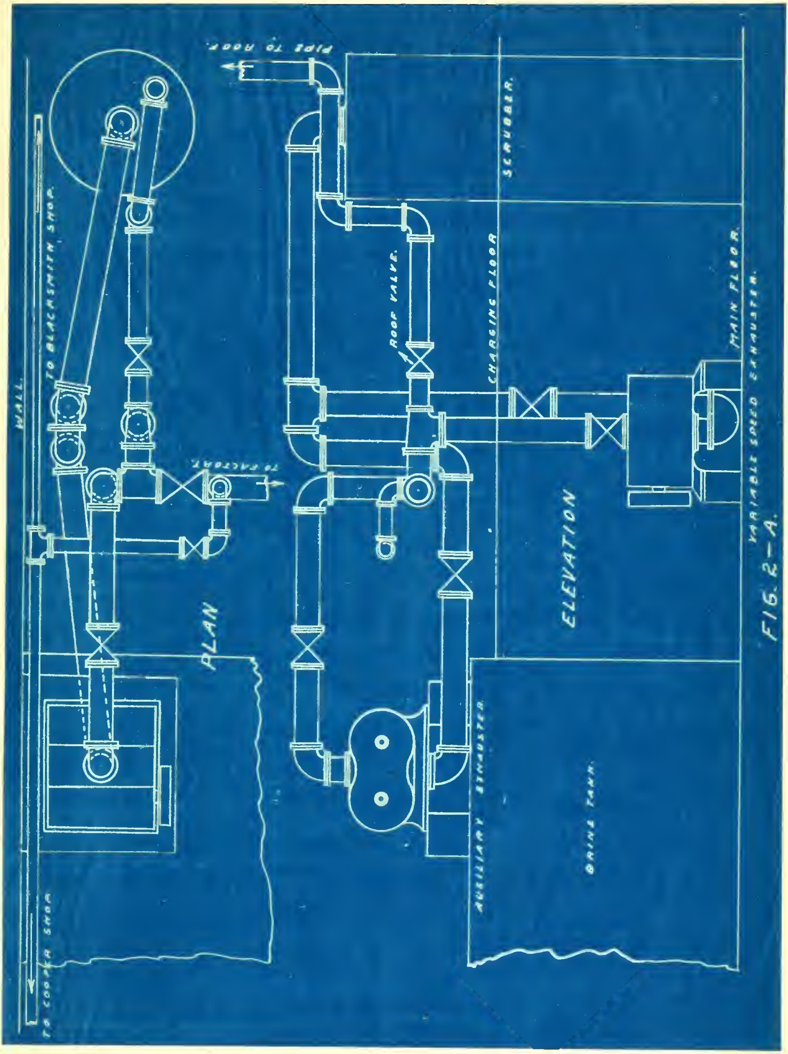

WALL.
TO BLACKSMITH SHOP.
TO COOPER SHOP
TO FACTORY
PLAN
PIPE TO ROOF.
ROOF VALVE.
SCRUBBER.
CHARGING FLOOR
MAIN FLOOR.
VARIABLE SPEED EXHAUSTER.
ELEVATION
AUXILIARY EXHAUSTER.
BRINE TANK.

FIG. 2-A.

and is as dry as need be for ordinary purposes.

Arrangement of the apparatus for the test:- To obtain the total water used in the plant, a 1 1/2" Empire water meter was placed in the water supply line and by-passed so that it could be cut out of service when not being used for testing. The water used by the scrubber was measured by a 1 1/2" Keystone water meter placed close to the scrubber, by-passed so that it could also be cut out of service when not in use for test purposes. These meters were thus arranged on account of the solid matter in the water, which would soon foul the meters and so cause them to give incorrect results. The difference between the readings of the two meters gave the amount of water used in the water cooled top of the generators and in the ash-pit seal.

Temperatures:- The temperature of the generator and the gas leaving the generator was obtained with a Hoskins Thermo-electric couple used in connection with a Weston milli voltmeter. The combination was calibrated against a Callander Electric Resistance Pyrometer before and after the test.

Test Of A 400 H.P. Gas Producer.

The pyrometer was inserted in one of the poke holes, and fire clay placed around it to prevent the escape of gas.

All other temperatures measured in this test were taken with mercurial thermometers, placed in the following positions; the temperature of the outside air was obtained by placing a 0-220 Deg.F. thermometer outside the building; temperature of the room by placing a 0-220 Deg.F. thermometer at some convenient place in the producer room; temperature of the gas from the economizer, by placing a 0-800 Deg.F. thermometer in the pipe B (Fig.2); temperature of the gas to the scrubber, by placing a 0-600 Deg.F. thermometer in the gas main just where it enters the scrubber; temperature of the gas leaving the scrubber, by placing a 0-220 Deg.F. thermometer in the pipe D (Fig.1); temperature of the gas in the factroy mains, by placing a 0-220 Deg.F. thermometer in the pipe leading from the exhauster; temperature of the air leaving the economizer, by placing a 0-600 Deg. F. thermometer in the pipe A (Fig.1).

The humidity of the atmosphere was obtained

by placing a wet and dry bulb thermometer in the room.

Pressures:- The pressure of the gas in the mains was obtained from a mercurial pressure gauge,graduated to read in pounds and ounces. The pressure of the steam was read from a Bourdon steam gauge,calibrated and found correct. U-tube water gauges were used to obtain all other pressures except the barometer observations.

The power consumed by the motor running the exhauster was measured by an integrating wattmeter.An attempt was made to measure the gas with a Pitot tube placed in the pipe leading from the exhauster, but the pulsating flow of the gas prevented any readings being taken.

Analyses of the coal and ash were obtained in the standard manner of quartering. The gas analysis was made with a Morehead Burette. The heating value of the gas was obtained by burning it in a Junker Gas Calorimeter.

The humidity of the gas was obtained by placing a calcium chloride tube (Fig.4-A) upon the discharge pipe from the exhauster and a known a-

Test Of A 400 H.P. Gas Producer.

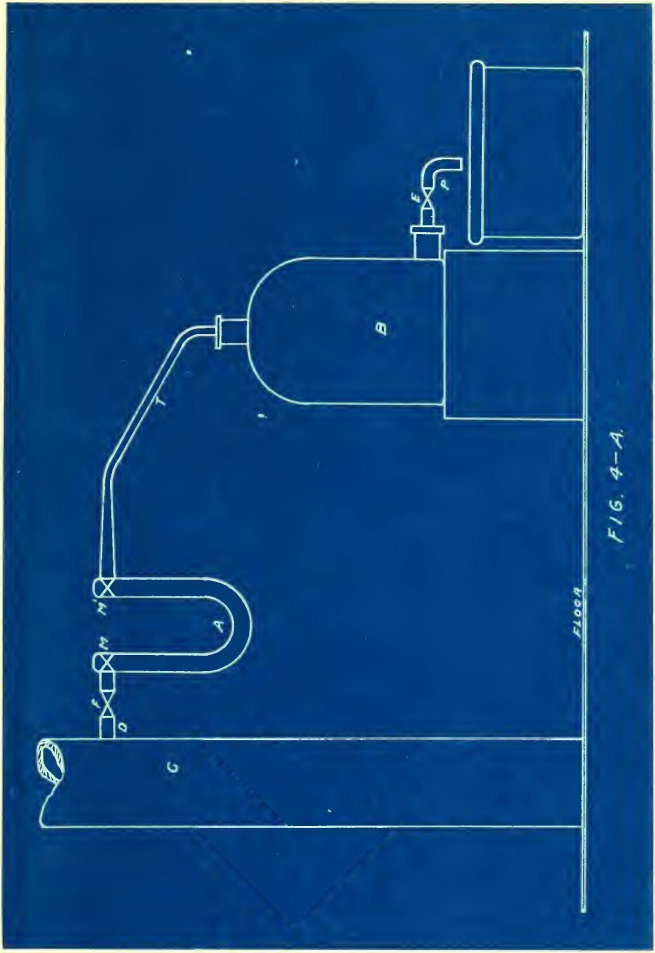


FIG. 4-A.

mount of gas thru. Referring to the figure, the gas main C was tapped and the pipe D with valve E placed in it. A rubber tube connected the U-tube to the pipe D. These connections were made as short as possible. The other leg of the U-tube was connected to the water bottle B by the rubber tube T. The ground glass cocks M,M' serve to regulate the flow of the gas. The water is allowed to drain from the bottle by means of the connection E and valve P.

In operation, the bottle B is filled with water as is the tube T. After blowing the gas to the atmosphere from D, to remove the air, the connection at M is made, the valve P opened, M, & M' opened so as to allow about 100 C.C. of gas per minute to flow thru the U-tube. The amount of water which is displaced (run out from the connection E) is caught and measured and represents the amount of gas passed thru the U-tube. By weighing the U-tube before and after using it the amount of water given up by the gas is found. If w= the weight in grams of the moisture absorbed, then $w \div 453.6$ = the weight in pounds of the moisture

absorbed.

The cubic feet of gas passed thru = .0000353 M, where M is the C.C. of water displaced by the gas.

Then the pounds of water per cubic foot of gas = W = w + (453.6 x .0000353) M = w + .0162 M. Knowing from Table 58, Gebhardt's Steam Power Plant Engineering, the weight of moisture in one cubic foot of the gas at the temperature of the gas which will saturate the gas, the relative humidity of the gas in per cent is calculated from the ratio of the amount of moisture actually present in the gas, to the maximum saturation at that temperature.

General Dimensions of the Plant.

Diameter of the economizers, ... 3'-5".

Diameter of generators (internal),. 6'-0".

Diameter of scrubber, ... 6'-0".

Height of economizers, ... 8'-7".

Height of generators, ... 10'-3".

Height of scrubber, ... 21'-9".

H.P. of exhauster motor, ... 25.

Kind of coal used, ... Anthracite Pea.

Number of coal burners, ... 2.

Test of A 400 H.P. Gas Producer.

Number of economizers, ... 2.

Number of purge pipes, ... 2.

Number of scrubbers, ... 1.

Number of generators, ... 2.

Size of charging floor, ... 22'-6" x 23'-10".

Size of exhauster room, ... 13'-8" x 22'-6".

Size of generator room, ... 22'-6" x 40'-0".

Source of power, ... The central station.

Source of the steam, ... The central station.

Source of the water supply, ... City mains.

Total capacity of the bunkers, ... 90 tons.

Type of building, ... Fire proof.

Type of exhauster, ... Roots Blower.

Test Of A 400 H.P. Gas Producer.

Part 3.

The actual test of this particular plant together with the data obtained, calculations and the results.

Test Of A 400 H.P. Gas Producer.

In making this test there was no chance to vary the load on the producer,as would br desirable in a test of this kind. The producer had to be used to generate gas for factory use just as was required,and under these conditions the tests were run. To get as great a variation as possible,and to get comparable results,it was decided to run tests on eight separate days so that by chance there would be some variation in the load. The enclosed data shows that there was a very marked variation from very light load to about five-eighths load. Only one generator was tested at a time since the load was such that one generator could easily carry it.

The alternate method of firing was used,since in a test of this nature there would be a great deal of uncertainty in starting this size producer with green fires,and conditions would hardly be adjusted in the time allotted to the test.

An attempt was made to meter the gas with a Pitot Tube,but,as before explained,the pulsating character of the exhauster disturbed the readings of the draft gauge in such a way that

no reliable results could be obtained. Also the sulphur in the gas soon attacked the material of which the tube was made and within about six hours the velocity tube was clogged. The air was not metered with a Pitot tube, because we found that it would be impossible to calibrate the instrument at the temperature which it would be used.

With these difficulties not overcome, it was decided to calculate the amounts of gas, air, steam and refuse, as outlined in the succeeding pages. The following table gives the factors used in all of the calculations. All factors are referred to 30" mercury and 62 Deg.F.

Items	Air	CO_2	CO	H	CH_4	N
Wt./cu.ft. lbs.	.0763	.1166	.0738	.005	.0424	.0741
B.T.U./cu.ft. High.	----	----	341.	345.	1065.	----
B.T.U./cu.ft. Low.	----	----	342	293.6	962.1	----
% of C by Weight.	----	23.7	42.9	----	75.0	----
% of H by Weight.	----	----	----	100.	25.0	----

The cubic feet of gas generated is most accurately calculated from the chemical analysis of the coal, ash and gas. The total carbon appear-

ing in the gas is that fed to the generator in the form of coal;less that lost in the ash-pit. From the analysis of the ash the total refuse in the ash-pit may be calculated,for,knowing the per cent of ash in the coal by analysis,it is at once evident that the weight of refuse is

$$W_r = W(C_a + C_a C_r). \qquad (1)$$

Where

W_r= the weight in pounds,of refuse in the ash-pit.

W = the weight of coal used.

C_a= the per cent of ash,plus half the per cent of sulphur in the coal.

C_r= the per cent of carbon in the refuse.

Practically all of the sulphur in this coal occurs as iron pyrites (FeS_2). Upon heating without excess air,the following changes take place,

$$2\ FeS_2 + C = 2\ FeS + CS_2. \qquad (2)$$

The carbon disulphide passes of in the gas,while the iron sulphide remains in the ash to form a fusible clinker. From the equation it can be seen that half the sulphur in the coal stays in the ash while the other half passes off in the gas.

The carbon contained in the gas is found in

the carbon dioxide, carbon monoxide and methane. The weight of carbon in pounds, in one cubic foot of the gas = $W_g = (.11665 \times .273 \times C_1) + (.07381 \times .429 \times C_2) + (.0424 \times .75 \times C_3)$. (3)

Where

W_g = the weight in pounds of carbon in one cubic foot of the gas.

C_1 = the proportion by volume of CO_2 in the gas.

C_2 = the proportion by volume of CO in the gas.

C_3 = the proportion by volume of CH_4 in the gas.

The constants refer to those in the table on page 34. The carbon appearing in combination with the sulphur as carbon disulphide is for the present, neglected. Simplifying Eq.(3),

$$W_g = .031845 C_1 + .03166 C_2 + .031785 C_3. \quad (4)$$

The weight in pounds of carbon from the coal actually gasified is

$$W_a = W C_c - W C_a C_r - W_s. \quad (5)$$

Where

W_a = weight of carbon actually gasified.

W = weight of coal burned.

C_c = the percent of carbon in the coal.

C_a = the percent of ash plus half the percent of

sulphur in the coal.

C_r = the percenr of carbon in the refuse.

W_s = the weight of carbon combined with the sulphur.

From equation (2) it may be seen that carbon combines with sulphur in the proportion of 12 to 64; that is ,3 pounds of carbon will combine with 16 pounds of sulphur. Now the weight of sulphur combining with the gas = $W_s' = W\ C_s \div 2.$ (6)

Where

W_s' = weight of sulphur in the carbon disulphide.

W = the weight of coal used.

C_s= the percent of sulphur in the coal.

Then the weight of carbon combining with this sulphur = $W_s = (W\ C_s \div 2)\ 3/16 = 3\ WC_s \div 32.$ (7)

Substituting this value of W_s in Eq.(5),

$W_a = W\ C_c - W\ C_a C_r - 3/32(W\ C_s).$ (8)

Knowing the weight of carbon gasified and the weight of carbon in one cubic foot of the gas, the cubic feet of gas generated =

$V = W_s \div W_g.$ (9)

It is believed that such losses as dust,absorbtion of gases by the scrubber water,etc.,may be neg-

lected as refinements not in keeping with the other observations.

In making the calculations of the air supplied it is assumed that there is no nitrogen in the coal and since this assumption is made, it is evident that all the nitrogen appearing in the gas must enter the system as a constituent of the air used. This air comes in thru the economizer, and with the steam. The amount of air entering thru the economizer is so large compared with that entering with the steam that it is assumed all the air enters the system thru the economizer. The leakage is negligable since the gas in under pressure. The weight of air can now be calculated from the equation,

$$A = .07411\ V\ C_n \div .768. \qquad (10)$$

Where

A = the weight of dry air in pounds.

C_n = the percent by volume of nitrogen in the gas.

V = the cubic feet of gas generated.

.07411 = the weight of a cubic foot of nitrogen.

.768 = the proportion by weight of nitrogen in the air. Simplifying Eq. (10),

Test Of A 400 H.P. Gas Producer.

$A = .0965\ V\ C_n.$ (11)

The cubic feet of dry air is

$A_v = 13.107 \times .0965\ V\ C_n.$ (12)

Where

13.107 is the volume in cubic feet, of one pound of air under standard conditions.

Simplifying the above expression,

$A_v = 1.2648\ V\ C_n.$ (13)

In making the calculations for the amount of steam used, the assumption is made that the moisture is supplied to the generator in the following ways; 1st., by the steam, 2nd., as moisture in the coal, 3d., as aqueous vapor in the air. All the hydrogen in the gas is supplied to the system as moisture (less that in the volatile combustible in the coal). Now the amount of hydrogen supplied by the moisture is

$H_m = H - H_v.$ (14)

Where

H_m = the hydrogen due to the moisture supplied.

H = the total hydrogen in the gas.

H_v = the hydrogen due to the volatile combustible in the coal.

Test Of A 400 H.P. Gas Producer.

$H_v = W (C_v \div 4)$. (15)

Where

W = the weight of coal burned.

C_v = the percent of volatile combustible in the coal. (1/4 of the volatile combustible by weight is hydrogen, assuming the volatile combustible to be CH_4).

The hydrogen in the gas due to the steam from the steam blower may now be calculated from the equation,

$H_s = H - W(C_m \div 9) - M_a$. (16)

Where

$W(C_m \div 9)$ = the weight of hydrogen supplied by the moisture in the coal.

C_m = the percent of moisture in the coal by weight.

M_a = the weight of moisture in the air used.

$M_a = H_a A_v K$. (17)

Where

H_a = the relative humidity of the air at the temperature of the room.

A_v = the cubic feet of air used.

K = the weight in pounds, of moisture which will saturate one cubic foot of air at the observed

temperature of the room.

Substituting this value of M_a in Eq.(16),

$$H_s = H - W(C_m + 9) - H_a A_v K. \qquad (18)$$

The pounds of steam used = $W_s = 9\ H_s$. (19)

since hydrogen is one-ninth by weight of water.

By means of the air tables and, knowing the relative humidity of the gas at its temperature in the factory mains, the weight of aqueous vapor taken up by the gas may be calculated. If

H_g = the relative humidity of the gas,

n_g = the weight in pounds of moisture necessary to saturate one foot of the gas at the observed temperature of the gas,

V = the cubic feet of gas,

M_g = the total weight of aqueous vapor in the gas,

Then $M_g = H_g V\ n_g$. (20)

With the preceding derived formulas and the data taken during the test, Tables 3,4,5 and 6 have been calculated. To show the method of calculating these tables and the application of the preceding formulas, the numerical calculations for run No.7 is here given:-

Length of the test = 8 hours.

Test Of A 400 H.P. Gas Producer.

Total coal used = 2375 lbs.

Coal used per hour = 296.9 lbs.

Moisture in the coal, by weight = 2.2%.

Total moisture in the coal = 2375 x .022 = 52.2 lbs.

Volatile combustible in the coal by weight = 4.4%.

Total volatile combustible in the coal =

2375 x .044 = 104.5 lbs.

Ash in the coal by weight = 11.2%.

Total ash in the coal = 2375 x .112 = 266 lbs.

Sulphur in the coal by weight = 1.9%.

Total sulphur in the coal = 2375 x .019 = 45.1 lbs.

Total sulphur in the refuse = 45.1 ÷ 2 = 22.6 lbs.

Total sulphur in the gas = 45.1 ÷ 2 = 22.6 lbs.

Fixed carbon in the coal by weight = 80.3%

Total fixed carbon in the coal =

2375 x .803 = 1907.3 lbs.

Total refuse in the ash-pit = 2375 (.112 +

(.112 x .0872)) = 316 lbs. (from Eq.1).

Total carbon in the ash-pit = 316 - (266 + 22.6)

= 27 lbs.

Total carbon in the carbon disulphide =

(3 x 2375 x .019) ÷ 32 = 4.2 lbs. (from Eq.7).

Total carbon disulphide = 16/3 x 4.2 = 26.8 lbs.

Test Of A 400 H.P. Gas Producer.

Total carbon in the volatile combustible =

104.5 x .75 = 78.3 lbs.

Total hydrogen in the coal = total hydrogen in

the volatile combustible = 104.5 - 78.3 = 26.1 lbs.

Total carbon in the coal = 1907.3 + 78.3 = 1985 lbs.

Area of the grate = 28.2744 sq.ft.

Coal burned per sq.ft. of grate per hour =

296.9 ÷ 28.2744 = 10.5 lbs.

Calculations of the gas, steam and air:-

Total carbon in the gas = 1985 - 4.2 - 27 = 1954 lbs.

Carbon in one cubic foot of the gas = .031845 x

.0658 + .031664 x .2137 + .031785 x .017 =

.009402 lbs. (from Eq.4)

Cubic feet of gas generated = 1954 ÷ .009402 =

207820 (from Eq.9)

Weight of nitrogen in the gas = .07411 x 207820

x .5446 = 8345.86 lbs.

Weight of air used = 8345.86 ÷ .768 = 10867 lbs.

Volume of air used = 10867 x 13.107 = 142424 cu.ft.

Air per pound of coal = 142424 ÷ 2375 = 59.9 cu.ft.

Total hydrogen in the gas = 207820 x .1589 x

.005 = 235.5 lbs.

Deducting the hydrogen in the coal, hydrogen due

to moisture = 235.5 - 26.1 = 209.4 lbs.

Total steam supplied = 209.4 x 9 = 1884.6 lbs.

Moisture in the air = .45 x .00221 x 142424 = 78.2 lbs.

Steam supplied = 1884.6 - (78.2+52.2) = 1754.2 lbs.

Steam per hour = 1754.2 ÷ 8 = 219.3 lbs.

Gas per pound of coal = 207820 ÷ 2375 = 87.5 lbs.

Steam per pound of coal = 1754.2 ÷ 2375 = .739 lbs.

Moisture in the gas = .7 x 207820 x .00225 = 327.3 lbs.

The pressure and temperature differances given in Tables 5 & 6 are calculated from the observed readings of temperatures and pressures. The corrected amount of water used in the various parts of the plant were read off from the calibration curves of the water meters. These meters were calibrated under the same conditions as they were used, the amount of water being varied from a maximum flow to the slip of the meter. The water run thru the meters in calibrating them was caught in tanks and weighed, the corresponding meter readings being taken. Knowing the amount of water used in the plant, the amount of

coal burned, and the gas generated, the water used per unit of coal or gas is easily calculated, and may be found in Table 6.

Heat Distribution:- This important part of a producer test is often the deciding point in the acceptance or not of a producer installation. However well a producer may make gas, its efficiency may not at all be sufficient to warrent installing, or even running. The conditions under which the gas is to be used must be such that the producer may be as economical if not more so, than any other method of fuel burning. The question of convenience and simplicity is also an item which bears consideration.

The producer gets its heat in two ways; first, from the fuel, either coal, water or air supplied to the producer; second, heat returned to the generator by the air and steam. The total heat supplied primarily, comes from the first source, but the efficiency of the producer largely depends upon the heat returned by the second source. In the following discussion and calculations, all amounts of heat are figured above 62 Deg.F., it

being assumed that the coal fed to the generator is at this temperature. The lower, or effective heating value of the gas is used, because in burning the gas in the factory, the products of combustion is not cooled back to the original temperature of the gas. The higher heating value of the coal is used, since, in bringing about the change from solid to gaseous fuel, the sensible heat of the coal is rendered latent in the gas.

Efficiencies:- The actual efficiency of the producer may be stated as the ratio of the latent heat in the gas to the total heat supplied by the fuel. This is also known as the cold gas efficiency. The commercial efficiency is the ratio of the latent heat in the gas (plus the sensible heat above 62 Deg.F.) to the heat supplied to the producer in the form of fuel plus the heat equivalent of the energy received by the producer from an outside source. The grate efficiency is the ratio of the B.T.U. of the coal burned in the producer to the B.T.U. of the fuel supplied to the producer. In some cases, as in this case, there is no grate in the generator, but this efficiency

will represent the ash-pit efficiency which is probably a more appropriate name for it. The efficiency of the economizer is the ratio of the heat actually taken up by the air, to the maximum amount which could be taken up by the air. The efficiency of an economizer depends altogether on its design. To obtain the highest efficiency from an economizer, all exposed surfaces should be well lagged, to reduce the radiation loss. The size must be such that there will be ample area for the heat transfer, the velocity of the gas and air thru the economizer must be low enough to allow the heat transfer to take place. As the heat transfer depends directly upon the temperature differance, for maximum efficiency the economizer should work on the counter current principle and should have as much surface exposed to the scrubbing action of the gases as possible, without creating an excessive resistance to the flow of the gases.

The heat supplied to the producer by the coal, is the weight of the coal in pounds times its B.T.U. per pound. The heat supplied by the steam is the

weight of steam used times the total heat in the steam at the observed pressure and quality. A steam separator is used to take all the entrained moisture from the steam, and a throttling calorimeter placed on the steam line showed practically dry steam. The velocity of the steam thru the steam separator was very low, and this accounted for its high efficiency. The heat supplied by the air is the weight of the air times its specific heat times the differance in temperature (above 62 Deg. F.). The total heat supplied may be represented by the equation,

$$H = H_c + H_s + H_a. \qquad (21)$$

Where

H = the total heat supplied.

H_c = the heat supplied by the coal.

H_s = the heat supplied by the steam.

H_a = the heat supplied by the air.

$$H_c = W\,h. \qquad (22)$$

Where

W = the weight of coal used in pounds.

h = the heat value of one pound of coal.

$$H_s = W_s(\,xr + q) \qquad (23)$$

Test Of A 400 H.P. Gas Producer.

Where

x = the quality of the steam.

r = the latent heat of evaporation, in B.T.U. of the steam at the observed pressure.

q = the heat of the liquid, in B.T.U. of the steam at the observed pressure.

W_s = the weight of steam used in pounds.

$$H_a = W_a S_a (t_r - 62). \qquad (24)$$

Where

W_a = the weight of air in pounds.

S_a = the specific heat of the air = .238.

t_r = the temperature of the room, in Deg.F.

Substituting these values in Eq.(21),

$$H = Wh + W_s(xr + q) + W_a S_a (t_r - 62). \qquad (25)$$

The latent heat in the gas is expressed by the equation,

$$H_g = V_g h_g. \qquad (26)$$

Where

H_g = the total heat in the gas.

V_g = the volume in cubic feet of gas generated.

h_g = the effective heat value of one cubic foot of the gas.

Then the actual efficiency of the producer is

Test Of A 400 H.P. Gas Producer.

$$E_a = V_g h_g \div (Wh + W_s(xr + q) + W_a S_a (t_r - 62)) \qquad (27)$$

If S_h is the sensible heat in the gas above 62 Deg. F., and B the heat equivalent of energy supplied to the producer from an outside source, then the commercial efficiency of the producer may be expressed by the equation,

$$E_c = (V_g h_g + S_h) \div (Wh + W_s(xr + q) + W_a S_a (t_r - 62) + B) \qquad (28)$$

When taking the observed data the energy furnished from an outside source was taken as kilowatt hours.

Then B = 3412 K . (29)

Where

K = the number of kilowatt hours used.

3412 = the heat equivalent of one K.W.Hr.

Substituting this value of B in Eq.(28),

$$E_c = (V_g h_g + S_h) \div (Wh + W_s(xr + q) + W_a S_a (t_r - 62) + 3412 K). \qquad (30)$$

The efficiency of the grate may be expressed by the equation,

$$E_g = (Wh - 14500 W_g) \div Wh \qquad (31)$$

Where

Wh = the heat supplied by the coal.

W_g = the weight in pounds of carbon in the ash-pit.

14500 = the heat of combustion of one pound of

Test Of A 400 H.P. Gas Producer.

carbon.

The efficiency of the economizer may be expressed by the equation,

$E_e = W_a S_a (t - t_1) \div W_a S_a (t_o - t_1) =$

$(t - t_1) \div (t_o - t_1)$ (32)

Where

t = temperature of the air leaving economizer.

t_1 = temperature of the air entering economizer.

t_o = temperature of the gas entering economizer.

Equation (32) is true since there is always more available heat in the gas than can be taken up by the air.

The specific heat of a mixture of gases, varies as the proportion of the gases in the mixture. The specific heat of a mixture of gases is obtained by multiplying the specific heat of each separate gas by its proportional weight in the mixture and adding the results. Gas generated from a gas producer generally contains carbon dioxide, carbon monoxide, hydrogen, methane and nitrogen. The specific heats due to,

$CO_2 = .2164 \times .1164\ C_1 = .0252\ C_1$.

$CO = .2479 \times .0738\ C_2 = .0183\ C_2$.

Test Of A 400 H.P. Gas Producer.

$H = 3.4046 \times .0053\ C_3 = .1702\ C_3.$

$CH_4 = .593 \times .0424\ C_4 = .0251\ C_4.$

$N = .244 \times .0741\ C_5 = .0181\ C_5.$

Where C_1, C_2, etc. refer to the percents by volume of the constituents in the gas. The specific heats in the previous equations refer to those at constant pressure, per pound of the gas. These specific heats have been determined by experiment and there seems to be such a differance with the differant experimenters, that it is not thought advisable to use them in these calculations.

Table 7 gives the results of the calculations of the heat distribution. As an example of the method of the calculations of this table, those of run No.7 is here given:-

Heat supplied by the coal = 296.9 x 12934 = 3,840,105 B.T.U.

Heat supplied by the steam = 219.3 (922 + 244 - 30) = 250,221 B.T.U.

Heat supplied by the air = 10,867 x .238 (72 -62) = 3,233 B.T.U.

Heat supplied as fuel = 3,840,105 + 250,221 + 3,233 = 4,093,559 B.T.U.

Heat supplied as energy = 136.25 x 3412 =

Test Of A 400 H.P. Gas Producer.

464,885 B.T.U.

Total heat supplied, fuel plus energy = 4,093,559 + 464,885 = 4,558,444 B.T.U.

Percent of the heat in the fuel supplied by the coal = 3,840,105 ÷ 4,093,559 = 93.9 %.

Percent of heat in the fuel supplied by the steam = 250,221 ÷ 4,093,559 = 6.05 %.

Percent of heat in the fuel supplied by the air = 3,233 ÷ 4,093,559 = 0.05 %.

Percent of the total heat supplied as energy = 464,885 ÷ 4,558,444 = 10.2 %.

Latent heat in the gas, high value, from analysis = 25,978 x 145.8 = 3,782,592 B.T.U.

Latent heat in the gas, low value, from analysis, = 25,978 x 135.9 = 3,530,410 B.T.U.

Latent heat in the gas, high value, from calorimeter = 25,978 x 144.8 = 3,761,614 B.T.U.

Latent heat in the gas, low value, from calorimeter = 25,978 x 134.9 = 3,507,030 B.T.U.

Heat lost as carbon in the ash-pit = 14,500 x 27 = 49,000 B.T.U.

Sensible heat in the gas at the temperature of the furnace = 4,093,559 - 3,530,410 = 563,149 B.T.U.

Heat taken up by the air in the economizer =

Test Of A 400 H.P. Gas Producer.

(10,867 ÷ 8) (238 x 325) = 105,040 B.T.U.

Percent of heat as fuel returned by the economizer = 105,040 ÷ 4,093,559 = 2.62 %.

Percent of the sensible heat returned by the economizer = 105,040 ÷ 563,149 = 18.6 %.

Heat taken up by the water in the scrubber = 61,158 ÷ 8) (80 - 38) = 321,029 B.T.U.

Heat added by the exhauster compressing the gas = 25,978 x .0198(92 - 50) = 20,393 B.T.U.

Ratio of compression heat to the energy heat = 20,393 ÷ 464,885 = 4.39

Heat lost to the water cooled top = (8000 ÷ 8) (138 - 38) = 100,000 B.T.U.

Radiation plus unaccounted for losses = 563,149 - (105,040 - 100,000 - 321,029) = 37,080 B.T.U.

Actual efficiency, E_a = 3,530,410 ÷ 4,093,559 = 86.3%.

Commercial efficiency, E_c = 3,530,410 ÷ 4,558,444 = 77.5 %.

Grate efficiency, E_g = (3,840,105 - 49,000) ÷ 3,840,105 = 98.73 %.

Economizer efficiency, E_e = (397 - 72) ÷ (1262 - 72) 27.8 %.

Ratio of E_a to E_c = 77.5 ÷ 86.3 = 89.9.

TABLE 3.

COAL AND ASH DATA.

NUMBER OF TEST	1	2	3	4	5	6	7	8	AVERAGE.
TOTAL COAL USED, LBS.	3375	1250	2650	1000	3125	2375	2375	2125	2037.6
COAL PER HOUR, LBS.	375.0	156.3	331.2	125.0	390.6	296.9	296.9	265.6	254.7
MOISTURE IN THE COAL, PERCENT BY WT.	2.5	2.5	2.5	2.5	2.5	2.2	2.2	2.2	2.4
VOLAT. COMB. IN THE COAL, PERCENT BY WT.	5.5	5.5	5.5	5.5	5.5	4.4	4.4	4.4	5.1
ASH IN THE COAL, PERCENT BY WT.	14.7	14.7	14.7	14.7	14.7	11.2	11.2	11.2	13.4
SULPHUR IN THE COAL, PERCENT BY WT.	1.2	1.2	1.2	1.2	1.2	1.9	1.9	1.9	1.46
FIXED CARBON IN THE COAL, PERCENT BY WT.	76.1	76.1	76.1	76.1	76.1	80.3	80.3	80.3	77.7
B.T.U. PER LB. OF COAL AS FIRED.	12613	12613	12613	12613	12613	12934	12934	12934	12733
CARBON IN ASH-PIT, PERCENT BY WT OF REFUSE.	5.60	4.83	6.47	6.80	5.00	11.20	8.72	9.10	7.09
TOTAL MOISTURE IN THE COAL, LBS.	84.4	31.2	66.2	25.0	78.1	52.2	52.2	46.7	54.5
TOTAL VOLAT. COMB. IN THE COAL, LBS.	185.6	68.8	146.0	55.0	172.0	104.5	104.5	93.5	116.2
TOTAL ASH IN THE COAL, LBS	496.1	183.7	389.5	147.0	459.4	266.0	266.0	238.0	305.7
TOTAL SULPHUR IN THE COAL, LBS.	40.5	15.0	31.8	12.0	37.5	45.1	45.1	40.4	33.4
TOTAL SULPHUR IN THE REFUSE, LBS.	20.3	7.5	15.9	6.0	18.7	22.5	22.6	20.2	16.7
TOTAL FIXED CARBON IN THE COAL, LBS.	2568.4	951.3	2016.7	761.0	2378.1	1907.3	1907.3	1706.4	1774.6
TOTAL REFUSE IN THE ASH-PIT, LBS.	547.0	201.0	429.0	164.0	503.0	325.0	316.0	284.0	346.1
TOTAL CARBON IN THE ASH-PIT, LBS.	31.0	10.0	24.0	11.0	25.0	36.0	27.0	26.0	23.8.
TOTAL CARBON IN THE CS_2, LBS.	3.8	1.4	3.0	1.2	3.5	4.2	4.2	3.8	3.14
TOTAL CS_2 (CARBON DISULPHIDE), LBS.	24.1	8.9	18.9	7.1	22.3	26.8	26.8	24.0	19.9
TOTAL CARBON IN THE VOLAT. COMB., LBS.	139.2	51.6	109.5	42.0	129.0	78.3	78.3	70.2	87.3
TOTAL HYDROGEN IN THE COAL, LBS.	46.4	17.2	36.5	14.0	43.0	26.1	26.1	23.4	29.1
TOTAL CARBON IN THE COAL, LBS.	2707.0	1003.0	2126.0	803.0	2507.0	1985.0	1985.0	1776.0	1861.5
COAL PER SQ. FT OF GRATE PER HR, LBS.	13.3	5.5	11.7	4.4	13.8	10.5	10.5	9.3	9.9
STEAM PER LB. OF COAL, LBS.	.564	.518	.649	.555	.682	.786	.739	.687	.648
AIR PER POUND OF COAL, CU. FT.	61.1	59.4	59.4	63.2	69.1	61.7	59.9	57.6	60.4
GAS PER POUND OF COAL, CU. FT.	83.6	83.6	84.5	85.9	94.0	89.3	87.5	84.5	86.6

TABLE 4

GAS, AIR AND STEAM DATA.

NUMBER OF RUN	1	2	3	4	5	6	7	8	AVERAGE
CO_2 IN THE GAS, PERCENT BY VOL.	7.00	5.93	6.14	7.92	5.43	6.57	6.58	7.8	6.67
CO IN THE GAS, PERCENT BY VOL.	21.09	22.19	21.60	19.34	20.23	20.62	21.37	20.80	20.90
H IN THE GAS, PERCENT BY VOL.	13.24	13.92	15.01	12.81	15.33	16.57	15.89	15.15	14.74
CH_4 IN THE GAS, PERCENT BY VOL.	1.79	1.79	1.82	1.75	0.93	1.70	1.70	1.79	1.66
N IN THE GAS, PERCENT BY VOL.	57.84	56.16	55.43	58.18	58.08	54.54	54.46	54.46	56.16
HUMIDITY OF THE GAS, PERCENT.	85	73	72	76	80	68	70	73	74.6
WT. OF CARBON IN 1 CU.FT. OF GAS, LBS.	.009473	.009484	.009343	.009202	.008431	.009162	.009402	.009639	.009270
WT. OF HYDROGEN IN 1 CU.FT. OF GAS, LBS.	.000984	.001025	.001093	.000954	.001018	.001174	.001133	.001099	.001060
WT. OF NITROGEN IN 1 CU.FT. OF GAS, LBS.	.042865	.041620	.041079	.043117	.043043	.040420	.040360	.040360	.041580
CALCULATED B.T.U. PER CU.FT., HIGH.	136.6	143.8	144.8	128.8	131.8	145.6	145.8	142.3	139.9
CALCULATED B.T.U. PER CU.FT., LOW.	129.0	135.8	134.5	120.4	123.0	135.4	135.9	132.7	130.8
FROM CALORIMETER, B.T.U. PER CU.FT., HIGH.	147.4	142.4	146.5	142.9	140.0	153.8	144.8	140.0	144.8
FROM CALORIMETER, B.T.U. PER CU.FT., LOW.	139.8	134.4	136.2	134.5	131.2	143.6	134.9	130.4	136.7
CUBIC FEET OF GAS, TOTAL.	281075	104560	224660	85938	293900	212280	207820	180100	197842
CUBIC FEET OF GAS PER HOUR.	31342	13069	28082	10742	36738	26535	25978	22512	24730
TOTAL MOISTURE IN THE GAS, LBS.	719.3	229.0	364.0	196.0	529.0	424.8	327.3	295.4	332.4
TOTAL CARBON IN THE GAS, LBS.	2672.0	991.6	2099.0	790.8	2478.5	1945.0	1954.0	1736.0	1834.0
TOTAL AIR USED, LBS.	15743	5666	12016	4825	16472	11172	10867	9418	10711
TOTAL AIR USED, CU. FT.	206330	74260	157483	63237	215884	146420	142424	122123	140380
TOTAL MOISTURE IN THE AIR, LBS.	94.5	41.0	96.0	31.7	96.0	87.7	78.2	64.1	74.9
TOTAL HYDROGEN IN THE GAS, LBS.	277.56	107.16	245.6	82.0	299.2	249.2	235.6	197.9	209.7
HYDROGEN IN GAS DUE TO MOISTURE, LBS.	231.2	90.0	209.1	68.0	256.2	223.1	209.4	174.5	180.6
TOTAL MOISTURE SUPPLIED, LBS.	2080.8	720.0	1881.9	612.0	2305.8	2007.9	1884.6	1570.5	1633.0
MOISTURE SUPPLIED BY AIR & COAL, LBS.	178.9	72.2	162.0	56.7	173.1	139.9	130.4	110.8	128.9
TOTAL STEAM SUPPLIED LBS.	1901.9	647.8	1719.9	555.3	2132.7	1868.0	1754.2	1459.7	1496.5
STEAM PER HOUR, LBS.	211.3	81.0	215.0	69.4	266.6	233.5	219.3	182.5	187.1

TABLE 5.

TEMPERATURE DATA, IN DEG. FAH.

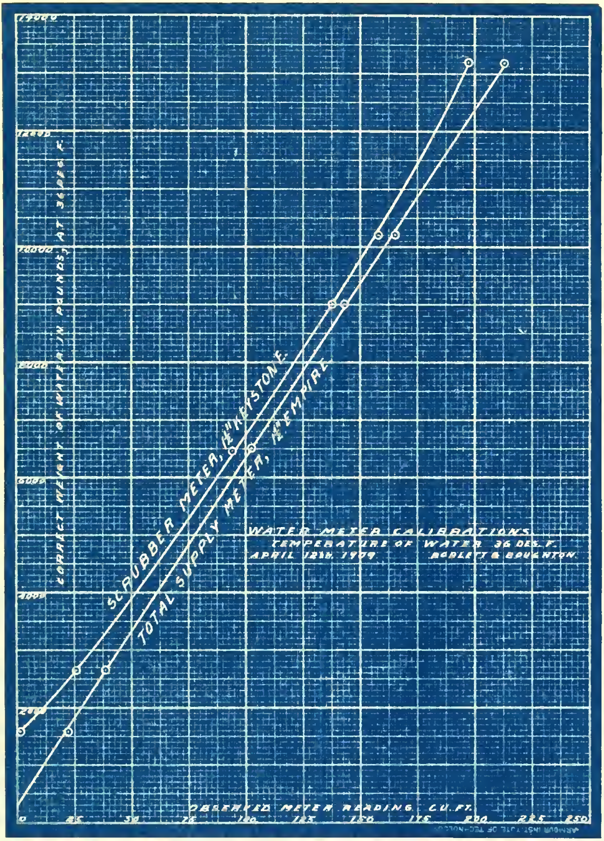
NUMBER OF RUN	1	2	3	4	5	6	7	8	AVERAGE
OUTSIDE AIR.	36.	49.	50	52	55.	51	49	54	50
AIR IN ROOM.	62	66	73	68	60	70	72	72	68
RISE IN TEMP. OF AIR IN ROOM	26	17	23	16	5	19	23	18	18
AIR TO ECONOMIZER.	62	66	73	68	60	70	72	72	70
AIR FROM ECONOMIZER	378	323	366	316	356	404	397	362	363
RISE IN TEMP. OF AIR IN ECONOMIZER	316	257	293	247	296	334	325	290	295
FURNACE	1300	1093	1198	1040	1244	1312	1262	1316	1221
GAS TO ECONOMIZER	1300	1093	1198	1040	1244	1312	1262	1316	1221
GAS FROM ECONOMIZER	616	426	569	375	594	568	623	596	546
DROP IN TEMP. OF GAS IN ECONOMIZER	684	667	629	665	650	744	639	720	675
GAS TO SCRUBBER	163	306	161	260	143	157	170	156	189
DROP IN TEMP. OF GAS TO SCRUBBER	521	362	468	405	507	587	469	564	486
GAS FROM SCRUBBER	51	50	49	51	54	50	50	50	52
DROP IN TEMP. OF GAS IN SCRUBBER.	112	255	112	209	89	107	120	106	139
GAS IN FACTORY MAINS.	107	102	92	106	92	91	92	90	97
RISE IN TEMP. OF GAS IN EXHAUSTER	56	52	43	55	38	41	42	40	46
WATER TO SCRUBBER	35	35	34	34	36	37	38	38	36
WATER FROM SCRUBBER.	75	57	62	49	85	89	80	78	72
RISE IN TEMP. OF WATER IN SCRUBBER	40	22	28	15	49	52	42	40	36
WATER TO WATER COOLED TOP.	35	35	34	34	36	37	38	38	36
WATER FROM WATER COOLED TOP.	109	95	157	68	125	101	138	104	112
RISE IN TEMP. OF WATER IN TOP.	74	60	123	34	89	64	100	64	76
WATER TO ASH-PIT SEAL.	109	95	157	68	125	101	138	104	112.
WATER FROM ASH-PIT SEAL.	92.	82	117	78	112	89	104	91	96
DROP IN TEMP. OF WATER IN ASH-PIT SEAL	17	13	40	−10	13	12	34	13	17

TABLE 6

PRESSURE, POWER AND WATER DATA.

NUMBER OF RUN.	1	2	3	4	5	6	7	8	AVERAGE.
PRESSURE IN BOTTOM OF GENERATOR, INS. H_2O.	2.04	2.18	1.50	2.36	2.50	2.03	1.60	2.02	2.03
PRESSURE IN TOP OF GENERATOR, INS. H_2O.	0.36	0.16	0.46	0.17	0.35	0.22	0.10	0.14	0.25
SUCTION OF EXHAUSTER, INS. H_2O.	4.13	1.08	2.43	0.51	3.33	3.28	3.12	3.82	2.71
PRESSURE TO OVERCOME RESISTANCE OF FUEL BED, INS. H_2O.	1.69	2.02	1.04	2.19	2.15	1.81	1.50	1.88	1.78
PRESSURE FURNISHED BY STEAM BLOWER, INS H_2O.	2.39	2.34	1.96	2.53	2.85	2.25	1.70	2.16	2.28
STEAM PRESSURE, LBS. PER SQ. IN.	59.4	10.8	35.6	20.1	46.0	48.0	45.0	44.0	39.2
PRESSURE IN FACTORY MAINS, LBS. PER SQ. IN.	2.82	2.75	2.75	2.63	2.50	2.63	2.50	2.54	2.64
BAROMETRIC PRESSURE, INS. HG.	29.83	29.32	29.21	29.52	28.86	29.36	29.52	29.23	29.36
BAROMETRIC PRESSURE, LBS. PER SQ. IN.	14.65	14.40	14.34	14.49	14.17	14.51	14.49	14.35	14.42
TOTAL WATER USED IN PLANT, LBS.	105750	64000	134385	122237	68747	56297	69158	81256	109041
TOTAL WATER USED IN PLANT, GALS.	12679	7674	16113	14659	8283	6783	8332	9799	13074
WATER USED IN SCRUBBER, LBS.	90450	51500	126384	108637	60107	50606	61158	64536	96000
WATER USED IN SCRUBBER, GALS.	10830	6140	15195	13020	7472	6097	7369	7775	11511
WATER USED IN WATER COOLED TOP, LBS.	15300	12800	8000	13600	8640	5691	8000	16720	13053
WATER USED IN WATER COOLED TOP, GALS.	1835	1534	959	1630	1041	685	964	2014	1565
WATER USED IN ASH-PIT SEAL, LBS.	15300	12800	8000	13600	8640	5691	8000	16720	13053
WATER USED IN ASH-PIT SEAL, GALS.	1835	1534	959	1630	1041	685	964	2014	1565
TOTAL WATER PER POUND OF COAL, GALS.	3.8	6.1	6.1	14.7	4.5	6.6	4.1	6.5	6.55
WATER IN SCRUBBER PER POUND OF COAL GALS.	3.2	4.9	5.7	13.0	3.9	5.9	3.7	5.6	5.74
WATER IN SCRUBBER PER 1000 CU. FT. GAS, GALS.	38.4	58.8	66.7	162.1	41.7	66.1	42.2	66.6	66.6
TOTAL WATER PER POUND OF COAL, LBS.	31.7	50.9	50.9	122.6	37.5	55.0	34.2	54.2	54.6
TOTAL WATER PER 1000 CU. FT. GAS., GALS.	45.6	73.2	71.4	170.5	48.2	73.9	46.7	76.1	79.5
TOTAL POWER USED, K.W. HRS.	1188.0	580.0	860.0	750.0	1100.0	990.0	1090.0	980.0	942.3
POWER USED PER HOUR, K. W. HRS.	132.00	72.50	107.50	93.75	137.50	123.75	136.25	122.50	116.5
POWER USED PER POUND OF COAL, K.W. HRS.	.352	.463	.325	.750	.352	.417	.459	.481	.450
POWER USED PER 1000 CU. FT. OF GAS, K.W. HRS.	4.224	5.556	3.803	8.775	3.766	4.670	5.233	5.628	5.220
POWER USED PER TON OF COAL, K.W. HRS.	704.	926.	650.	1500.	704.	834.	918.	962.	900.

Test Of A 400 H.P. Gas Produ_er.



Test Of A 400 H.P. Gas Producer.

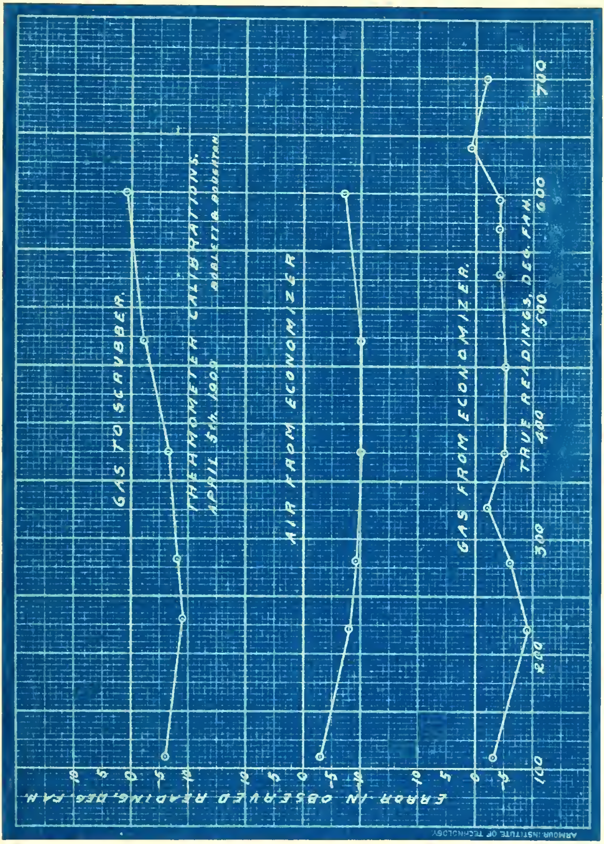


TABLE 7.

HEAT DISTRIBUTION, IN B.T.U. PER HOUR, ABOVE 62° F.

NUMBER OF RUN.	1	2	3	4	5	6	7	8	AVERAGE
HEAT SUPPLIED BY THE COAL.	4,729,875	1,971,412	4,[illegible]7,426	1,576,625	4,926,638	3,840,105	3,840,105	3,435,270	3,562,182
HEAT SUPPLIED BY THE STEAM.	242,043	91,157	2[illegible]4,606	78,491	304,324	266,657	250,221	209,470	210,675
HEAT SUPPLIED BY THE AIR.	0.0	674	3,929	861	−490	2,659	3,233	2,802	1,709
HEAT SUPPLIED AS FUEL.	4,971,898	2,063,243	4,[illegible]25,961	1,655,977	5,230,472	4,109,421	4,093,559	3,646,542	3,774,566
HEAT SUPPLIED AS ENERGY.	450,384	247,370	3[illegible]6,790	319,875	469,150	422,235	464,885	417,970	394,824
TOTAL HEAT SUPPLIED, FUEL PLUS ENERGY.	5,422,282	2,310,613	4,[illegible]92,751	1,975,852	5,699,622	4,531,656	4,558,444	4,064,512	4,169,390
HEAT SUPPLIED AS COAL, PERCENT OF HEAT IN FUEL.	95.2	95.4	[illegible]4.2	95.2	94.2	93.5	93.9	94.1	94.46
HEAT SUPPLIED AS STEAM, PERCENT OF HEAT IN FUEL.	4.8	4.4	5.5	4.7	6.0	6.45	6.05	5.73	5.45
HEAT SUPPLIED AS AIR, PERCENT OF HEAT IN FUEL.	0.0	0.2	[illegible].3	0.3	−0.2	0.05	0.05	0.17	0.04
HEAT SUPPLIED AS ENERGY, PERCENT OF TOTAL HEAT.	8.3	10.7	8.2	16.4	8.2	9.3	10.2	10.3	10.2
LATENT HEAT IN THE GAS, HIGH VALUE, ANALYSIS.	4,281,307	1,879,322	4,[illegible]66,274	1,383,570	4,842,068	3,863,496	3,782,592	3,203,458	3,462,200
LATENT HEAT IN THE GAS, LOW VALUE, ANALYSIS.	4,043,118	1,774,770	3,[illegible]77,029	1,293,337	4,518,774	3,592,839	3,530,410	2,997,342	3,189,702
LATENT HEAT IN THE GAS, HIGH VALUE, CALORIMETER.	4,619,811	1,861,026	4,[illegible]4,013	1,536,106	5,143,320	4,081,083	3,761,614	3,151,680	3,580,904
LATENT HEAT IN THE GAS, LOW VALUE, CALORIMETER.	4,381,612	1,756,474	3,[illegible]24,768	1,444,799	4,820,026	3,810,426	3,507,030	2,935,565	3,355,861
HEAT LOST AS CARBON IN THE ASH-PIT	49,933	18,125	[illegible]3,500	20,000	45,315	65,250	49,000	47,125	43,140
SENSIBLE HEAT IN THE GAS, ABOVE FURNACE TEMP.	928,780	288,473	6[illegible]8,932	362,640	711,698	516,582	563,149	659,200	584,864
HEAT TAKEN UP BY AIR IN ECONOMIZER.	133,467	43,320	1[illegible]9,741	35,448	145,123	111,055	105,040	81,237	94,930
PERCENT OF HEAT, AS FUEL, RETURNED BY ECONOMIZER.	2.69	2.10	[illegible].36	2.14	2.78	2.70	2.62	2.23	2.45
PERCENT OF SENSIBLE HEAT RETURNED BY ECONOMIZER.	14.4	16.0	16.2	9.8	20.4	21.6	18.6	12.3	16.3
HEAT TAKEN UP BY WATER IN SCRUBBER.	488,320	141,614	3[illegible]2,344	203,685	368,155	329,000	321,029	346,795	317,618
HEAT ADDED BY EXHAUSTER COMPRESSING GAS.	33,223	12,677	[illegible]2,466	11,064	25,974	20,353	20,393	16,884	21,268
RATIO OF COMPRESSION HEAT TO ENERGY HEAT.	7.40	5.12	6.13	3.46	5.52	4.82	4.39	4.03	5.38
HEAT LOST TO WATER-COOLED TOP.	141,525	96,000	123,000	57,800	96,130	45,527	100,000	133,760	124,002
RADIATION PLUS UNACCOUNTED FOR LOSSES.	79,143	25,774	118,847	65,477	2,290	31,000	37,080	26,072	48,314
ACTUAL EFFICIENCY, E_a.	81.4	85.9	85.3	78.2	86.3	87.3	86.3	84.3	85.6
COMMERCIAL EFFICIENCY, E_c.	74.6	76.6	78.7	65.5	79.3	79.2	77.5	73.7	76.6
GRATE EFFICIENCY, E_g.	98.95	99.08	98.96	98.73	99.08	98.30	98.73	98.63	98.79
ECONOMIZER EFFICIENCY E_e.	29.0	29.5	30.5	30.3	28.6	30.9	31.5	27.8	29.8
RATIO OF E_a TO E_c.	91.7	89.3	92.3	83.8	91.9	90.8	89.9	87.5	89.5

MOBLETT & BOUGHTON.

TIME		
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4:40		
5:00	3375	9.7
AVERAGES TOTALS	3375	7.4

MARCH 11 1909 LOG OF TEST RUN NO. 1 ON GENERATOR NO. 2.

TIME	FUEL USED LBS.	TEMPERATURES DEG FAHR. — AIR — OUTSIDE	AIR — ROOM	AIR — FROM ECONOMIZER	GAS — OF GENERATOR OR TO ECONOMIZER	GAS — FROM ECONOMIZER	GAS — TO SCRUBBER	GAS — FROM SCRUBBER	GAS — IN FACTORY MAIN	WATER — WATER SUPPLY	WATER — FROM SCRUBBER	WATER — FROM WATER COOLED TOP TO ASH-PIT SEAL	WATER — FROM ASH-PIT SEAL	PRESSURES — STEAM LBS/SQ IN	BOTTOM OF GENERATOR IN. OF WATER	TOP OF GENERATOR IN. OF WATER	SUCTION OF EXHAUSTER LESS THAT IN THE GENERATOR IN. OF WATER	IN FACTORY MAINS LBS. & OZ.	BAROMETER INS. OF HG.	METER READING — WATER — TOTAL WATER CU. FT.	WATER — SCRUBBER WATER CU. FT.	POWER — WATT METER 10 KW. HR.	GAS ANALYSIS PER CENT BY VOL. — CO_2	CO	H_2	CH_4	N_2	HEATING VALUE OF THE GAS — FROM ANALYSIS B.T.U. PER CU. FT. HIGH	FROM ANALYSIS B.T.U. PER CU. FT. LOW	FROM CALORIMETER B.T.U. PER CU. FT. HIGH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
8:00		41	60	343	1140	568	162	50	1005	35	85	77	80	60	2.0	0.0	3.5	2-14		238734	0005	10123								
8:20		38	56	324	1170	564	124	50	103	35	52	68	76	65	2.0	0.5	3.9	2-10												
8:40		40	58	324	1370	624	133	51	106	35	52	77	74	64	2.0	0.3	4.6	2-15												
9:00		41	59	343	1215	615	143	51	98	35	53	81	79	74	2.0	-0.4	4.6	2-14	29.86	238858	159	10136	5.9	18.0	10.4	1.14	64.56	109.4	105.4	148.0
9:20		41	59	344	1245	591	143	51	100	35	52	94	81	59	2.1	0.3	4.6	3-0												
9:40		34	60	343	1295	628	133	50	98	35	52	148	85	77	2.0	0.0	5.8	2-15												
10:00		38	60	346	1260	623	143	51	97	35	51	158	92	68	1.9	-0.3	4.3	2-13		238982	275	10149								
10:20		38	61	350	1305	648	133	52	97	35	51	160	98	82	1.9	0.0	5.3	2-12												
10:40		42	65	364	1225	718	149	52	93	35	51	142	114	82	1.9	0.5	5.5	2-12												
11:00		34	63	376	1185	636	260	52	95	35	104	82	93	62	2.0	-0.3	3.3	2-14	29.84	239107	395	10152	7.6	20.6	12.64	3.59	55.57	152.1	145.1	138.8
11:20		34	64	390	1420	638	136	51	95	35	91	147	99	78	2.0	-0.3	5.0	2-13												
11:40		35	66	382	1480	666	138	51	96	35	92	147	100	87	2.0	0.0	4.0	2-14												
12:00		36	63	420	1440	560	260	51	114	35	75	83	100	19	2.1	0.6	1.0	3-2		239444	606	10165								
12:20		33	60	380	1260	488	278	51	123	35	60	78	95	19	2.1	1.0	1.3	3-1												
12:40		35	60	345	1270	616	128	51	119	36	62	74	92	67	2.1	0.7	4.4	2-1												
1:00		35	62	360	1415	674	135	50	118	35	79	99	86	75	2.0	0.5	4.5	2-11	29.82	239768	819	10178	8.0	21.7	15.47	1.44	63.38	142.4	135.2	153.0
1:20		35	64	376	1400	626	142	50	118	35	82	150	98	46	2.0	0.0	3.0	2-11												
1:40		35	64	370	1405	673	136	51	119	35	81	93	92	66	2.0	0.6	4-0	2-10												
2:00		35	64	372	1390	660	131	50	103	35	89	90	93	95	2.0	1.1	5.5	2-13		239867	1004	10199								
2:20		35	65	378	1190	634	142	51	104	35	88	91	96	60	2.0	0.9	3.6	2-12												
2:40		34	66	384	1280	650	132	51	105	35	84	95	93	63	2.0	0.9	3.9	2-12												
3:00		35	66	386	1240	670	142	51	106	35	90	119	97	64	2.0	1.4	3.9	2-12	29.82	240043	1145	10221	7.0	22.1	11.34	1.42	58.14	129.6	122.1	147.8
3:20		35	66	396	1300	680	142	51	105	35	92	94	62	62	2.0	0.6	2.6	2-14												
3:40		35	65	383	1430	658	143	51	109	35	87	129	100	57	2.0	0.3	3.1	2-13												
4:00		35	65	383	1445	674	143	51	106	35	96	88	93	52	2.0	0.2	3.0	2-13		240106	1267	10230								
4:20		35	64	390	1330	554	240	52	112	35	92	94	93	15	2.1	0.3	2.7	2-15												
4:40		35	59	384	1160	434	288	52	129	35	78	146	96	8	2.1	0.2	3.9	3-0												
5:00	3375	34	59	364	1200	366	247	52	140	35	72	132	92	7	2.1	0.3	3.0	3-0	29.79	240343	1393	10242	6.5	23.0	16.33	1.40	52.77	149.7	142.3	149.7
AVERAGES TOTALS	3375	36.4	62.3	367.6	1300.2	613.7	156.2	51	107.4	35	74.75	109	91.8	59.4	2.04	0.36	3.78	2-13.1	29.83	1609.	1388	118.8	7.0	21.05	13.24	1.79	57.84	133.6	129.0	147.4

MARCH 13 1909 — LOG OF TEST RUN NO. 2 — ON GENERATOR NO. 2

TIME	FUEL USED LBS.	TEMPERATURES DEG. FAHR. — AIR — OUTSIDE	AIR — ROOM	AIR — FROM ECONOMIZER	GAS — OF GENERATOR OR TO ECONOMIZER	GAS — FROM ECONOMIZER	GAS — TO SCRUBBER	GAS — FROM SCRUBBER	GAS — IN FACTORY MAIN	WATER — WATER SUPPLY	WATER — FROM SCRUBBER	WATER — FROM WATER COOLED TOP TO ASH-PIT SEAL	WATER — FROM ASH-PIT SEAL	PRESSURES — STEAM LBS/SQ.IN	BOTTOM OF GENERATOR IN. OF WATER	TOP OF GENERATOR IN. OF WATER	SUCTION OF EXHAUSTER LESS THAT IN THE GENERATOR IN. OF WATER	IN FACTORY MAINS LBS & OZ.	BAROMETER INS. OF HG.	METER READING — WATER — TOTAL WATER CU. FT.	SCRUBBER WATER CU. FT.	POWER — WATT METER 10 K.W. HR.	GAS ANALYSIS PER CENT BY VOL. — CO_2	CO	H_2	CH_4	N_2	HEATING VALUE OF THE GAS — FROM ANALYSIS B.T.U. PER CU.FT. HIGH	FROM ANALYSIS B.T.U. PER CU.FT. LOW	FROM CALORIMETER B.T.U. PER CU.FT. HIGH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7:30		45	58	312	990	368	228		83	35	55	93	80	10		0.5	1.8	2-13		240379	1437	10302								
7:50		49	60	312	1080	370	252		90	35	54	122	89	12		0.4	1.3	2-10												
8:10		39	58	300	960	367	251		94	35	56	114	94	9		0.4	1.1	2-11	29.38											
8:30		41	58	298	1060	374	266		97	35	56	129	92	8		0.3	1.2	2-12		240485	1536	10309	4.44	24.04	18.6	1.77	51.15	164.2		146.3
8:50		49	64	300	1130	398	286		98	35	56	86	91	4		0.3	1.2	2-10												
9:10		49	64	298	980	417	312		98	35	59	65	82	15		0.7	1.0	2-8												
9:30		50	64	320	1110	418	312		100	35	59	88	83	15		0.3	0.9	2-9		240600	1621	10316								
9:50		50	66	302	1160	408	306		100	35	58	132	82	10		0.3	0.5	2-12												
10:10		51	68	316	1245	466	357		100	35	58	125	91	16		0.3	1.0	2-10	29.36	240700	1704	10322								
10:30		51	68	318	1130	456	341		101	35	62	105	92	13		0.0	1.1	2-9					6.4	23.0	14.1	2.12	54.38	149.7		113.7
10:50		51	68	322	1205	459	330		100	35	61	116	92	14		0.0	1.2	2-11												
11:10		49	87	316	1060	414	318		101	35	60	90	83	8		0.0	1.0	2-11												
11:30		48	67	316	1160	404	326		102	35	60	76	81	9		0.0	1.1	2-11		240827	1798	10330	6.4	21.3	13.4	1.44	57.46	134.5		
11:50		50	68	320	1010	458	344		101	35	62	80	81	15		0.2	1.1	2-11												
12:10		52	69	320	1106	402	282		102	35	60	121	78	8		0.4	0.5	2-11												
12:30		53	69	318	1125	344	245		104	35	52	124	94	8		0.0	0.6	2-11		241070	1912	10338								
12:50		50	68	312	1020	410	310		109	35	52	67	75	10		0.0	1.1	2-7												
1:10		52	69	310	1100	444	332		107	35	59	60	73	15		0.0	0.8	2-7	29.28											
1:30		48	69	314	1200	484	354		108	35	60	100	75	17		0.0	1.2	2-11		241105	1954	10345	5.4	20.6	7.40	2.20	64.38	129.4		162.2
1:50		51	68	332	1060	448	332		107	35	61	107	81	9		0.0	1.1	2-11												
2:10		53	68	322	1120	434	304		107	35	57	121	84	11		0.0	0.5	2-11												
2:30		50	68	330	1180	422	292		108	35	55	87	91	9		0.0	0.4	2-10		241330	2071	10357								
2:50		45	66	328	1000	480	270		110	35	54	55	70	7		0.0	0.6	2-11												
3:10		48	68	312	1040	349	244		110	35	52	58	62	9		0.0	0.5	2-11	29.28											
3:30	1250	52	68	304	1090	342	228		112	35	50	74	65	9		0.0	0.4	2-10		2414000	2193	10360	7.01	22.0	16.0	1.41	53.58	141.3		147.4
AVERAGES & TOTALS	1250	49.4	66.0	314	1093	421.4	297		102	35	57.1	95.8	82.4	10.8		.16	0.92	2-10.4	29.32	1021	756	580	5.9	22.2	13.9	1.79	56.21	143.8		142.4

READINGS NOT CORRECTED

BOBLETT & BOUGHTON.

MARCH 19 1909 LOG OF TEST. RUN NO. 3 ON GENERATOR NO. 2.

TIME	FUEL USED LBS	TEMPERATURES DEG. FAHR. — AIR — OUTSIDE	AIR — ROOM	AIR — FROM ECONOMIZER	GAS — OF GENERATOR OR TO ECONOMIZER	GAS — FROM ECONOMIZER	GAS — TO SCRUBBER	GAS — FROM SCRUBBER	GAS — IN FACTORY MAIN	WATER — WATER SUPPLY	WATER — FROM SCRUBBER	WATER — FROM WATER COOLED TOP TO ASH-PIT SEAL	WATER — FROM ASH-PIT SEAL	PRESSURES — STEAM LBS/SQ. IN.	BOTTOM OF GENERATOR IN. OF WATER	TOP OF GENERATOR IN. OF WATER	SUCTION OF EXHAUSTER LESS THAT IN THE GENERATOR IN. OF WATER	IN FACTORY MAINS LBS. & OZ.	BAROMETER IN. HG.	METER READING — WATER — TOTAL WATER CU. FT.	WATER — SCRUBBER WATER CU. FT.	POWER — WATT METER 10 K.W. HR.	GAS ANALYSIS PER CENT BY VOL. — CO_2	CO	H_2	CH_4	N_2	HEATING VALUE OF THE GAS — FROM ANALYSIS B.T.U. PER CU. FT. HIGH	FROM ANALYSIS B.T.U. PER CU. FT. LOW	FROM CALORIMETER B.T.U. PER CU. FT. HIGH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7:40		50	69	345	24.3	573	148	49	90	35	74	154	110	36	1.0	0.5	2.4	2-11		241475	2251	10926								
8:00		51	68	340	26.0	554	148	49	90	34	60	157	115	39	1.1	0.0	2.5	2-9												
8:20		51	68	340	23.0	566	132	48	88	35	58	162	104	39	2.0	0.2	2.5	2-10												
8:40		48	68	338	24.1	563	130	48	89	34	58	161	118	43	3.0	1.0	2.5	2-10		241828	2553	10936	6.6	21.4	15.36	21.6	54.45	148.9	138.8	
9:00		49	67	332	23.2	540	140	48	90	34	59	162	112	42	2.9	1.6	1.7	2-15												
9:20		48	69	332	24.4	546	138	47	91	34	58	162	114	41	1.3	0.1	2.6	2-10												
9:40		48	72	352	27.3	556	132	48	91	34	58	173	122	40	1.4	0.0	2.8	2-10		242121	2853	10947								
10:00		49	71	344	22.5	538	140	48	82	34	60	172	114	40	2.1	1.0	2.1	2-13												
10:20		53	70	354	21.4	566	134	48	91	34	60	178	114	4.2	1.70	0.2	3.1	2-8												
10:40		47	72	356	21.3	602	133	48	88	34	59	183	125	42	1.3	0.5	2.8	2-10	29.20	242400	3156	10957	6.2	19.1	13.94	2.99	57.77	145.1	134.8	158.2
11:00		52	76	354	25.0	558	135	48	90	34	61	176	124	40	1.0	0.0	1.5	2-11												
11:20		51	73	362	28.8	601	144	48	90	34	61	180	125	44	1.5	0.0	3.4	2-10												
11:40		50	75	368	26.0	611	138	48	90	34	61	180	125	34	1.0	0.1	3.3	2-13		242656	3377	10968								
12:00		51	75	368	24.5	552	220	49	95	34	64	182	124	20	1.5	1.0	0.0	2-15												
12:20		51	72	378	26.0	466	270	50	96	34	56	180	127	15	2.0	1.5	0.0	2-12												
12:40		50	70	344	24.8	559	136	49	97	34	57	174	125	38	0.6	0.1	2.4	2-11	29.20	242940	3654	10978	5.7	20.5	14.76	0.74	58.30	128.7	120.4	145.6
1:00		50	72	347	26.0	572	136	49	94	34	61	183	126	40	1.1	0.1	2.7	2-10												
1:20		49	74	362	24.0	618	130	49	91	34	63	182	127	50	2.7	0.0	3.7	2-9												
1:40		52	77	388	24.6	640	146	49	94	34	66	175	126	40	0.0	0.4	2.2	2-4	29.21	243151	3895	10989	6.7	23.3	14.93	2.80	52.27	156.8	146.3	139.6
2:00		51	77	380	23.0	590	146	49	94	34	68	111	119	36	1.4	0.4	1.0	2-11												
2:20		50	72	382	24.0	585	146	49	95	34	68	114	112	36	1.5	0.5	2.2	2-14												
2:40		51	72	360	22.0	542	181	49	94	34	62	96	110	35	1.6	0.0	0.0	2-13		243395	4121	11000								
3:00		50	75	364	23.0	560	180	49	95	34	64	120	112	40	1.8	0.4	1.0	2-12												
3:20		53	73	358	25.2	538	248	49	94	34	63	95	105	36	2.5	1.1	1.3	2-14												
3:40	2650	60	72	354	24.4	550	146	51	103	34	63	93	105	32	1.0	0.8	0.6	2-13	29.34	243623	4306	11012	5.5	23.7	16.05	0.42	50.55	140.7	132.0	142.2
AVERAGES & TOTALS	2650	50.2	72.6	356	24.3	565	154	49	92.4	34	62	156.6	117.4	35.6	1.5	0.46	1.97	2-12	29.21	2148	2055	860	6.14	21.6	15.01	1.82	55.43	144.8	134.5	146.5

READINGS NOT CORRECTED

BOBLETT & BOUGHTON.

MARCH 23 1909 LOG OF TEST RUN NO. 4. ON GENERATOR NO. 2.

TIME	FUEL USED LBS.	TEMPERATURES DEG. FAHR. — AIR: OUTSIDE	AIR: ROOM	AIR: FROM ECONOMIZER	GAS: OF GENERATOR OR TO ECONOMIZER	GAS: FROM ECONOMIZER	GAS: TO SCRUBBER	GAS: FROM SCRUBBER	GAS: IN FACTORY MAIN	WATER: WATER SUPPLY	WATER: FROM SCRUBBER	WATER: FROM WATER COOLED TOP TO ASH-PIT SEAL	WATER: FROM ASH-PIT SEAL
1	2	3	4	5	6	7	8	9	10	11	12	13	14
7:40		40	55	302	16.5	318	230	51	95	34	58	61	84
8:00		41	56	282	18.6	316	227	50	98	34	52	61	79
8:20		42	60	294	19.5	340	240	50	100	34	52	65	76
8:40		44	62	278	18.0	316	238	50	103	34	53	63	75
9:00		44	60	284	20.0	344	241	50	106	34	52	66	73
9:20		45	62	284	18.2	380	264	50	105	34	52	66	73
9:40		46	63	298	20.9	385	265	50	106	34	54	68	73
10:00		46	66	312	22.5	330	287	50	105	34	53	76	74
10:20		48	67	310	20.0	406	274	49	105	34	49	75	75
10:40		49	68	310	18.8	394	268	48	105	34	47	75	75
11:00		49	68	320	19.6	388	254	49	106	34	47	76	75
11:20		51	70	298	21.4	420	290	50	106	34	49	76	78
11:40		52	69	320	22.5	421	286	50	106	34	49	77	78
12:00		55	69	310	21.4	388	192	51	105	34	48	76	81
12:20		56	71	320	19.6	380	190	51	106	34	46	77	80
12:40		56	71	281	19.5	330	192	52	105	34	46	77	82
1:00		58	72	295	18.8	344	234	52	108	34	45	66	82
1:20		58	71	310	19.8	378	260	52	110	34	44	62	83
1:40		59	72	322	19.8	381	264	52	113	34	43	60	83
2:00		59	72	318	21.0	366	268	53	113	34	46	62	80
2:20		60	72	330	20.0	360	270	53	112	34	48	60	76
2:40		60	72	321	20.0	396	274	53	112	34	50	58	73
3:00		61	72	310	21.0	390	270	53	110	34	50	60	75
3:20		62	72	316	22.8	380	250	53	110	34	51	62	76
3:40	1000	62	316	31.6	22.8	380	250	53	110	34	51	62	78
AVERAGES & TOTALS	1000	52	67.5	306	20.1	370.2	251	50.6	106	34	49	67.5	77.5

TIME	PRESSURES: STEAM LBS/SQ.IN.	BOTTOM OF GENERATOR IN. OF WATER	TOP OF GENERATOR IN. OF WATER	SUCTION OF EXHAUSTER LESS THAN IN THE GENERATOR IN. OF WATER	IN FACTORY MAINS LBS & OZ.	BAROMETER INS. OF HG.	METER READING — WATER: TOTAL WATER CU. FT.	WATER: SCRUBBER WATER CU. FT.	POWER: WATT METER 10 KW. HR.	GAS ANALYSIS PERCENT BY VOL.: CO_2	CO	H_2	CH_4	N_2	HEATING VALUE OF THE GAS: FROM ANALYSIS B.T.U. PER CU.FT. HIGH	FROM ANALYSIS BTU PER CU.FT. LOW	FROM CALORIMETER B.T.U. PER CU.FT. HIGH
1	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7:40	10	0.8	0.0	0.0	2-14		243701	4368	11309								
8:00	10	0.8	0.0	0.0	2-15												
8:20	24	2.5	0.7	0.6	2-10					6.7	20.3	8.27	2.19	62.54	121.1	114.6	
8:40	20	3.00	0.5	1.3	2-10		243911	4634	11318								
9:00	24	2.2	0.3	0.5	2-10												
9:20	24	3.8	0.0	0.2	2-7	29.55											148.5
9:40	26	3.5	0.6	0.0	2-11		244265	4905	11327								
10:00	25	2.4	0.0	0.1	2-8												
10:20	25	2.4	0.0	0.2	2-9					8.8	20.0	11.87	2.14	57.13	131.9	123.6	
10:40	27	3.2	0.0	0.4	2-8		244523	5139	11337								
11:00	25	3.10	0.2	0.6	2-10												
11:20	25	3.4	0.1	0.0	2-10	29.52				8.4	19.9	14.8	1.43	55.47	133.6	124.5	151
11:40	25	3.0	0.0	0.1	2-10		244780	5368	11357								
12:00	25	3.0	0.0	0.4	2-8												
12:20	18	2.4	0.1	0.0	2-12												
12:40	15	1.4	0.4	0.0	2-11		245016	5585	11366								
1:00	16	1.6	0.0	0.2	2-12												
1:20	16	1.8	0.1	0.1	2-10					7.8	16.8	15.58	1.51	58.31	127.1	117.5	
1:40	18	2.0	0.2	0.6	2-11		245253	5806	11369								
2:00	17	2.2	0.0	0.0	2-12												
2:20	19	1.8	0.6	0.8	2-12	29.52				7.9	19.7	13.51	1.45	57.44	129.2	128.8	143.1
2:40	19	1.8	0.1	1.2	2-12		245490	6018	11374								
3:00	18	1.6	0.0	0.1	2-11												
3:20	16	2.2	0.1	0.6	2-11	29.50											129.2
3:40	16	2.0	0.2	0.4	2-10		245729	6210	11384								
AVERAGES & TOTALS	20.1	2.36	0.17	0.34	2-10	29.52	2028	1842	750	7.92	19.34	12.81	1.76	58.18	128.8	120.4	142.9

READINGS NOT CORRECTED

BOBLETT & BOUGHTON.

MARCH 26, 1909. LOG OF TEST RUN NO. 5 ON GENERATOR NO. 1.

TIME	FUEL USED LBS.	TEMPERATURE DEG. FAHR. — AIR: OUTSIDE	AIR: ROOM	GAS: FROM ECONOMIZER	GAS: OF GENERATOR OR TO ECONOMIZER	GAS: FROM ECONOMIZER	GAS: TO SCRUBBER	GAS: FROM SCRUBBER	GAS: IN FACTORY MAIN	WATER: WATER SUPPLY	WATER: FROM SCRUBBER	WATER: FROM WATER COOLED TOP TO ASH-PIT SEAL	WATER: FROM ASH-PIT SEAL	PRESSURES — STEAM LBS./SQ. IN.	BOTTOM OF GENERATOR OR IN. OF WATER	TOP OF GENERATOR IN. OF WATER	SUCTION OF EXHAUSTER LESS THAN IN THE GENERATOR IN. OF WATER	IN FACTORY MAINS LBS. & OZ.	BAROMETER INS. OF HG.	METER READ'G — WATER: TOTAL WATER CU. FT.	WATER: SCRUBBER WATER CU. FT.	POWER: WATT METER 10 KW HR.	GAS ANALYSIS PER CENT VOLUME — CO_2	CO	H_2	CH_4	N_2	HEATING VALUE OF THE GAS — FROM ANALYSIS B.T.U. PER CU. FT.	FROM ANALYSIS B.T.U. PER CU. FT. LOW	FROM ANALYSIS B.T.U. PER CU. FT. HIGH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
8:00		50	51	310	20.5	511	122	51	88	36	82	106	92	47	3.8	0.2	3.6	2-9		245821	6666	11593								
8:20		50	53	300	22.0	514	132	51	90	36	69	111	96	47	2.7	0.2	3.5	2-11	28.94				6.5	20.8	19.4	1.45	51.86	153.3	141.9	153.3
8:40		50	53	304	24.4	500	131	51	90	36	69	110	98	50	3.0	0.3	3.6	2-10												
9:00		50	53	308	26.0	508	131	51	88	36	69	110	101	50	2.7	0.9	3.9	2-9		246136	6955	1193								
9:20		51	51	321	20.0	558	137	51	90	36	76	125	97	49	3.0	0.9	3.0	2-10					6.5	18.9	14.4	0.75	59.4	122.3	114.1	131.2
9:40		50	54	318	21.6	565	136	52	90	36	72	155	100	46	1.8	0.4	2.6	2-10												
10:00		51	55	307	22.2	574	130	52	90	36	72	160	104	42	1.1	0.5	2.7	2-9		246380	7175	11976								
10:20		51	58	321	23.0	530	123	52	86	36	73	156	112	55	1.7	0.0	4.4	2-8	28.92				5.8	20.2	16.5	0.00	55.5	133.0	123.5	144.3
10:40		52	58	328	24.2	570	130	53	88	36	84	168	116	52	1.6	0.4	3.6	2-9												
11:00		52	58	352	25.5	660	136	52	88	36	86	182	118	52	2.0	1.0	3.3	2-10		246617	7384	11990								
11:20		52	61	357	24.0	701	134	52	86	36	88	155	112	52	2.2	0.0	4.3	2-8	28.91				3.8	20.0	17.1	0.76	58.3	135.5	125.9	141.8
11:40		53	62	356	26.0	585	188	52	86	36	93	170	114	42	2.0	0.0	3.0	2-10												
12:00		54	65	352	28.4	546	252	54	99	36	93	190	115	30	2.8	0.2	2.0	2-10		246862	7587	12002								
12:20		55	69	356	25.8	594	138	57	92	36	93	192	114	33	3.0	0.2	1.3	2-12	28.79				5.9	19.9	10.8	1.48	61.9	120.4	113.8	147.9
12:40		57	69	358	25.6	590	136	57	96	36	92	190	111	38	3.2	0.4	1.8	2-10		247056										
1:00		56	64	361	25.5	692	136	57	96	36	92	192	102	58	3.6	1.0	3.0	2-5		247056	7792	12012								
1:20		57	67	360	26.0	646	140	57	99	36	90	193	121	35	2.0	0.2	2.1	2-6	28.79				4.4	21.7	12.8	0.74	60.4	125.8	118.4	135.6
1:40		57	66	362	27.2	630	136	57	94	36	89	190	121	41	1.8	0.3	2.6	2-5												
2:00		58	70	363	28.9	610	130	57	95	36	94	187	120	44	3.4	0.0	2.4	2-4		247246	7974	12025								
2:20		60	67	379	29.0	620	138	57	95	36	94	190	122	48	2.8	0.0	3.0	2-6	28.79				5.3	20.2	14.9	0.75	59.9	128.5	120.1	131.4
2:40		60	66	380	28.8	616	136	57	94	36	93	186	124	48	2.2	0.0	3.0	2-6												
3:00		61	70	384	29.0	588	138	57	96	36	93	180	126	45	1.9	0.2	3.1	2-5		247434	8151	12048								
3:20		59	66	378	28.6	623	138	57	96	36	96	185	124	45	2.3	0.6	3.0	2-6	28.78				5.2	20.1	14.7	1.47	58.5	135.1	126.0	134.6
3:40		60	66	378	30.0	618	140	57	97	36	96	190	120	46	2.6	0.7	2.8	2-6												
4:00	3125	60	65	380	25.5	598	142	57	97	36	93	163	118	40	3.0	0.2	3.0	2-6		247637	8340	12062								
AVERAGE & TOTALS	3125	54.6	60	346	25.5	590	136.4	54.3	92.2	36	85.4	125	112	46	2.5	0.35	2.98	2-8	28.86	1876	1674	1100	5.43	20.23	15.33	0.93	58.08	131.8	123.0	140.0

READINGS NOT CORRECTED.

BOBLETT & BOUGHTON.

MARCH 29, 1909. LOG OF TEST RUN NO. 6. ON GENERATOR NO. 2.

TIME	FUEL USED LBS.	Temperature Deg. Fahr. — Air: Outside	Air: Room	Air: From Economizer	Gas: Of Generator or To Economizer	Gas: From Economizer	Gas: To Scrubber	Gas: From Scrubber	Gas: In Factory Main	Water: Water Supply	Water: From Scrubber	Water: From Water Cooled Top to Ash-Pit Seal	Water: From Ash-Pit Seal	Pressures: Steam Lbs./Sq. In.	Bottom of Generator In. Water	Top of Generator In. Water	Suction of Exhauster Less Than in Generator In. of Water	In Factory Main Lbs. & Oz.	Barometer In. Hg.	Meter Readings — Water: Total Water Supply Cu. Ft.	Water: Scrubber Water Cu. Ft.	Power: Watt Meter 10 K.W. Hr.	Gas Analysis Per Cent by Volume: CO_2	CO	H_2	CH_4	N_2	Heating Value of the Gas: From Analysis B.T.U. per Cu. Ft.	From Analysis L B.T.U. per Cu. Ft. Low	From Calorimeter B.T.U. per Cu. Ft. High
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7:30		48	57	312	21.2	492	138	50	84	37	64	105	79	45	1.00	0.9	2.40	2-10		247688	8374	12452								
7:50		49	60	314	21.4	472	136	49	90	37	64	110	85	34	1.70	0.2	2.00	2-8												
8:10		50	60	320	21.4	480	136	49	92	37	65	108	82	36	1.60	0.0	2.20	2-8												
8:30		50	62	328	24.5	516	134	49	93	37	67	161	90	39	1.80	0.2	2.30	2-9		247893	8552	12465	5.7	21.5	21.84	1.46	49.0	164.2	151.5	
8:50		51	63	352	25.5	520	132	49	94	37	68	159	92	44	1.60	0.5	2.50	2-8												
9:10		52	64	360	25.6	530	134	49	94	37	70	150	90	42	1.70	0.2	2.40	2-9												
9:30		53	66	374	26.0	570	134	49	93	37	74	112	107	53	2.00	0.0	3.20	2-7	29.35	248073	8713	12477								163.8
9:50		53	68	392	28.0	568	130	49	93	37	76	85	90	55	1.30	0.2	3.40	2-7												
10:10		54	68	384	28.1	570	132	49	93	37	78	87	92	53	1.40	0.4	3.40	2-7												
10:30		54	67	374	26.5	534	136	49	93	37	80	79	86	41	2.80	-0.5	2.50	2-8	29.35	248234	8865	12489	7.1	21.0	19.65	2.16	50.09	161.4	149.0	152.5
10:50		54	72	384	26.1	538	143	49	93	37	85	127	105	40	1.70	0.4	2.00	2-9												
11:10		52	72	390	26.2	540	140	51	92	37	86	120	102	42	1.80	0.0	2.20	2-8												
11:30		52	70	398	29.3	572	142	50	89	37	91	80	90	53	1.20	0.0	3.60	2-8	29.36	248385	9090	12501	6.4	20.6	15.09	2.19	55.72	145.7	135.7	163.8
11:50		50	72	418	29.1	552	208	50	90	37	101	140	92	29	1.80	0.2	1.80	2-11												
12:10		51	70	416	29.0	560	210	50	90	37	104	110	90	36	1.60	0.3	2.20	2-10												
12:30		51	70	400	26.0	572	222	50	101	37	74	88	88	45	-1.00	0.2	2.70	2-8		248559	9135	12514	6.8	20.8	14.00	1.45	56.95	134.8	126.1	
12:50		51	74	412	29.0	604	142	51	91	37	94	79	90	53	2.40	1.0	3.70	2-8												
1:10		52	76	420	28.6	600	140	51	90	37	94	98	92	55	2.50	0.2	3.00	2-8												152.0
1:30		53	76	430	30.0	584	150	51	89	37	110	79	94	57	3.60	0.0	2.90	2-9	29.37	248718	9244	12527	7.0	20.2	15.04	1.46	56.30	135.4	126.1	
1:50		52	76	430	30.0	612	152	51	86	37	120	72	89	65	2.40	0.0	4.20	2-7												
2:10		53	78	430	29.6	608	152	51	88	37	118	76	90	60	3.10	0.1	4.00	2-7												
2:30		53	75	430	30.0	628	150	51	89	37	112	70	79	52	3.40	0.0	4.50	2-7	29.37	248839	9350	12540								147.7
2:50		52	78	450	29.5	620	150	52	85	37	118	76	78	62	3.00	0.1	4.40	2-7												
3:10		52	78	460	32.1	640	152	52	86	37	110	78	76	60	3.20	0.2	4.50	2-8												
3:30	2375	52	76	460	30.6	620	154	52	88	37	108	76	78	44	3.10	0.6	4.60	2-8	29.37	248991	9462	12551	6.4	19.6	13.81	1.48	58.71	130.3	121.6	143.1
AVERAGES & TOTALS	2375	51	70	394	27.3	564	150	50	91	37	101	101	89	48	2.03	0.22	3.06	2-8	29.36	1303	1088	99.0	6.57	20.62	16.57	1.70	54.54	145.6	135.4	153.8

READINGS NOT CORRECTED

BOBLETT & BOUGHTON.

APRIL 1, 1909. LOG OF TEST RUN NO.7 ON GENERATOR NO.2

TIME	FUEL USED LBS.	TEMPERATURES DEGREE FAHR.												PRESSURES						METER READINGS			GAS ANALYSIS					HEATING VALUE OF THE GAS.		
		AIR			GAS					WATER										WATER		POWER	PER CENT BY VOLUME							
		OUTSIDE	ROOM	FROM ECONOMIZER	OF GENERATOR OR TO ECONOMIZER	FROM ECONOMIZER	TO SCRUBBER	FROM SCRUBBER	IN FACTORY MAIN	WATER SUPPLY	FROM SCRUBBER	FROM WATER COOLED TOP TO ASH	FROM ASH-PIT SEAL	STEAM LBS/SQ.IN.	BOTTOM OF GENERATOR IN. WATOR	/	SUCTION OF EXHAUSTER LESS THAT IN GENERATOR INCHES OF WATER	IN FACTORY MAINS LBS. & OZ.	BAROMETER INS. HG.	TOTAL WATER SUPPLY CU. FT.	SCRUBBER WATER CU. FT.	WATT METER 10 K.W. HR.	CO_2	CO	H_2	CH_4	N_2	FROM ANALYSIS B.T.U. PER CU.FT. HIGH	FROM ANALYSIS B.T.U. PER CU.FT. LOW	FROM CALORIMETER B.T.U. PER CU.FT. HIGH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7:30		47	61	320	22.0	534	138	49	85	38	78	118	92	48	1.50	0.0	3.00	2-10		249028	9501	12754								
7:50		44	61	343	24.5	592	134	48	88	38	74	164	98	50	3.00	0.3	-3.00	2-9												
8:10		50	64	346	24.6	600	136	48	88	38	74	154	90	47	1.60	0.2	3.10	2-10												
8:30		50	65	353	25.5	624	137	48	90	38	74	70	87	47	1.40	0.0	3.20	2-8		249187	9642	12768	5.80	22.4	16.75	1.56	53.48	151.1	141.0	
8:50		50	66	382	22.0	644	142	48	90	38	82	137	92	45	1.90	0.0	3.10	2-7	29.54											149.4
9:10		50	67	380	23.6	638	141	48	88	38	86	142	96	50	2.20	0.0	3.80	2-7												
9:30		50	69	381	25.5	640	140	48	86	38	89	168	104	57	2.60	0.0	4.40	2-8		249326	9763	12781								
9:50		52	73	394	29.4	674	143	48	87	38	91	167	108	70	1.80	0.0	4.80	2-8												
10:10		51	73	394	27.4	644	144	49	87	38	90	160	106	60	1.60	0.0	4.20	2-8												
10:30		51	73	400	26.5	654	146	49	87	38	91	143	104	53	2.00	0.1	3.40	2-8		249463	9888	12975	5.40	22.2	14.9	2.16	55.34	150.3	140.4	
10:50		55	76	409	28.3	668	146	49	85	38	101	105	113	52	1.80	1.0	2.80	2-8	29.53											151.2
11:10		55	75	406	28.0	660	144	50	85	38	102	12.0	110	50	2.40	0.91	3.60	2-9												
11:30		55	75	400	27.4	650	142	50	85	38	103	135	103	50	3.00	0.0	3.50	2-8		249600	10000	12809	6.60	21.0	17.86	14.5	53.05	148.6	137.9	
11:50		53	80	410	24.5	600	292	50	90	38	81	84	105	10	1.80	0.0	0.90	2-8	29.53											133.0
12:10		51	76	400	24.2	580	310	50	90	38	80	80	96	16	1.40	0.0	1.30	2-9												
12:30		46	73	372	22.2	506	335	51	89	38	57	76	92	28	0.00	0.0	1.50	2-10		249813	10198	12822	7.80	20.6	14.28	2.14	55.18	142.5	133.0	
12:50		46	72	378	23.0	592	141	51	104	38	63	143	100	45	1.20	0.1	3.00	2-9	29.53											135.3
1:10		46	72	376	24.4	620	140	51	102	38	66	140	110	44	1.60	0.2	3.10	2-8												
1:30		48	72	372	27.0	633	140	52	101	38	71	174	111	42	1.80	0.0	3.30	2-9		249998	10365	12836	6.95	21.2	17.11	1.43	53.31	146.6	136.3	
1:50		48	75	400	27.5	634	141	52	100	38	70	153	111	45	1.20	0.0	2.70	2-9	29.50											155.2
2:10		46	76	410	28.0	642	141	52	100	38	72	140	110	40	1.20	0.0	2.60	2-10												
2:30		45	76	412	29.0	650	142	52	99	38	74	120	109	35	1.20	0.0	2.20	2-11	?	250273	10532	12849	6.90	20.8	14.44	1.44	56.12	135.1	126.2	
2:50		46	78	407	28.0	656	138	52	100	38	72	180	117	55	1.10	0.0	3.50	2-10	29.49											144.8
3:10		45	78	412	28.6	610	144	52	99	38	76	186	116	4.6	0.80	0.1	2.80	2-9												
3:30	2375	45	78	418	29.0	627	148	52	98	38	82	186	120	44	0.30	0.2	2.60	2-9		250329	10670	12863								
AVERAGES & TOTALS	2375	49	72	387	26.0	622	162	50	92	38	80	138	104	45	1.60	0.1	3.02	2-8.7	29.52	1301	1169	1090	6.58	21.37	15.69	1.70	54.46	145.8	135.9	144.8

READINGS NOT CORRECTED

BOBLETT & BOUGHTON.

APRIL 2, 1909. LOG OF TEST RUN NO. 8 ON GENERATOR NO. 2

TIME	FUEL USED LBS.	TEMPERATURE DEG. F. — AIR: OUTSIDE	AIR: ROOM	AIR: FROM ECONOMIZER	GAS: OF GENERATOR OR TO ECONOMIZER	GAS: FROM ECONOMIZER	GAS: TO SCRUBBER	GAS: FROM SCRUBBER	GAS: IN FACTORY MAIN	WATER: WATER SUPPLY	WATER: FROM SCRUBBER	WATER: FROM WATER COOLED TOP TO ASH-PIT SEAL	WATER: FROM ASH-PIT SEAL	PRESSURES — STEAM LBS./SQ. IN.	BOTTOM OF GENERATOR IN. WATER
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
7:30		52	62	262	22.5	478	132	50	87	38	76	70	68	52	1.80
8:50		52	67	320	24.9	552	143	50	86	38	92	83	72	48	1.20
8:10		54	67	340	24.8	534	142	49	88	38	90	90	76	48	1.70
8:30		55	69	338	21.3	570	144	49	90	38	89	104	81	50	2.90
8:50		54	71	364	23.5	580	146	49	92	38	85	143	84	55	2.60
9:10		52	71	380	24.4	595	148	49	90	38	100	122	84	62	1.40
9:30		52	71	388	25.5	610	140	50	80	38	106	70	80	47	2.50
9:50		49	75	426	29.0	646	138	50	86	38	95	75	75	52	3.80
10:10		50	74	426	29.6	650	128	50	86	38	86	76	78	65	1.10
10:30		49	73	428	30.0	666	144	50	85	38	75	78	78	48	1.60
10:50		50	74	432	29.7	570	142	50	90	38	69	90	85	45	1.00
11:10		56	75	426	29.2	640	196	50	86	38	72	90	86	50	2.60
11:30		58	76	418	28.7	674	196	50	83	38	77	93	86	82	2.00
11:50		56	76	440	29.7	616	260	50	88	38	73	111	91	50	1.80
12:10		57	75	430	27.6	608	140	51	94	38	76	120	96	35	1.80
12:30		59	74	415	25.2	484	132	52	101	38	57	122	100	22	3.20
12:50		57	74	424	30.4	619	140	52	95	38	65	140	100	63	2.50
1:10		55	73	420	27.5	610	140	51	94	38	68	155	104	50	1.80
1:30		52	72	412	25.4	562	138	52	93	38	69	160	106	47	2.00
1:50		56	72	412	28.8	596	140	51	90	38	70	181	108	55	2.20
2:10		54	72	420	29.0	600	144	51	90	38	71	138	110	52	1.80
2:20		57	72	428	30.5	604	146	51	92	38	65	140	110	50	1.20
2:50		57	72	421	29.0	572	144	51	96	38	70	156	112	42	1.60
3:10		53	72	424	28.8	576	143	51	94	38	66	160	108	46	2.00
3:30	2125	53	72	422	28.8	578	144	51	96	38	68	140	104	50	2.20
AVERAGES & TOTALS	2125	54	72	352	27.4	592	149	50	90	38	78	104	91	49	2.02

TIME	PRESSURES — TOP OF GENERATOR IN. WATER	SUCTION OF EXHAUSTER LESS THAT IN GENERATOR IN. WATER	IN FACTORY MAIN LBS. & OZ.	BAROMETER IN. HG.	METER READINGS — WATER: TOTAL WATER SUPPLY CU. FT.	WATER: SCRUBBER WATER CU. FT.	POWER: WATT METER 10 K.W. HR.	GAS ANALYSIS PER CENT BY VOLUME — CO_2	CO	H_2	CH_4	N_2	HEATING VALUE OF THE GAS — FROM ANALYSIS B.T.U./CU. FT. HIGH	FROM ANALYSIS B.T.U./CU. FT. LOW	FROM CALORIMETER B.T.U./CU. FT. HIGH
1	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
7:30	0.0	3.10	2-6		250454	10671	12923								
8:50	0.4	2.70	2-9												
8:10	0.1	2.80	2-8					7.9	21.0	16.12	2.13	5285	149.9	1394	
8:30	0.0	2.90	2-8	29.29	250566	10794	12935								1384
8:50	0.1	3.00	2-8												
9:10	0.1	3.50	2-7					7.4	20.0	15.00	14.5	5616	1354	12.62	
9:30	0.0	4.00	2-6	29.29	250705	10921	12947								132.6
9:50	0.0	3.50	2-8												
10:10	0.0	4.50	2-7					7.7	20.7	1288	2.86	5586	14.55	136.0	
10:30	0.0	5.00	2-7	29.29	250793	11048	12959								1293
10:50	0.0	3.50	2-9												
11:10	0.2	4.60	2-7					7.6	220	1549	1.41	5350	14.35	1341	
11:30	0.0	6.60	2-5		251258	11301	12972								
11:50	0.0	3.70	2-8												
12:10	0.1	3.00	2-8												
12:30	0.2	2.60	2-7	29.19	251540	11581	12983								138.0
12:50	0.9	4.40	2-9												
1:10	0.3	3.90	2-9					8.6	20.0	14.76	1.43	55.12	14.76	138.5	
1:30	0.0	3.30	2-9	29.18	251805	11817	12996								155.2
1:50	0.2	4.00	2-9												
2:10	0.5	3.70	2-					8.6	21.1	16.64	1.43	5323	141.1	131.1	
2:20	0.0	3.30	2-9	29.17	252060	12050	13010								144.0
2:50	0.2	2.70	2-9												
3:10	0.2	3.20	2-9												
3:30	0.0	4.20	2-9	29.17	252295	12883	13021								
AVERAGES & TOTALS	0.14	3.68	2-8	29.23	1841	1612	980	7.8	20.8	15.15	1.79	54.46	142.3	132.7	140.0

READINGS NOT CORRECTED

BOBLETT & BOUGHTON.

Test Of A 400 H.P. Gas Producer.

Part 4.

A brief discussion of the various items which enter into the cost of generating gas in a gas producer, and the total cost of this particular gas.

Test Of A 400 H.P. Gas Producer.

Cost of installation and of operation:- Regardless of what are the commercial, the constructive principles, and the modes of action of a gas producer, the complete problem of adjusting the conditions so far as possible, of any plant must take into account; (1) cost of fuel to obtain the heat generation along with other accompanying expenses; (2) cost of bulk and weight of the apparatus; (3) profitableness of the investment.

The cost of maintaining and operating a gas producer consists of the following items:

(a) Interest on the capital invested.
(b) Depreciation of the plant and buildings.
(c) Insurance and taxes.
(d) Fuel cost.
(e) Cost of cooling water.
(f) Attendance.
(g) Maintenance and repairs.

The first three items may be termed "Fixed Charges", and the rest "Operating Charges". The sum of the two is termed the "Total Operating Costs". The fixed charges cover all expenses

which remain constant,whatever the output of the plant may be. The operating charges are those which are proportional to the output of the plant, and which stops when the plant is shut down.

(a) Interest on the investment:- The usual rate of interest on capital in this country is 6 % per annum.

(b) Depreciation of plant and buildings:- The wear and tear on a gas producer installation is very slight. The generators,if reasonably well cared for need be relined only once in two or three years. If not well cared for they may need be relined in three to five months. It is considered in gas producer practice that money will be saved by putting in a good grade of lining when the producer is installed,because the loss incurred in shutting down the producer and putting in a new lining is much greater than the differance in cost between a good and a poor grade of lining. The scrubber should be refilled with coke and excelsior,probably once in a year. The upkeep of the exhauster and the motor is also very small. Taking it altogether,an allowance of

7 % of the investment should cover the deprec-ciation of both the producer and the building. The depreciation on the building should be very small,not more than 2 to 3% of the cost of the building. By making a charge of 7% against the total plant,rental may be included in this item.

(c) Insurance and taxes:- This item is very small since the plant is fireproof throughout. The maximum charge for this item should not exceed 2% of the total investment.

(d) Fuel costs:- This item is most generally the criterion of the economic status of a plant,but in most cases this is not true. Generally,as in this case,the fuel charge is the major part of the expense charge to the plant. But where the plant is of high efficiency,as is the cases with most producer plants,the incidental expenses determine pretty much,whether or not the plant is a paying investment.

The fuel cost varies with the quality of the fuel and the character of the load. If the plant is operating intermittantly the fuel cost will be higher than if operating on the twenty four

hour basis. The coal used in these tests cost $5.50 per ton delivered on the side track,or $5.56 per ton unloaded. This coal is an ordinary quality of pea anthracite,usually quite dry. The steam is received from the central station and the cost of producing it is about .4 cts. per boiler H.P. hour,or .0116 cts. per pound ~~per hour~~.

(e) Cost of water for cooling:- Many estimates of the total operating costs totally neglect the costs of water for cooling,but this may in some cases amount to quite an item. At this plant a pumping charge of 7 cts. per 1000 gallons is assumed,that it may be even less than this.

(f) Attendance:- This item depends upon the size of the plant,the nature of the use of the gas,and the number of labor saving devices installed. In the plant tested,there are three men employed for various times. The tenders get 25.cts.per hour one working eleven hours and the other thirteen hours. The ash wheeler gets 17.5 cts.per hour, and works five hours. This is equivalent to one man working 24 hours for 28.6 cts. per hour. There seems to be an idea among gas users that

Test Of A 400 H.P. Gas Producer.

a gas producer installation does not require much attention. Gas producer manufacturers should discourage this idea among gas users because their sales depend on the economical working of the plants, and a producer plant cannot go without attention for any length of time.

(g) Maintenance and repairs:- The expenditures for maintenance and repairs should not exceed 2% of the total investment. This refers to the expense of keeping the plant in running order over and above the cost of attendance. It includes cost of upkeep, replacement and precautionary measures, This latter item includes renewal of working parts, painting of perishable or exposed material, and replaceing worn out and defective material.

The cost of the gas made is most conveniently expressed per 1000 cubic feet of standard gas. The coal burned per 1000 cubic feet of gas = 1000 ÷ 86.6 = 11.55 lbs. (from Table 3). The steam used per 1000 cubic feet of gas = 11.55 x .65 = 7.51 lbs. The power used to run the exhauster per 1000 cubic feet of gas = 5.22 K.W.Hrs.

Test Of A 400 H.P. Gas Producer.

Reducing this to boiler H.P.Hrs.,the power used per 1000 cubic feet of gas = 5.22 x .725 = 3.875 B.H.P.Hrs.. The total water used in gallons per 1000 cubic feet of gas = 79.5.

The cost of material may thus be summed up;

Cost of coal,@ $5.56 per ton .... 3.176 cts.
Cost of steam, @ .4 per B.H.P.Hr. .... 0.087 cts.
Cost of power, @ .4 cts. per B.H.P.Hr. ... 1.514 cts.
Cost of water, @ 7.0 cts. per 1000 gals... 0.556 cts.
Total cost of material, ... 5.333 cts.

The cost of labor per hour is 28.6 cts. and an average of 24,730 cu.ft. of gas are generated per hour so that the cost for labor per 1000 cu.ft. of gas = 28.6 ÷ 24.73 = 1.157 cts.

Summing up the total fixed charges;

Interest on the investment, ... 6%.
Depreciation of the plant and buildings, ... 7%.
Insurance and taxes, ... 2%.
Maintenance and repairs, ... 3%.
Total charges , ...18%.

The total investment,including all piping thru the factory ,and all the work done on the plant installing it is $17,563.00. Therefore

Test Of A 400 H.P. Gas Producer.

the total fixed charges = \$17,563 x .18 = \$3161.00 per year, or \$3161.00 ÷ 8760 = 36.1 cts per hour, or 36.1 ÷ 24.73 = 1.419 cts. per 1000 cu.ft. of gas.

Therefore the total cost of the gas is;

Total cost of material supplied, ...	5.333 cts.
Cost of attendance, ...	1.157 cts.
Fixed charges, ...	1.419 cts.
Total cost per 1000 cu.ft. of gas	7.909 cts.

The plant was running under about one-fourth load as an average of the tests. If the plant was running full load, the cost of attendance and the fixed charges would be only one-fourth as much per 1000 cu.ft. of gas, or the cost of the gas under full load conditions would be 5.333 + (2.576 ÷ 4) = 5.977 cts.

The following table shows in amanner, the distribution of the total cost of the plant;

Total charge to the plant, ...	\$17,563.00
Flinn & Dreffein's bill for producer,	5,200.00
One 5 H.P. constant speed motor, ...	128.00
One25 H.P. constant speed motor, ...	400.00
One 25 H.P. variable speed motor, ...	610.00

Test Of A 400 H.P. Gas Producer.

Cost of 2 Root's exhausters, ...	$958.00
Total cost of apparatus, ...	$7296.00
Material.	
Carpenter's material, ...	$2898.00
Machinists & gas fitters material, ...	1875.91
Mason's & brick layers material, ...	363.61
Tinsmith's & common labor, ...	75.85
Total cost of material, ...	$5223.37
Labor.	
Carpenter's, ...	$ 543.83
Machinists & gas fitters, ...	2393.86
Mason's & brick layers, ...	1995.02
Tinsmith's & common labor, ...	110.92
Total cost of labor, ...	$ 5043.63

The preceding table shows at a glance that there are a great many things charged to the plant that in ordinaty producer practice is not charged to the installation. As an illustration of the peculier charges made against the plant, the writer saw an item on the construction sheet for $64.60 worth of Garlock packing, for the two exhausters, which is more packing than would be used on these exhausters in at least ten years. There is also

Test Of A 400 H.P. Gas Producer.

another charge of $46.75 for suppers to the men who worked overtime. From this it may be seen that the total fixed charges which AArmour & Co. place against their producer installation is a very broad figure, and could be easily reduced 25 %, and still be a very reasonable figure.

Test Of A 400 H.P. Gas Producer.

Part 5.

Conclusions, and Bibliography.

Test Of A 400 H.P. Gas Producer.

Conclusions:- There are several noticable points well worth mentioning as regards this installation.

(1) Uniform quality of the gas.

(2) Average high thermal efficiency.

(3) Flexibility of the installation.

(4) Simplicity and safety of operation.

(5) Compactness of the plant.

(6) Ventilation.

(7) Rating.

(1) Uniform quality of the gas: The gas generated from this producer never failed to burn in the Junker calorimeter and at the test burners in the gas house. Even at the lightest loads the gas burned with an even blue flame in the calorimeter with a pressure of from .6 to 1.2 inches of water. In the gas house the burners were under a pressure of 2.5 pounds per sq.in.,but the gas burned easily and quietly under both conditions. No special burner is required for this gas,as is the case with some kinds of fuel and oil gas. As seen from Table 4,the lowest high heating value of the gas was 128.8 B.T.U., while the highest high heating value was 145.8 B.T.U.,with an average of 139.9

B.T.U.. When the gas was running 128.8 B.T.U.,only 4.4 lbs. of coal per sq.ft. of grate per hour was being gasified,so that this might be termed rather remarkable.

(2) Average high thermal efficiency: The lowest thermal efficiency found during the test was 78.2 % when the producer was gasifying 4.4 lbs. of coal per sq.ft. of grate per hour,and the highest thermal efficiency, 87.3 % was obtained when gasifying 10.5 lbs. of coal per sq.ft. of grate per hour. The careful attention given to the fuel column,and the pressures in the various parts of the system cannot help but account,in part, for the high average efficiency of 85.6 %. It also seems that the unit is so designed that with ordinary coal,a good average efficiency is sure to result. For example the depth of the water in the ash-pit seal is such that not more than three inches of water pressure can be had at the bottom of the fuel column,thus preventing excessive pressure in the top of the generator. The standby losses are also very small,since the fuel bed is not disturbed when removing the ashes,and

no fuelcan be lost in this way.

(3) Flexibility of the installation: The one proof pointing to this fact is shown that at dinner time, from 12:00 to 12:30 the roof valve was not opened while the tests were being made. The steam pressure was lowered (see log of tests, Part 3) and the fires lay waiting to deliver gas when required. Tests of the gas shortly after 12:30 showed it to be of the same quality as that made at any other time. It was stated by one of the tenders that a generator could lie dormant for six days and nights and could be started up in twenty minutes, making as good quality of gas as the one already running. There are no steam boiler installations, or coal fired furnaces of any kind, to the writers' knowledge, which can be brought into full action after being banked, for the same length of time.

(4) Simplicity and safety of operation: Practically unskilled labor is caring for this plant. They are men of ordinary intelligence, without any theoretical training. There are but a few things to do to get the plant started, and these are very

simple. The plant is so arranged that the gas will be sucked out of the generator while the ashes and cinders are being removed. The speed of the exhauster may be varied to suit the quantity of gas generated, thus saving power. The steam pressure is easily and quickly regulated to obtain zero gauge pressure in the top of the generator. In the writers' opinion this regulation of the pressure in the top of the generator is one of the best points in the entire installation. for, being thus arranged, no gas can escape to make the room uncomfortable, neither does the air enter to burn the gas. High pressures are entirely absent from the producer, so that no danger can be had from explosions. Various parts of the apparatus are water sealed, making the plant entirely safe.

(5) Compactness of the plant: The plant occupies a floor space of 1188 sq.ft. or 2.97 sq.ft. per rated H.P. This is just a little less than the average space required for producer installations. The arrangement of the plant is such that it may be easily manipulated, and does not require any

unnecessary steps for the tender. An improvement might be made in the arrangement of all gauges on one board, with the steam regulating valve and motor controller at the same point, so that the temder could adjust the steam to bring all gauges to the operating height, without leaving his position.

(6) Ventilation: The ventilation of the producer room is very bad at times; especially when the wind is from the South. Windows are on the North side of the building only, and the wind must be from the West or North to obtain reasonable ventilation. There are four ventilators on the roof, but they do not seem to remove the heat and gases from the lower part of the room. At the present time plans are being drawn for a mechanical draft ventilating system which will no doubt much improve the comfort of the tenders.

(7) Rating: This producer is rated at 400 H.P.. If a gas engine, using this gas had a thermal efficiency of 20 %, the amount of heat required per B.H.P.Hr. would be 2545 ÷ .2 = 12725 B.T.U. which would be approximately 91 cubic feet of this

gas. The maximum amount of gas generated per hour on one generator was 36738 cubic feet, so that the B.H.P. of one generator would be 36738 ÷ 91 = 403 B.H.P. or 806 B.H.P. for the entire plant. Carrying this load, the producer did not seem to be overloaded, but seemed rather to be working at its best at this rate of operation.

The Messrs. Flinn & Dreffein, consulting engineers, who designed this plant, are graduates of the Armour Institute Of Technology. It would not be more than proper to give these gentlemen the credit of having designed, installed and placed in operation, a model producer gas plant, complete in its details, and a plant which should be studied even closer than has been done in this investigation.

Respectfully submitted,

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Test Of A 400 H.P. Gas Producer.

Bibliography.

Text Books:-

Allen,
Modern power gas producer practice.

Carpenter & Diederichs,
Internal combustion engines.

Dowson,
Producer gas.

Haenssgen,
Suction gas.

Hutton,
The gas engine.

Junge,
Gas power.

Mathot,
Gas engines & producer gas plants.

Sexton,
Producer gas.

Wyer,
Catechism on producer gas.

Wyer,
Treatise on producer gas & gas producers.

Test Of A 400 H.P. Gas Producer.

Bibliography.

Periodicals:-

Advantages of producer gas firing,
Cassier's 33:462 Jan.1908.

A notable producer gas power station,
Power 29:1023 Dec.22 1908.

An endurance test of a gas producer,
Engineering Record 53:614 May 19 1906.

A successful suction gas producer central station.
Power 25:788 Dec.1905.

A satisfactory producer gas plant,
Power 28:619 Apr.21 1908.

Chief requisites for successful producer operation,
Power 28:734 May.12 1908.

Commercial method of testing producer gas for sulphur,
Engineering News 58:110 Aug.1 1907.

Composition of producer gas used in electric

light power plant,
Engineering 70:202 Aug.17 1900.

Chemistry of producer gas,
Engineering 72:662 May 16 1902.

Destruction of tar in gas producers,
Engineering 85:141 Jan.31 1908.
85:171 Feb.7 1908.

Design of a 25 H.P. gas producer,
Power 29:6-1 Oct.20 1908
29:927 Dec. 1 1908.

Fuel tests of gas producer division of U.S. Geological survey,
Amer.Society Mechanical Engineers, 28:829.

Test Of A 400 H.P. Gas Producer.

Bibliography.

Periodicals,continued:-

Fuel for gas producers,
Gas Power, 4: Oct.1906.
Nov.1906.
Jan.1906.
Feb.1906.
Mar.1906.

Further experiments upon gas producer practice,
Engineering 86:837 Dec.18 1908.

Further experiments upon gas producer practice,
Mechanical Engineer 22:458 Oct.9 1908.
22.485 Oct.16 1908.

Foreigen gas producers,
Engineering 70:169 Aug.10 1900.
70:275 Aug.31 1900.

Gas Producers,
Gas Power Oct.1904.
Nov.1905.

Gas producer operation,
Power 28:960 June 16 1908.

Gas producer power plants,
Engineering Record 51:656 June 10 1905.

Gas producer power plants,
Gas Power May 1905.

Gas producers for power,
Power 24:520 Sept. 1904.

Gas producers for bituminous coal,
Cassier's 34:503 Oct. 1908.

Gas producers for bituminous coal,
Engineering 80:261 Aug.25 1905.

Test Of A 400 H.P. Gas Producer.

Bibliography.

Periodicals, continued:-

Gas producers for power purposes,
Engineering News 55:538 May 17 1906.

Gas producers for bituminous coal,
Engineering 78:540 Oct.21 1904.

General principles in the construction of

modern gas producers,
Engineering magazine, 33:553 July 1907.

German rules for testing gas producers,
Power 27:94 Feb. 1907.

How to run a suction gas producer,
Power 29:821 Nov.17 1908.

Low grade fuel in gas producers,
Engineer (U.S.) 44:1005 Nov.1 1907.

Lime burning with producer gas,
Engineering Record 52:416 Oct.7 1905.

Management of suction gas producers,
Engineering Record 53:656 May.26 1906.

Producer gas and its use in engineering,
Cassier's 33:199 Nov. 1907.

Producer gas for bituminous coal,
Cassier's 22:500 Aug. 1902.

Producer gas for engine use,
Electric Railway Review 19.571
Street Railway Journal 31:824

Producer gas,
Electrical Review (London) 63:415

Test Of A 400 H.P. Gas Producer.

Bibliography.

Periodicals, continued:-

Producer gas for power and fuel,
Engineer (U.S.) 43:746 Nov.15 1906.

Producer gas,
Engineering 86:354 Sept.11 1908.

Producer gas and the crude oil supply,
Gas Power Jan. 1904.

Producer gas,
Mechanical Engineer 17:464 Apr. 7 1906.
17:500 Apr.14 1906.

Producer gas and gas producers,
Power 26:92 Feb. 1906.

Producer gas for power and fuel,
Sibley Journal 21:1 Oct. 1906.

Producer gas tests of U.S. Geological testing plant, Amer.Society Mech.Engineers 26:302

Producer gas plant at Newark N.J.
Engineer (U.S.) 44:770 Aug.15 1907.

Producer gas plant of the Heyman Co.,
Engineer (U.S.) 44:872 Sept.16 1907.

Production of cheap power by suction plants,
Engineering 86:338 Sept.11 1908.

Power plant of the Montezuma Copper Co.,
Engineering & Mining Journal 77:359 Mar.3 1904.

Power gas plant, (New Orleans),
Engineering Record 52:490 Oct.28 1905.

Present status of the producer gas plant in the U.S.,
Journal Western Society Engineers Oct. 1907.

Power plant operation on producer gas,
Mechanical Engineer 21:816 June.26 1908.

Test Of A 400 H.P. Gas Producer.

Bibliography.

Periodicals, continued:-

Recent progress in gas producers,
Engineer (U.S.) 44:874 Sept.16 1907.

Recent developements in suction gas producers,
Practical Engineer 33:589 May 11 1906.
33:626 May 18 1906.
33:648 May 25 1906.
33:685 June 1 1906.
33:714 June 8 1906.

Reliability of the producer gas plant,
Cassier's 35:351 Dec. 1908.

Steam in gas producer practice,
Engineering 83:659 May.17 1907.

Suction gas producer plants (Tests),
Engineering 80:674 Nov.17 1905.

Suction trials at Derby,
Engineering 82:805 Dec.14 1906.

Suction gas producer gas plant,
Engineer (U.S.) 42:586 Sept.1 1905.
43:310 May 1 1906.

Sustion gas plants,
Mechanical Engineer 18:236 Aug.18 1906.

Suction gas producer trials,
Engineer (London) 101:602 June 15 1906.
101:627 June 22 1906.
101:659 June 29 1906.

Suction gas producer,
Mechanical Engineer 17:551 Apr.21 1906.
17:585 Apr.28 1906.

Suction gas producers,
Power 24:736 Dec. 1904.

Test Of A 400 H.P. Gas Producer.

Bibliography.

Periodicals, continued:-

Suction gas producer plant at Rocky Ford, Colo., Power 27:533 Aug. 1907.

Test of a gas producer electrical plant, Electrical World 50:229 Aug. 3 1907.

Testing of gas producers, Practical Engineer 32:473 Sept. 22 1905.

Test of a small gas plant, Engineering Record 57:375 Mar. 28 1908.

Trials of suction gas plants at Derby, 1906. Mechanical Engineer 19:49 Jan. 12 1907.
19:87 Jan. 19 1907.
19:121 Jan. 26 1907.

The suction gas producer,
Electrical Review, London, 55:1051 Dec. 30 1904.
Electrical World 48:52 July. 7 1906.
Engineer, London, 98:450 Nov. 4 1904.

Trials of suction gas producer plants, Power 26:97 Feb. 1906.

Why gas producers are not more economical, Power 28:1022 June 30 1908.