THESIS

POWER GAS APPARATUS

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THESIS

PRESENT PRACTICE in PROPORTIONS of POWER GAS APPARATUS

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Department of Mechanical Engineering.

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Preface

The object of this Thesis is to determine the Standard Practice in the Operation and Proportions of Gas Producer Apparatus. The purpose was to find out actual conditions existing in the modern use and construction of producers, relations existing between different varying details of construction and to establish empirical formulae showing these relations for use in design.

Letters asking for information were sent to forty six different companies who advertised Gas Producers in the various Engineering Magazines. Inclosed in each letter was a list of sixty one questions covering approximately every detail relative to the producers, economizers, vaporizers, tar extractors, scrubbers, purifiers, gas holders and their operation. Out of the forty six letters sent, twenty four answers were received; of these, four returned favorable answers giving us the data asked for, fourteen answered that they were not manufacturing producers any longer, three refused to disclose their information and three manufactured producers to order only, and had no standard sizes.

It is interesting to note the difficulty apparently encountered in the manufacture of efficient gas producers, testified to by the fact that 14 of the 24 answers received stated that the company had discontinued the manufacture while the remaining 10 either had no definite information to give or else were too conservative to disclose it.

From the four favorable answers returned the following deductions were obtained.

Results from letters sent to manufacturers.

Companies written to	46
Complete replies	4
Discontinued the manufacture of producers	14
No answer returned	23
Refused to disclose information	3
Manufacture producers to order only	3

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Features of Producer Gas Power Plant Development in Europe --------------- Bulletin No. 4.

Bulletin from University of Illinois. Tests of a Suction Gas Producer ------------------ Bulletin No. 30.

HISTORY .

In dealing with the subject of gas-producers one should be thoroughly acquainted with the meaning of a gas-producer and the functions it is designed to perform, as understood in the world of industry. " A gas-producer " as defined by Walter O. Amsler, D. Sc. " is a device for creating a combustible gas from a carbonaceous fuel by incomplete combustion."

A producer consists of a fire brick lined chamber of a size varying with the capacity desired. It is provided with means for feeding the fuel into the fire bed as required, for removing the ash or solid products of combustion, for inducing a draft (usually a jet of steam, although in some cases they use a natural draft) and means for conveying the gas from the produser to the gas main. The three main types are, namely: Suction, Pressure and Down-draft.

Suction Producers .

A suction gas-producer is one in which the engine develops its charge of gas in the producer by means of its own suction stroke. The essential parts of a suction gas-producer plant are the gas generator or furnace, the steam generator or boiler and the gas cleaners or scrubbers. The fuel used in this type is charcoal,coke or anthracite coal, no tarry fuels can be used because of the gumming effect the tarry products have on the piston and cylinders of the engine when the gas containing these products is sucked into the cylinders

After a fire has been started on the grate the fuel from which the gas is made is gradually charged into the producer. Draft is furnished by ahand or power driven blower, at the bottom of the producer, until the gas is of such a quality that it can be turned into the engine. The quality is determined by a flame test by lighting the gas at a small test cock. After the gas is once started into the engine the draft needed for the further manufacture is furnished by the suction stroke of the engine itself.

Air alone as a draft causes the temperature of the fuel bed to rise too high for satisfactory work. The gas must be cooled to as low a temperature as possible and practicable, to increase its density, in order that the heat value of the charge taken into the cylinder shall be as large as possible. The means taken for cooling the gas is to generate steam at atmospheric pressure by the hot gases passing thru the boiler on their way to the scrubber. This steam is picked up by the air blast and a mixture of air and steam is then drawn up thru the fuel bed. This moist air is decomposed while passing thru the hot fuel bed thus adding certain amount of H to the gas. The gas thus produced has approximately a heating value of 130 to 140 B. T. U. per cubic foot.

The gas after leaving the boiler passes to the base of the scrubber. The scrubber is usually a cast iron or sheet steel tower in which the dust, soot and other impurities are removed. Generally the cylindrical sheal is filled with coke over which water is sprayed. The water is entering the scrubber continually in the form of fine spray and the coke or other filler offers a greater amount of damp surface for

the gas to come in contact with. As the gas passes upward thru this bed of damp material it is divided and comes in contact with the fine water spray which washes out most of the impurities. The gas enters the scrubber at a comparatively high temperature (800 to 1,000 degrees Fahrenheit) and leaves it at about atmospheric temperature, going to the engine as a comparatively dry, clean, cool gas. In some plants the gas also passes thru a dry scrubber consisting of a chamber filled with excelsior, shavings or similar material This further aids in drying the gas and removing impurities.

Because of the high price of fuels that have to used in the suction type producer the plants though numerou are of small power, few exceeding 300 horse power per unit and most of them not exceeding 100 H.P.

PRESSURE PRODUCER PLANTS.

A pressure producer develops its gas under a slight pressure due to the introduction of an air and steam blast while the gas is stored in a gas holder until required for use. This type of producer plant consists of a generator, an injector,fed by a boiler, a fan or compressor by means of which a mixture of ~~gas~~ air and steam is blown into the bottom of the generating furnace, gas purifying apparatus and a gas holder.

The generator consists of a retort of refractory clay vertically mounted and either cylindrical or conical in form. It is protected by an exterior metal jacket with an intermediate layer of sand to reduce the loss of heat by radiation. Fuel is charged thru the top and a double closure is provided to prevent leakage. The generator rests upon a grid at the base of the retort upon which grid the ashed fall. The outlet of the injector pipe opens into the ash pit into which a mixture of steam and air passes. Openings are usaily arranged in the upper part thru which the fire may be poked and clinkers dislodged.

Much more care must be exercised in washing and purify -ing the gas in pressure plants than in the suction type because the fuels generally used contain more tarry products and other impurities. Sufficient pressure id needed to drive the gas thru the apparatus. The gases coming out of the generator are highly heated and this heat is used to warm the injected water or to generate steam fed into the furnace.The gases then enter the washing apparatus consisting of a coke filled scrubber and continually sprayed with fine water sprays on the inside. From there to the tar extractor, quite often a centrifugal pump, which extracts the tar that has been condensed in the water jacketed mains and as the gas passes thru the extractor the tar drips to a water sealed pit. From here the gas passes thru the purifier which is usually an iron box about 20 feet square and 2 feet deep. This is filled with oxide of iron and shaving by means of which the sulphur is removed. From here the gas passes to the water sealed gas holders.

DOWN)DRAFT PRODUCER PLANTS.

The down-draft producers fix the tar as a permanent gas and therefore completely utilizes the volatile hydro-carbons in fuels such as bituminous coal, lignite and peat. The essential difference between this and the other types of producers is that the blast of air and steam is drawn in at the top of the retort thru the charging doors and down-ward thru the fuel bed.

CHEMISTRY OF PRODUCER-GAS .

Producer-gas is a mixture of a number of different gases. The chief consituent is CO. As fumes can be noticed rising from a coal fire when fresh fuel is thrown upon the fire which readily unite with air and are of a bluish color likewise is it with a gas producer. The coal stove is a gas producer for a few minutes only, while the producer itself maintains this condition continuous by keeping an abnormally thick fuel bed so that not a sufficient amount of air passe thru the fuel to effect complete combustion. The result of this incomplete combustion is the gas of a blue color and known as CO.

The steam used in the blast passing thru the fire is broken up into its two elements, H. and O. The O combines with the C of the fuel to form CO and the H passes out as a valuable addition to the heating value of the gas. The O of the air unites with the C of the fuel to form the bulk of the CO leaving the N to enter the gas as a harmless diluent

A small proportion of the fuel will be consumed to CO_2 and smaller the amount the better the gas. Some O will pass thru the fuel bed without uniting with any carbon which too should be a small proportion.

DEVELOPMENT OF PRODUCERS.

The use of producer-gas plants for power purposes has been confined to recent dates. A few scattered plants were used prior to 1900 in the United States but the application of this type of power in any general sense has developed since that date. During the first few years of its develop-ment, anthracite coal, coke and charcoal were used almost exclusively on account of the deleterious effect of the tar in the more tarry fuels.

The Gas-producer is developed from the regenerative furnaces such as were employed by Siemens in the process of steel making. Names of Dowson and Dr. Mond are mention-ed among those who took an active part in the development of the early forms of producers. The latter evolved a gas-producer system suited to the utilization of low grade bituminous coal with the recovery of the by-products in the form of NH_3SO_4 used extensively in agricultural pursuits. Producers are now designed to utilize a great many different kinds of fuel. The main fuels are, viz: charcoal, lignite, anthracite coal, bituminous coal, coke, peat, wood and saw-dust while experiments have been made whereby roof-coal slabs culm, coal washery refuse, hay, tanbark, straw, corncobs, cornstalks and even scraps of leather have been used as fuels

but they have not come into general use.

The development of the gas producer by making improvements in the production of cheap gas directly from the fuel has made possible a rapid advance in the use of large gas engines and has consequently been a great aid to the use of gas for power purposes.

Following are the questions submitted to the manufacturers and from the answers to which the data herein used has been obtained.

QUESTIONS.

Gas Producers and accessories.

PRODUCERS.

(1) Type. (Suction or Pressure)

(2) Rated capacity-- H.P.

(3) Kind of fuel used.

(4) Method of charging.

(5) Dimensions of charging machine.

(6) Type of grate.(Conical or flat: Stationary or revolving)

(7) Dimensions of grate.

(8) Mean diameter of fuel bed.

(9) Depth of fuel bed.

(10) Approximate width of air spaces in the grate.

(11) Area of air spaces in Sq. Ft.

(12) Depth of ash bed.

(13) Outside diameter of shell of producer.

(14) Height of discharge pipe above grate.

(15) Length of shell from base to top of the magazine.

(16) Diameter of discharge pipe.

(17) Height of fire brick lining.

(18) Thickness of fire brick lining.

ECONOMIZER AND VAPORIZER.

(19) Types(if any used).

(20) Water heating surface in sq.ft.

(21) Number of gas tubes(if gas is passed thru tubes).

(22) Dimensions of gas tubes.

(23) Point of entrance of gas (top or bottom).

(24) Air blast heating surface-- sq.ft.

(25) Point of entrance of air for blast.

TAR EXTRACTOR.

(26) Type

(27) Dimensions.

(28) If centrifugal- Diameter and R.P.M.

PURIFIER (For Sulphur etc.)

(29) Type (If any used.)

(30) Designed to remove what impurities.

(31) Contents of Purifier- purifying agent.

(32) Volume of purifying material-- cu.ft.

(33) Dimensions of purifier.

(34) How often are contents to be changed under normal load.

SCRUBBER.

(35) Type.

(36) Height.

(37) Diameter.

(38) Filler for the scrubber.

(39) Depth of bed for the filler.

(40) Method of introducing the wash water.

(41) Amount of water used per 1000 cu.ft. of gas.

(42) Number of cu.ft. of gas designed to pass thru scrubber per minute.

GAS HOLDER.

(43) Type.

(44) Diameter.

(45) Height.

(46) Maximum capacity.

(47) Pressure in the holder.

BLAST.

(48) Force of blast furnished to the producer.

(49) Method of distribution of blast under the grate.

(50) Do you use steam in the producer?

(51) Ratio of air to steam in the blast.

(52) How is the steam introduced?

(53) Pounds of steam per pound of fuel.

OPERATION .

(54) At normal load. Pounds of fuel fired per hour per sq.ft. of grate surface.

(55) Capacity for overload.

(56) What arrangement for shaking the fire

(57) Do you advise "barring"?

(58) To what extent? How often?

(59) Is there any provision for poking? From side? From top?

(60) How often should producer be charged?

(61) What thermal efficiency should the producer give?

Following is a copy of the letter which was sent with the above questions to the manufacturers

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Gentlemen:

Under the direction of the Mechanical Engineering Department of Michigan State College two of our senior students, Mr. Hotchin and Mr. Idules, are working up a thesis on the "Standard Practice in Gas Power Apparatus Proportions". The Producers, Scrubbers and other accessories, omitting the engines, are being investigated, with the object of determining dimensions and general specifications regarding the different sizes and types. We therefore are sending you a set of questions herewith which we ask you to kindly fill out and return to us.

The information thus obtained from several companies will be tabulated, correlated and arranged, if possible, in the form of empirical formulae for use in instruction in the study and design of Gas Producers. The names of the companies giving the information will not be divulged and neither will the data in it's original form be made public. If the results are sufficiently satisfactory, the deductions regarding standard dimensions, which can be obtained from the data may be published. If so due credit will be given and if not published the results will be sent to you upon request.

Kindly give us the information regarding as many different types and sizes as possible so that the results may be representative.

We feel sure that you appreciate the need of co-operation between the manufacturer and the Technical College in such matters and trust that you will make a favorable reply.

Thanking you in advance we beg to remain,

Yours truly,

Mechanical Engineering Department, M.A.C.

Per.

RESULTS.

We found two general classes of producers- Anthracite and Bituminous-. In looking over the data obtained there were two interdependent variables which were immediately noticed. These were the rated Horse Power and the diameter of the fuel bed. The former determining the capacity and the latter being the principal dimension of the gas generator and perhaps the first one to be determined.

We then undertook to express the relation between these two variables by an equation. First the points were plotted as shown in Plate 1., the diameter of the fuel bed in inches as abscissa and the rated horse power as ordinates Upon drawing the approximate curve thru these points it was evident that the curve was not a straight line and we judged that an equation of the following general form would most likely fit the curve:

Let H = rated horse power

D = diameter of fuel bed in inches

Then the general form of equation would be

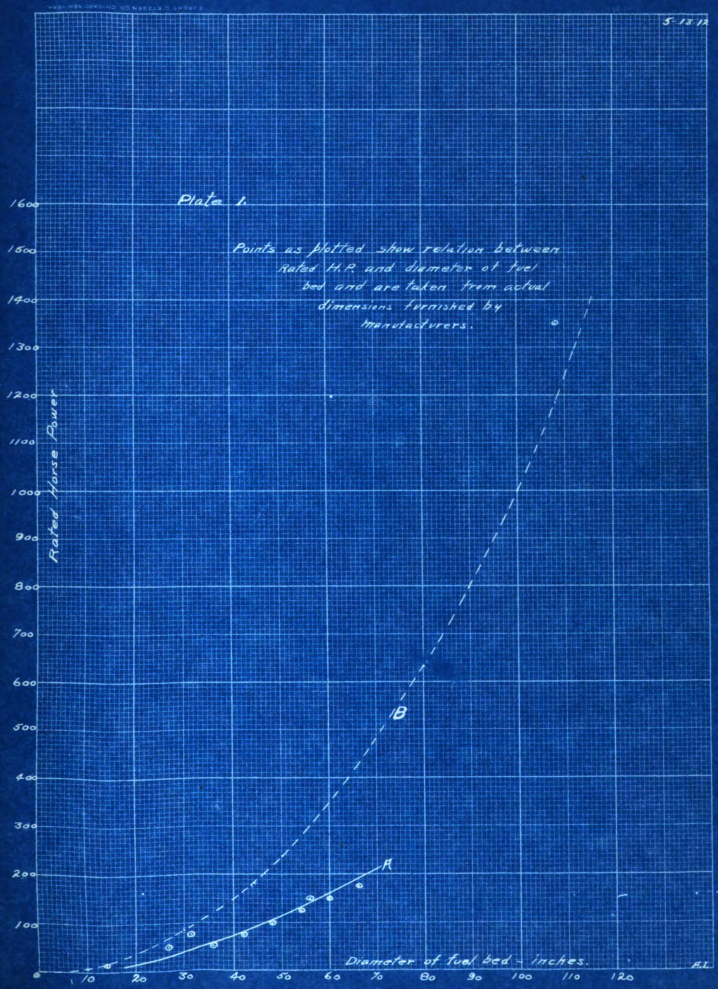

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Plate I.
Points as plotted show relation between Rated H.P. and diameter of fuel bed and are taken from actual dimensions furnished by manufacturers.
Rated Horse Power
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
B
A
Diameter of fuel bed - inches.
10
20
30
40
50
60
70
80
90
100
110
120
B.I.

$$H = K D^2 + K' D^3$$

This determined we considered the theory of least squares as a means of determining the equation of the most probable curve for these given points.

By the theory of least squares we have the following:

Given the general form $H = K D^2 + K' D^3$

Then K and K' are the constants for which we are solving and the unknowns in the equation. Multiply each side of the equation by the coefficient of K or D^2 and we have $H D^2 = KD^4 + K'D^5$ and by the coefficient of K' or D^3 and we have $HD^3 = KD^5 + K'D^6$. This gives us two simultaneous equations. Take summations on each side and we have,

$$\begin{cases} HD^2 = K\ D^4 + K'\ D^5 \\ HD^3 = K\ D^5 + K'\ D^6 \end{cases}$$

These summations were calculated as shown in the following table. (A log log slide rule was used in calculating these values.)

TABLE OF VALUES.

H	D	D^2	D^3	D^2H	D^3H
15	14	196	2740	2940	41,000
50	27	729	19700	36400	98,500
75	31.5	991	31000	74[illegible]00	2,3[illegible]5,000
50	36	1296	46600	64800	2,3[illegible]0,000
75	42	1760	74000	132000	5,550,000
100	48	2300	110000	230000	11,000,000
125	54	2916	157000	364000	19,600,000
150	60	3600	216000	540000	32,400,000
175	66	4350	288000	7[illegible]2000	50,000,000
1350	108	11664	1260000	15750000	1717,000,000
150	56	3130	175000	470000	26,250,000

Table of values (Cont.)

D^4	D^5	D^6
41,000		
38,400	538,000	7,530,000
530,000	1,440,000	387,000,000
980 ,000	3,100,000	970,000,000
1,670,000	60,000,000	2,190,000,000
3,110,000	130,000,000	5,500,000,000
5,350,000	230,000,000	12,200,000,000
8,500,000	400,000,000	24,900,000,000
13,000,000	775,000,000	46,600,000,000
19,000,000	1,240,000,000	82,000,000,000
136,000,000	14 ,690,000,000	1,580,000,000,000
9,850,000	550,000,000	30,800,000,000
198,028,400	18,165,078,000	1791,554,520,000

Substituting these values in the two equations and solving as follows we have:

$$\begin{cases} D^2H = K\,D^4 + K'\,D^5 \\ D^3H = K\,D^5 + K'\,D^6 \end{cases}$$

18,447,640 = K 198,028,400 + K' 165,078,000
1,866,564,500 = K 18,165,078,000 + K' 1,791,554,500,000

Divide thru by 1,000,000 and we have:

$$\begin{cases} 18 = 198\ K + 18{,}165\ K' & (1) \\ 1{,}867 = 18{,}165\ K + 1{,}791{,}500\ K' & (2) \end{cases}$$

Multiply (1) by 987 and we have :

17,760 = 195,300 K + 1,791,500 K'
1,867 = 18,165 K + 1,791,500 K'

subtract 15,893 = 177,135 K

Therefore $K = \frac{15{,}893}{177{,}135} = .0898$

Substitute value of K in equation (1)

and K' = 0.00001101

Whence the most probable equation of this general form

is $H = 0.0898\ D^2 + 0.00001101\ D^3$

Calculating values from this equation and passing the curve thru these plotted points one obtains Curve B Plate 1.

Curve A Plate 1 is an approximate curve drawn thru all the points except the one representing 1350 H.P. and 108 inch diameter. It can be seen at a glance that there is considerable difference between Curve B and Curve A. It is evident that this equation for curve B ($H = 0.0898\ D^2 + 0.00001101\ D^3$) cannot give values for H which correspond in any way with known data. It is therefore evident that this one point, 1350 H.P. and 108 inch diameter, effects the calculations so greatly and in the wrong direction that it would be wise to leave it out. Dropping this point by subtracting its horizontal column from the table on pages 15 and 16 we have summations for all the points which we can readily substitute in the general equation as follows:

$$D^2H = 2,697,000$$
$$D^3H = 149,000,000$$
$$D^4H = 62,000,000$$
$$D^5 = 3,475,000,000$$
$$D^6 = 205,000,000,000$$

Dividing both sides by 1,000,000 we have two simultaneous equations,

$$\begin{cases} 2.7 = 62\ K + 3475\ K' \\ 149 = 3475\ K + 205\,000\ K' \end{cases}$$

Whence $K = 0.0435$ and $K' = 0.00000126$

Whence the equation desired is:

$$H = 0.0435\ D^2 + 0.00000126\ D^3$$

Values for H and D computed from this equation and plotted give Curve A Plate 2. It will be noted that this

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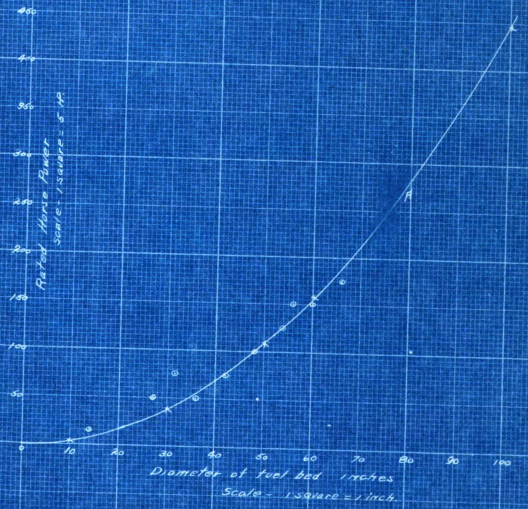
Plate-2.

Points as plotted show relation between Rated H.P and diameter of fuel bed and are taken from actual dimensions furnished by manufacturers.

Curve equation is. $H = .0435\,D^2 + .00000126\,D^3$



curve corresponds very closely to the points plotted from the manufacturers data and up to three hundred horse power will give results which correspond very closely with practice . For values up to about 150 H.P. the second term, D^3 , can be neglected without appreciable error; in fact the equation $H = 0.0165\ D^2$ is close enough for all practical purposes.

It may be well to note here the basis for H.P. rating The following plan is used by all our informants and is mentioned in Kent's Mech. Engineers Pocketbook. The number of pounds of fuel which it is possible to gasify per hour per sq.ft. of grate surface is determined by experience and varies considerably with different classes of fuels. Kent gives as an average value ten pounds per sq.ft. of grate surface per hour for bituminous coal with 10% ash and 1% Sulphur and for Anthracite and states that with good gas coal , viz: high volatile content and low ash, an average value is 18 lbs. per sq.ft. per hour. In the data which we have obtained this quantity varied between 8 lbs. per hour per sq.ft. to 15 lbs. The producers using 15 lbs. per hour per sq.ft. were small and the overload capacity was only 15% while in the lower values, i.e. 8 lbs/, the producers were of large size and covered greater range of H.P. and the guaranteed overload capacity was 25% for two hours. The average of the data obtained, considering the overload capacity, was about 10 lbs. per hour per sq.ft. of grate surface with a 20% overload capacity. T

The next item needed in calculating the H.P. rating is the number of lbs. of coal used per H.P.Hour.

Kent gives 1½ lbs. as an average . Following are the calculations for this value from the data obtained(referring to anthracite).

The area of grate was calculated from the diameter and the result multiplied by the number of lbs. of coal per sq.ft.per hour as given in the data. This divided by the rated H.P. gave the number of lbs. of coal per H.P.Hour as in the following table.

Diam. grate.	area.	Rated H.P.	#coal/sq.ft.	#coal/hr.	#/HPhr.
42"	9.6	50	8	76.8	1.537
48"	12.5	75	8	100	1.333
54"	1[illegible].86	100	8	126.8	1.268
60"	19.65	125	8	157.2	1.26
66"	23.7	150	8	189.6	1.26
72"	28.2	175	8	225.6	1.28
14"	1.067	15	15	16	1.067
27"	3.96	50	15	59.4	1.19
31.5"	5.4	75	15	81	1.08
#06	17.1	150	10	171	1.14
				Average =	1.242

In looking over this table the question arises: What is the relation between the area of the grate, the H.P. of the generator and the number of pounds of fuel fired per H.P. hour. Using the values as found in the table above and plotting pounds of fuel per H.P. hour as abscissa and area of grate in sq.ft. as ordinates the points as shown in Plate 5 were found. These points evidently lie on no particular form of curve so their average value was taken (leaving out as before the value obtained for the 1350 H.P. producer, which differed widely from the others). A vertical line drawn down thru this average point seemed to approximate the

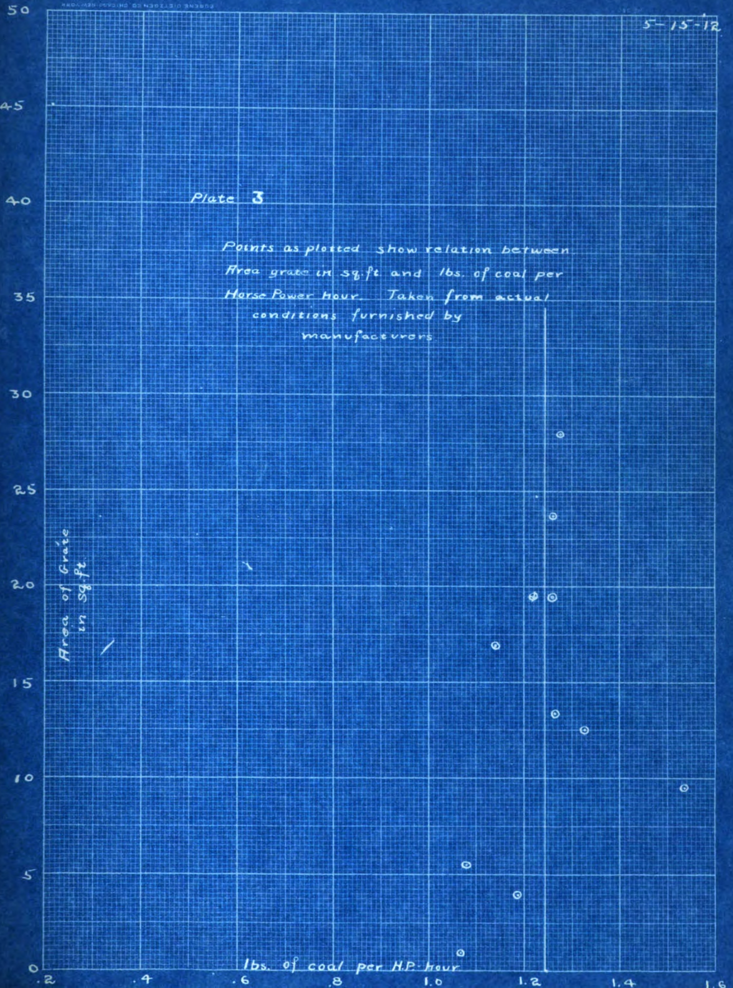

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Plate 3
Points as plotted show relation between Area grate in sq. ft. and lbs. of coal per Horse Power hour. Taken from actual conditions furnished by manufacturers.
Area of Grate in sq. ft.
lbs. of coal per H.P. hour
50
45
40
35
30
25
20
15
10
5
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6

law followed by the plotted points. The average value for coal per H.P.hour, as seen in the table, is 1.242 lbs. It is to be noted here that for the large producers of 1550 H.P. capacity the pounds of coal fired per H.P. hour is very much below this value being .403 lbs., pointing to the probable fact that in large units the efficiency can be largely increased and the coal consumption per H.P. hour correspondingly decreased.

Taking this value for coal consumed per H.P. hour and combining with the number of pounds of coal fired per sq. ft. of grate surface, as determined above, (10 lbs. per sq.ft.) we obtain a basis for H.P. rating. The sq.ft. of grate surface multiplied by 10 lbs. (lbs. of coal per sq.ft. per hour) divided by 1 (lbs. of coal per H.P. hour) gives the rated H.P.

RELATION BETWEEN H.P. AND DIAMETER OF DISCHARGE PIPE.

In looking over the data relating to the size of the discharge pipe thru which the gas is taken to the gas holder or engine, it was evident that its size should and probably would vary with the amount of gas produced per hour, while upon this factor depends the H.P. of the producer. Hence we have decided to investigate the relation between the rated H.P. and the sectional area of the discharge pipe. Since the sectional area of the discharge pipe varies directly as the square of the diameter, we drew an approximate curve A Plate No. 4 thru the points found by plotting values of rated H.P. as ordinates and values of diameter of

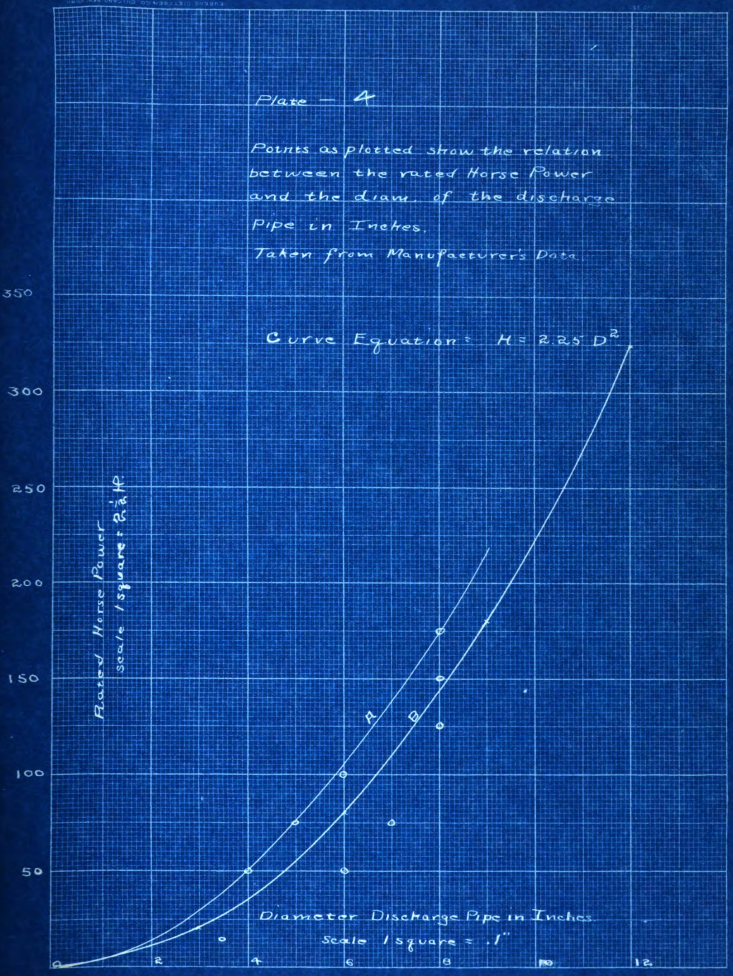
Plate — 4
Points as plotted show the relation between the rated Horse Power and the diam. of the discharge Pipe in Inches.
Taken from Manufacturer's Data.
Curve Equation: H = 2.25 D²
Rated Horse Power
Scale 1 square = 2½ H.P.
Diameter Discharge Pipe in Inches.
Scale 1 square = .1"
A
B
350
300
250
200
150
100
50
2
4
6
8
10
12

discharge pipe as abscissa as obtained from the data sent by the manufacturers.

This curve A seemed to approach a parabola in form and hence we took the general form of equation for a parabola, $H = K D^2$, wherein H = rated H.P. and K = a constant. Using the theory of least squares and omitting the values for the 1350 H.P. producer again, a value for K was found = 2.75. This gives the equation $H = 2.75 D^2$, which shows the relation between the rated H.P. of producers and the size of the discharge pipe. These values when plotted give curve B Plate No. 4.

GRATES

There was neither uniformity nor any apparent law for the kind of grates which were used. Almost all were provided with means for shaking; in some, especially the smaller ones, the whole grate could be shaken while in the larger ones the center part only was capable of being shaken. All but two were flat, one of these was stepped while the other really used no grate. The bottom of the latter generator was water sealed and the ashes were removed from the water. Where the grates are used the average % of air space was 41% of the total grate area.

DEPTH OF FUEL BED.

The depths of the fuel bed varied between three feet and five feet, except depth apparently depending upon the capacity obtaining. The average value was a little more than the diameter of the fuel bed up to about five feet or the approximate maximum depth for any fuel bed.

THICKNESS OF LINING.

In all producers described by manufacturers the lining was of fire brick and had a thickness of nine inches except for one very small producer of 15 H.P. capacity whose fire brick lining was 4½ inches. In some mention was made of a layer of sand of one inch thickness, apparently for insulation. This use of sand seemed to be preferred in the larger sizes, above seven or eight hundred H.P.

VAPORIZERS AND ECONOMIZERS.

In all the producers noted there was provision for generating steam and introducing it with the air blast or air suction supply. This steam tends to keep the temperature of the fuel bed within possible working limits and also tends to lessen the dilution of the produced gas by lessening the relative percentage of nitrogen. The steam is decomposed into H and O which two elements unite again when the gas is used in the engine. There is no heat gained except insofar as the steam in its dissociation absorbs heat which otherwise might be lost by radiation. It really acts as storage for considerable sensible heat and thereby increases the efficiency of the producer somewhat as well as serving the very necessary function of keeping the fuel bed from becoming too hot.

In the majority of producers the steam is generated in an economizer or vaporizer placed in the top of the producer. The sensible heat from the fuel bed below and the hot gases passing thru on their way to the engine, furnishes the means whereby the water is vaporized. We were unable to find any standard dimensions for these vaporizers. It appears that provision is usually made for sufficient heating surface to saturate the incoming air although the whole proposition is rather indefinite as far as our results are concerned.

TAR EXTRACTORS .

In anthracite producers tar extractors are not needed In those using bituminous coal centrifugal tar extractors are used. One type used is the kind wherein two rotors revolve in opposite directions and close together. We obtained no definite information regarding dimensions except that the average speed for the centrifugal rotors was about 1400 R.P.M.

PURIFIERS .

Purifiers were seldom recomended and when used the reason seemed to be to take care of the sulphur in the cheaper grades of coal. A number of trays containing iron oxide mixed with shavings or similar material seemed to be the type used where purifiers were mentioned. The principal and methods were a similar to the purifiers used in ordinary illuminating gas practice.

SCRUBBERS .

There seem to be two kinds of scrubbers in use, one using coke filler and the other using either wood or iron baffles. In both types water is introduced at the top and as it passes downward it meets the upcoming gas and washes it. The size varies directly as the H.P. of the producer and perhaps a little with the kind of fuel used. Our data showed that they were designed to handle about 1.3 cu.ft. of gas per rated H.P. per min. There seemed to be no stand-ard relation between the diameter and height, the ratio varying from 1 : 3.5 to 1 : 10 . The amount of water used varied widely, from twenty gallons to one hundred gallons per one thousand cu.ft. of gas passing thru the scrubber. The guiding factor is to cool the gas to about 60 degrees Fahrenheit before it is delivered to the engine and the amount of cooling necessary for this result depends large-ly upon how much steam is introduced with the blast and the consequent temperature of the gas produced. This amount of steam varies widely also, from 0.6 lbs. per lb. of fuel to 1.[illegible] lbs. of steam per pound of fuel giving an average value of about 1 lb. of steam per lb. of fuel.

EFFICIENCY .

Thermal efficiency for producers varied from [illegible]% to 86%, a more general value being 7[illegible]%. This item depends large-ly upon the kind of fuel used. The lower grades of fuel give lower efficiencies but it must be remembered in this connec-tion that these lower values are for lower grades of fuel which can hardly be utilized in any other apparatus at all. The producer will handle any fuel at a higher efficiency than a steam boiler can handle the same fuel.

The period of charging varies with the kind of fuel and the size of producer from one half hour to twelve hours. The aim is to keep a sufficiently constant depth of fuel bed and this depends upon the rate of combustion and the ash con-tent of the fuel.

In all producers there was provision made for poking the fire from the top and in some also from the side. This a act is necessary only when clinkers or other causes bring about a condition wherein the fuel bed is not uniform in composition and density. Chimneys or air passages are then formed thru which the air passes and the oxygen then pene-trates into the producer gas without coming into contact with carbon and being thereby transformed into CO gas. The fuel bed must then be poked till these air chimneys are closed and the resistance to the passage of air is uniform through-out the section. This will make possible the best perform-ance of the producer.

CONCLUSION

At the close we wish to call attention to the limitations imposed upon this thesis, to draw a few conclusions and to make a few observations. The data obtained from the manufacturers was largely in referance to Anthracite Producers and their accompaning apparatus . Most of these Anthracite Producers are of the suction type. Hence our data and results apply more particularly to suction anthracite producers and very little was learned about the pressure type or those types using cheap bituminous coal, lignite and refuse. This is but natural when one considers that the greater number of plants now in use burn pea anthracite, a fuel which is comparatively easy to procure in the United States and which when used at its market cost will generate power at less cost than can a steam plant burning any steaming fuel. In Europe, however, where fuel of this high quality is not easy to procure, more attention has been paid to the development of bituminous and lignite producers and it is from there that one learns about those types.

It seems from the data returned from the manufacturers that for very high grades of bituminous coal the same type of producer can be used as for anthracite, the only additional apparatus needed being a tar extractor. However this does not apparantly point to the fact that the two types are the same in their most efficient form. The bituminous producer practice seems to point to the pressure producers and sometimes to the down draft and double flow types. The formulae found in this thesis apply thus particularily to suction anthracite producers and may be applied to suction bituminous producers provided the bituminous coal is of high quality i.e. low in ash and sulphur.

The table showing the number of manufacturers written to, those who answered and those who no longer manufacture power producers seems to point to the fact that fewer companies are engaged in making gas producers now than in former days; that it is a difficult task to make a commercially successfull producer and that the producer business is settling down to a more conservative basisthan when radical claims were wont to be made for it and many companies were entering the field of manufacture of gas producers.Its introduction is taking on a more steady growth and as time progresses the chances are that the size and number of units will increase and the producer will fill a constantly widening field of usefullness.

[illegible]