GAS PRODUCER TESTS WITH VARYING SIZES OF FUEL

BY

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THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1913

UNIVERSITY OF ILLINOIS

May 31 1913

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

Walter Arthur Blakeslee and Charles Robert Ogle

ENTITLED Gas Producer Tests with Varying Sizes of Fuel

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

DEGREE OF Bachelor of Science in Mechanical Engineering

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GAS PRODUCER TESTS WITH VARYING SIZES OF FUEL.

Introduction.

The work appearing herein was performed as a partial requirement toward obtaining the degree of Bachelor of Science in Mechanical Engineering. All tests were performed upon a suction gas producer installation, located in the Mechanical Engineering Laboratory, of the University of Illinois. The work was done under the supervision of A. P. Kratz, instructor in mechanical engineering.

1.-Object of the Tests.-- The small suction gas producer, using anthracite coal, has now, in conjunction with the gas engine, made a place for itself in the power production field. In the present day of accurate cost accounting systems, of obtaining the most for the least outlay, it was found desirable to learn just what effect varying the sizes of fuel would have upon the efficiency of a producer of this type. It is with this object in view that the present work was carried out.

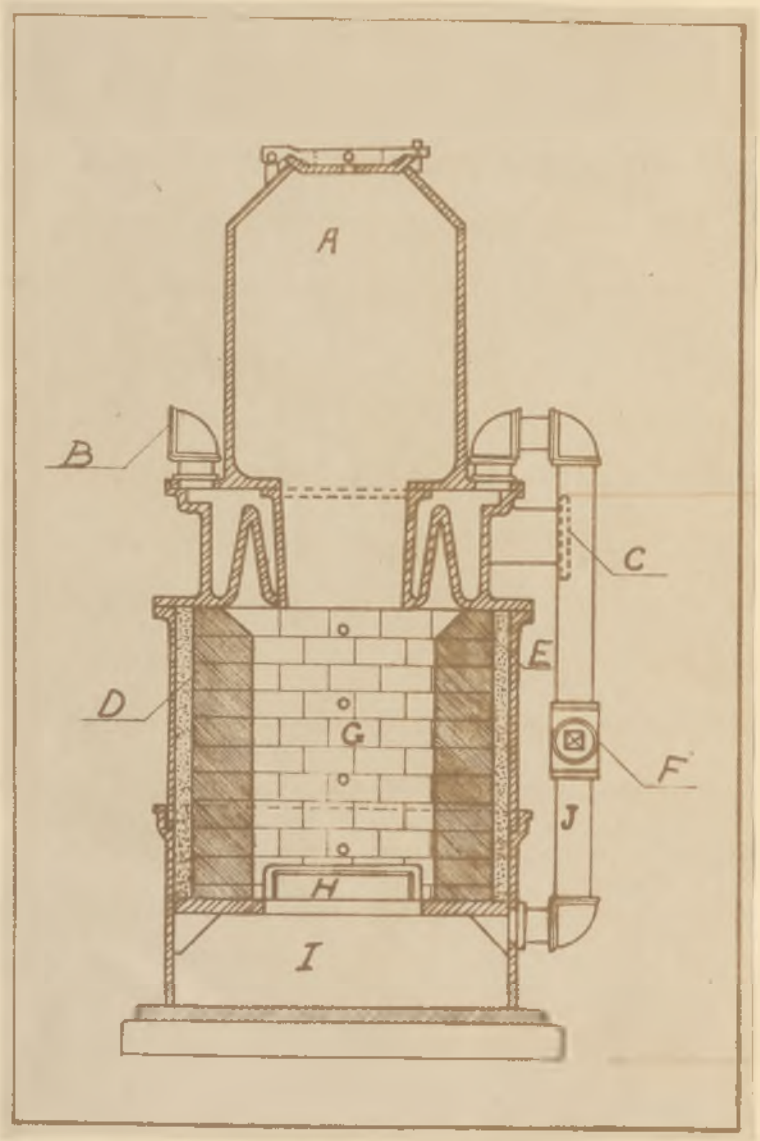


Figure 1.

CHAPTER 1 .

The Installation.

The installation, as originally made by the Otto Gas Engine Works, consisted of the producer, a wet scrubber, a gas receiver, and a twenty-three horsepower producer engine, known as their No.7 engine. The plant has since been modified for testing the producer without operating the engine. The present arrangement will be discussed later.

2 .- The Producer.-- The producer is listed by the Otto Engine Works as their No.3 producer. Its rated output is a capacity for supplying gas for sixty horsepower, or a maximum equivalent production of 8,100 cubic feet of gas per hour. The specifications furnished with the producer stated that it was designed for intermittent operation, and that the length of runs should not be greater than twelve hours. Figure 1 shows the producer in section. It is of the contained vaporizer type and is provided with a plain bar grate.

3 .- The Plant.-- A diagramatic sketch of the plant as modified for testing is shown in figure 2 . The producer B is provided with a fan blower A for starting. In the tests this was not used, as the Schutte-Koerting steam ejector at F furnished the necessary draft for starting, as well as for running the tests. The ejector has a capacity of 12,000 cubic feet per hour.

The wet scrubber D was filled with coke. The water enters at the top and passes out thru the overflow. The two-way valve C between the producer and the wet scrubber permits the gases leaving the producer to pass into the atmosphere at the completion of a test, or whenever the ejector may be shut down. The steam used by the ejector is condensed in the second wet scrubber I . The suspended moisture is removed by the separator K and the dryer L . The latter is a gas bell filled with straw. The Westinghouse meter at N made its use necessary. This meter is of the "wet" type, so that were the dryer not used, the suspended moisture in the gas would tend to collect in the meter and raise the level of the sealing fluid.

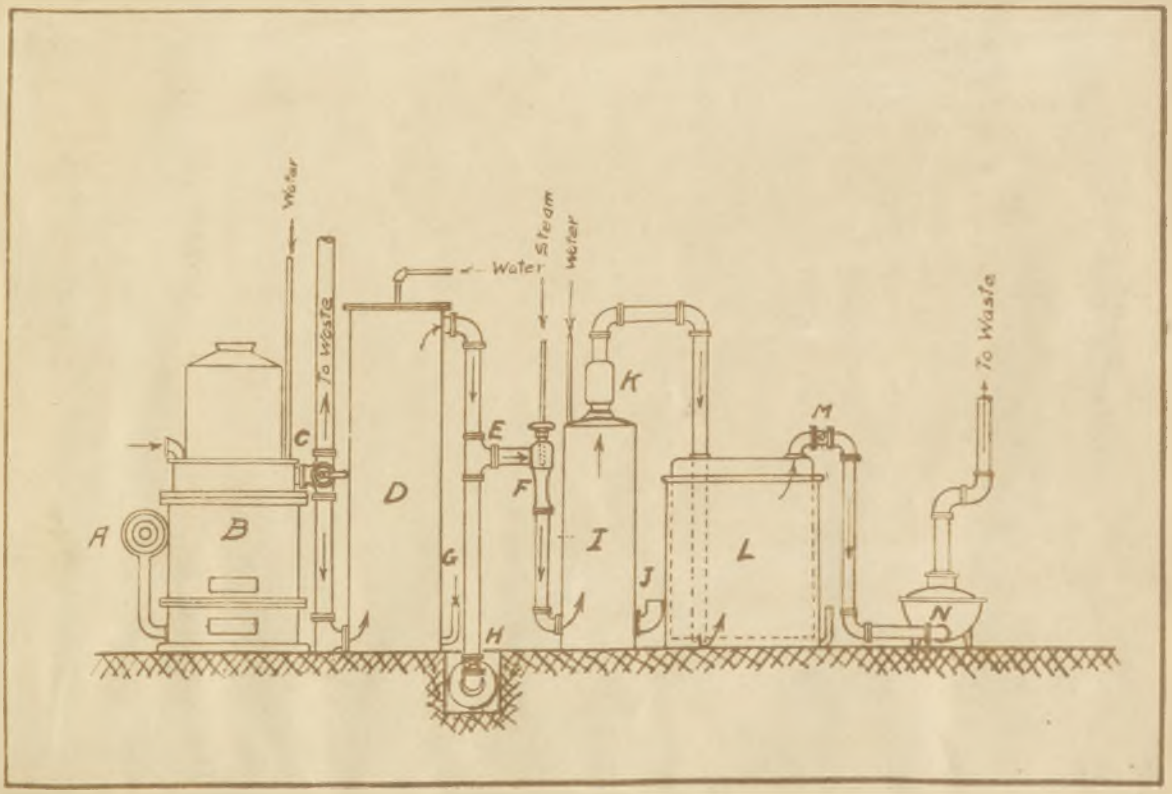


Figure 2.

CHAPTER 2.

Method of Conducting the Tests.

In conducting the tests, four items were considered, the weight of coal, the heating value of the coal, the volume of the gas, and the heating value of the gas.

4.- Method of Determining the Weight of Coal Fired.-- The producer was started and after it had been in operation some time the ash and clinker were removed, the fuel bed was worked with a slice bar until it was in a uniform condition, the magazine was filled, and the test was started. These operations were duplicated at the end of the test. The coal fired during the test together with that required to fill the producer at the end of the test was then taken as the amount of fuel used. This method, while somewhat in error, is the only practical one that can be applied to a test of this kind.

An attempt was made in all cases to keep the pressure at the meter constant throughout the test. The volume of gas flowing thru the meter was kept as near the same for all tests as possible.

5.- Method of Determining the Heating Value and Analysis of the Coal.-- Samples of coal were taken equal to about ten per cent of the total weight of the coal fired. These were quartered and broken up in the usual manner, and a sample sufficient to about fill a quart jar was sent to the chemist for analysis and for the determination of the heating value.

The coal used in the tests was stored indoors and was practically air-dry as fired. Two varieties of coal were used, an analysis and a heating value determination being made in each instance. The buckwheat coal was assumed to have the same heating value and analysis as the pea coal, as a quantity of the latter was crushed to produce the buckwheat size.

6.- Method of Measuring the Volume of the Gas.-- The volume of the gas generated was measured by a Westinghouse meter of the "wet" type. The volume as recorded by the meter was then reduced to standard gas, i.e., to dry gas at a temperature of 62°F . This value was checked by calculating from the weight and analysis of the fuel and the analysis of the gas the volume of the gas generated. In test one and four these checked within five per cent. A considerable discrepancy appeared in test five. The formulae for making the above calculations will appear later.

7.- Method of Sampling the Gas.-- In order to obtain a uniform sample the method illustrated in figure 3 was used. The tubes

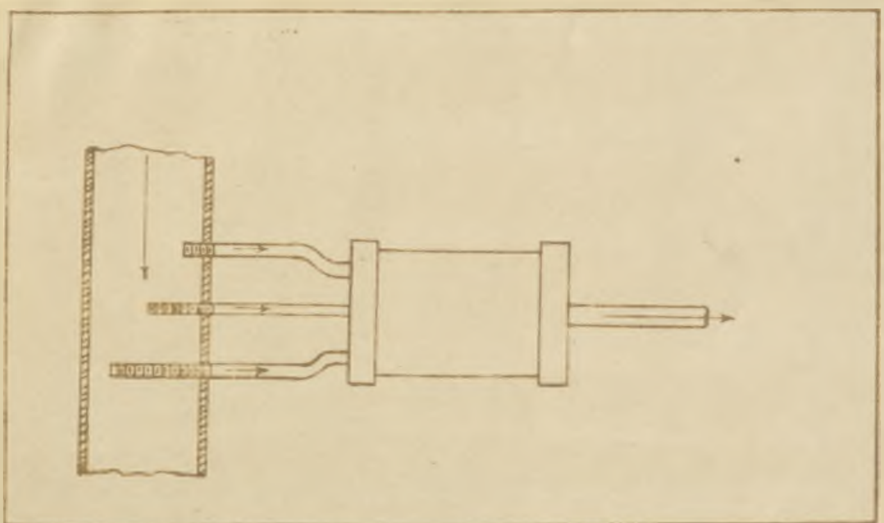


Figure 3.

draw their respective supplies from three separate points in the main. These volumes are united in the receiver, in this instance a section of pipe somewhat larger than the tubes. The samples both for the calorimeter and for analysis were drawn from this receiver.

The device was inserted beyond the second scrubber, at which point the gas was under pressure, so that it had only to be led to the desired location thru tubing. A trap was inserted between the receiver and the calorimeter. This removed any suspended moisture in the gas.

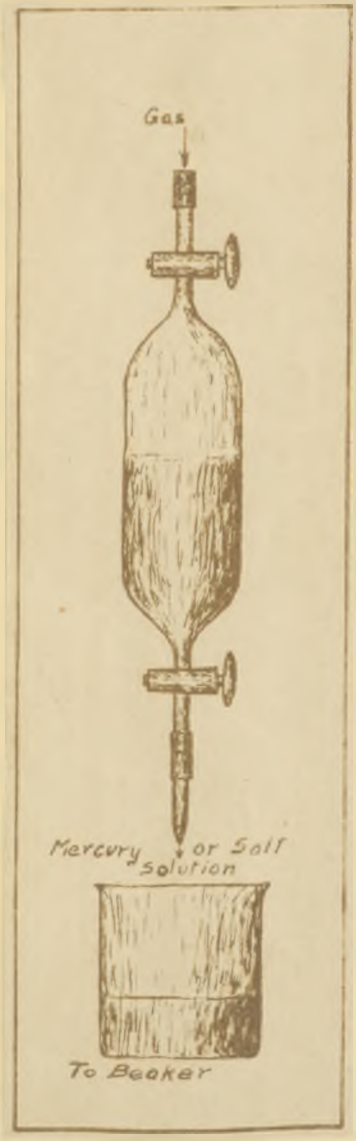


Figure 4 .

The sample used for analysis was collected as shown in figure 4 . The gas containers used held about 600 cubic centimeters. In some of the tests they were filled with mercury. An accident, resulting in the loss of the mercury, forced the use of a saturated solution of salt water for the remaining tests. The salt solution was saturated with the gas before the containers were filled. After filling, they were connected as shown in figure 4 and the liquid permitted to flow slowly thru the glass cock into the beaker below. The rate of flow was so regulated that three samples were taken over approximately equal intervals of time for each ten hour test.

8.- Methods of Determining the Heat Value of the Gas.-- Two methods were used in the determination of the heating value of the gas. The first was by means of a calorimeter, by which the heating value was obtained at frequent intervals throughout the tests. The second method was based upon a calculation from the analysis of the gas as furnished by the chemist. The values obtained by the latter method are probably the more correct, as the calorimeter was operated periodically, while the analyses were made from practically continuous gas samples. Errors of manipulation and inaccuracies of the instruments also effected the calorimeter determinations. The values obtained from the analyses were considered the more accurate and have therefore been used in all calculations. All formulae required in the above work will appear under "Formulae".

9.- Method of Measuring the Weight of Air Used.-- The weight of air used was calculated from the weight of nitrogen appearing in the gas.

10.- Methods of Measuring the Temperatures.-- With the exception of the temperature of the gases leaving the producer, all temperatures were taken with mercury thermometers. The temperature of the gases leaving the producer was measured with a Hoskins' base metal pyrometer.

11.- Methods of Measuring the Water Used.-- The water fed to the first wet scrubber was measured by means of a water meter calibrated in cubic feet. No record was made of the water used in the second wet scrubber. The water fed to the producer from the vaporizer was obtained by weighing in a tank resting upon platform scales, which were located on the charging platform above the producer. The water was conducted from this tank thru a flexible tube to the top of the vaporizer. A second tank was placed upon platform scales under the constant level overflow of the vaporizer. The difference between the weight of water in the supply tank and that in the overflow tank equaled the water fed to the producer by the vaporizer.

12.- Method of Obtaining the Weight of Moisture in the Gas.-- This item was obtained by taking the difference between the total weight of moisture entering the producer and the weight of water decomposed in the fuel bed as computed from the analysis of the gas.

13.- Method of Determining the Ash and Refuse.-- All ash and refuse removed during the test, as well as that taken from the producer at the end of the test, were collected and weighed. This was quartered in the usual manner and a sample sent to the chemist for analysis. The weight of the carbon lost thru the grate was then obtained from this analysis and from the weight of the ash and refuse.

CHAPTER 3.

Theory.

The principal conditions effecting the results of the tests are as follows:-

14.- The Amount of Surface in Contact.-- This condition is dependent upon the size and form of the fuel. In the case of the fuels used in these tests the form was of minor importance as it likely averaged the same for all sizes employed.

15.- The Area.-- This varies inversely as the size of the fuel as is shown in the following:-

Let

T = the total area of the fuel in contact with the gas,

A = the area of one average piece of coal,

N = the number of pieces of coal,

v = the volume of one piece of coal, and

V = the volume of the fuel bed.

Assume that the fuel is spherical.

Let

D = the mean diameter of one piece of fuel, and

K_1, K_2, C_1, and C_2 = constants.

$$T = K_1AN \qquad (1.)$$

As the volume of the fuel bed is constant

$N = V/v = C_1/D^3$, and

$A = C_2D^2$

Substituting the values for A and N in equation 1.

$$T = K_2 D^2/D^3 = K_2/D \qquad (2.)$$

16.- The Time of Contact.-- This is dependent upon the size of the fuel, increasing as the size decreases due to the more tortuous passages the gas is forced to take thru the fuel bed when the smaller sizes are used.

Bulletin No. 30 of the Engineering Experiment Station of the University of Illinois states that for any given temperature the amount of CO formed is dependent upon the area of fuel and upon the time of contact. These in turn depend upon the size of the fuel employed, so that the size of the fuel has a direct bearing upon the amount of CO formed. The following will show the truth of this statement.

Assuming that the temperature remains constant, and that the rate of gasification remains the same for all tests, it is desired to prove that the velocity of the gases thru the fuel bed is the same for all sizes of fuel. Excluding frictional resistance the velocity is dependent upon the area of the cross section of the voids. That this is constant is shown by the following calculations.

Assume the coal is spherical in form. Let figure 5 represent a section of the fuel bed.

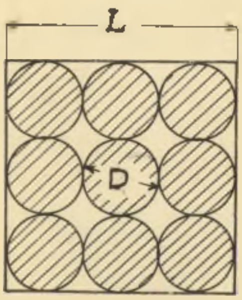


Figure 5.

Let

L = the length of one side of the section, and

D = the diameter of one piece of fuel.

Then

$A = L^2$ = the area of the section,

$A_1 = \pi D^2/4$ = the sectional area of one piece of fuel,

$A_2 = L^2\pi D^2/4D^2 = \pi L^2/4$ = total area of fuel section,

$A - A_2 = L^2(1 - \pi/4) = K$ = area of the voids

where K is a constant.

CHAPTER 4.

Efficiencies.

17.- Hot Gas Efficiency.-- The hot gas efficiency, based on the high heating value of the gas, appears under item 154. It is of no special importance in the production of power gas.

18.-Cold Gas Efficiency.-- The cold gas efficiencies, based on the high and low heating values of the gas, appear respectively under items 155 and 155.1 . Both of the above efficiencies, as well as the hot gas efficiency, were also calculated based on one hundred per cent grate efficiency. These values appear as items 155a, 155b, and 155c.

CHAPTER 5.

Forms for Computation.

All forms for computation were obtained from bulletin No.50 of the Engineering Experiment Station, of the University of Illinois. A few of the more important forms appear below, together with the proper substitution of the values as obtained in test one. The derivation of these formulae will not be gone into here, as they are thoroughly discussed in the above mentioned bulletin.

19.- Items 119 and 119a.--

High Heating Value.--119.

CO 0.1279 x 319 = 40.75 B.t.u.

H_2 0.1476 x 328 = 48.4 " .

CH_4 0.0017 x 1010 = 1.72 " .

90.87 B.t.u. per cubic foot of standard gas.

Low Heating Value.-- 119a.

CO 0.1279 x 319 = 40.75 B.t.u.

H_2 0.1476 x 276 = 40.77 " .

CH_4 0.0017 x 910 = 1.55 " .

83.07 B.t.u. per cubic foot of standard gas.

20.- Item 120.--

High Heating Value.

Let T_g = absolute temperature of entering gas, deg. cent.

r = the rise in temperature, deg. cent.,

G_1 = cu. ft. of gas used, from meter,

p_g = the absolute pressure of the entering gas in inches of Hg., corrected for vapor pressure of water, and

3.29 = a constant, derived in bulletin.

then $H = (T_g \times r \times 3.29)/(G_1 \times p_g)$ = the high heating value,

$= (295 \times 3.4 \times 3.29)/(1.34 \times 28.68)$

= 85.7 B.t.u.

21.- Item 125.--

Volume of Standard Gas.

Item 125 = (Item 124 x Item 26 x 17.4)/(Item 45)

= (41820 x 28.93 x 17.4)/(556.5)

= 37,950 cubic feet.

22.- Item 126.--

Volume of Standard Gas.

Item 126 = Item 144 x (Item 51 x Item 61 - Item 52 x Item 68)-:-(0.116 x Item 135) x (0.273 x Item 144 + 0.75 x Item 148 + 0.429 x Item 145 + 0.858 x Item 149)

= 20.3 (440 x 81 - 112 x 59.9)-:- (.116 x 12.04) x (20.3 x .273 + .75 x .11 + .429 x 13.63)

= 36,700 cubic feet.

CHAPTER 6.

Discussion of Tests.

23.- Test One.-- This test was started at 11:45 a.m. on March 21, 1913, and concluded at 9:45 p.m. on the same date. Scranton pea coal was used. Frequent pokings were necessary in order to keep the temperature in the producer from rising excessively. Gas samples for this test were taken over mercury. Considerable trouble was experienced with the Junker calorimeter, as the gas burned only at intervals. This was due to the poor quality of the gas rather than to lack of pressure.

24 .- Test Two.-- Test two was started at 10:15 a.m. on March 22, 1913, and was completed at 8:15 p.m. on the same date. Lehigh Valley chestnut coal was used. Frequent pokings were resorted to, to keep the temperature in the producer at the proper point. The gas samples were taken over mercury. Quite a few calorimeter determinations were made with the Junker calorimeter, as the gas burned well throughout the test.

This test was not used in obtaining the final results, for the Chemist's report showed that air had in some way leaked into the gas containers.

25.- Test Three.-- The producer was started on the morning of March 24, 1913. Soon after setting the apparatus in operation, it became obstructed in some manner.An explosion resulted in the producer causing a charge of fine coal to be blown out of the air intake, incapacitating one of the operators. A substitute was secured and an attempt made to carry on a test, but as no results were obtained the work was discontinued about five o'clock in the afternoon.

Before an attempt was made to run test four the scrubber and dryer were thoroughly overhauled.

26.- Test Four.-- Test four was started at 10:00 a.m. on April 12, 1913, and concluded at 8:00 p.m. on the same date. Lehigh Valley chestnut coal was used. Due to an accident resulting in a loss of the mercury used for gas sampling, the gas samples were taken over a saturated salt solution. Before filling the tubes with the solution, gas from the producer was passed through the liquid. While the amount of CO_2 as shown by the chemist's report was somewhat lower than would have been the case had mercury been used, the difference was probably inappreciable.

27.- Test Five.-- Test five was started at 9:00 a.m. on April 19, 1913, and completed at 7:00 p.m. on the same date. Lehigh Valley buckwheat coal was used. This was obtained by crushing the pea size and removing the finely powdered coal by screening the crushed fuel.

When somewhat over half way thru the test, some part of the installation became obstructed so that no draft could be obtained thru the producer. As the trouble could not be located, the gas sample was shut off, the ash and refuse were removed from the producer, the magazine filled, and readings of all instruments made.

After some time the producer was again started, readings were taken, and the second part of the test was carried out. This was conducted as a separate test in order to prevent the loss of the results of the first part of the test, if for any reason it became necessary again to shut down the plant. However, no further trouble was experieneced, so that the two parts were consisdered as a single test and are recorded as test five.

C. E. Clyde — University of Illinois

Efficiency with varying sizes of Fuel.

Plain Bar

Body of thesis

Suction —

Date	4-19-13	4-12-13	3-21-13
Duration	10 hrs.	10 hrs.	10 hrs.

DIMENSIONS AND PROPORTIONS

1.85 x 1.33
1.665
1.564
2.210
1.877
7.875
0.5
0.722
43.3
0.168
3.0
2.853
7.156
1.8
48.8

29.61	29.41	29.40
29.30	29.32	29.32
0.28	0.52	0.485
3.16	1.62	1.253
29.27	29.19	29.28
4.38	4.6	4.32
29.82	29.60	29.66
3.457	1.733	1.03
26.36	28.927	28.63
78.0	91.0	73.1
67.6	91.3	72.7
527.6	551.3	532.7
210.9	210.9	210.9
68.0	63.6	66.6
185.3	196.9	189.0
145.3	147.4	144.5
65.0	65.6	64.5
140.0	166.0	186.5
79.0	106.4	91.8
860.0	908.9	838.2
1260.0	1360.3	1048.2
123.5	183.8	146.7
585.3	608.8	604.7
678.9	758.7	710.3
130.2	96.4	138.1
580.2	356.4	598.1

TEST NUMBER

FUEL

	Buckwheat	Pea	Chestnut
[illegible]	¼"	⅝"	1"
[illegible]	303.5	447.8	421.9
[illegible]	1.66	1.66	1.64
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	81.0	112.0	126.5
[illegible]	High	in carbon	
[illegible]	194.9	503.5	216.6
[illegible]	27.1	23.41	45.5

PROXIMATE ANALYSIS OF COAL — AS FIRED

[illegible]	78.81	[illegible]	78.60
[illegible]	7.79	[illegible]	7.53
[illegible]	1.66	[illegible]	[illegible]
[illegible]	17.74	[illegible]	16.21
[illegible]	1.37	[illegible]	0.79

ULTIMATE ANALYSIS OF DRY COAL — DRY BASIS

Carbon, C, per cent	81.00	81.00	77.76
Hydrogen, H, per cent	2.16	2.16	1.69
Oxygen, O, per cent	2.20	2.20	2.26
Nitrogen, N, per cent	1.81	0.81	0.81
Sulphur, S, per cent	1.39	1.39	0.80
Ash, per cent	12.44	12.44	16.48
[illegible]	1.66	1.66	1.64

ANALYSIS OF DRY ASH AND REFUSE

Carbon, per cent	70.13	59.90	61.40
[illegible]	29.84	40.10	38.60

FUEL PER HOUR

[illegible]	[illegible]	44.00	41.46
[illegible]	[illegible]	30.39	21.68
[illegible]	17.92	26.40	24.90
[illegible]	11.96	18.20	13.01
[illegible]	15.91	23.45	22.10
[illegible]	10.39	16.18	11.56
[illegible]	7.20	10.61	10.00
[illegible]	4.70	7.31	5.23

CALORIFIC VALUE OF FUEL

[illegible]	13010.0	13010.0	12359.0
[illegible]	15680.0	15620.0	15820.0
[illegible]	12998.0	12998.0	12354.0
[illegible]	15640.0	15654.0	15618.0

WATER

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	410.5	613.2	582.6
[illegible]	426.8	638.2	561.82
[illegible]	410.5	613.2	542.6
[illegible]	0.26	17.6	12.53
[illegible]	5.04	7.47	6.90
[illegible]	426.8	638.2	561.82
[illegible]	160.05	191.57	115.10
[illegible]	160.05	191.5	116.10
[illegible]	266.75	446.7	446.72
[illegible]	[illegible]	0.300	0.209
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	0.630	0.552
[illegible]	0.095	[illegible]	[illegible]
[illegible]	1.43	[illegible]	[illegible]
[illegible]	2.19	1.	[illegible]
[illegible]	0.254	0.508	0.371
[illegible]	3470.0	4720.0	3526.0

WATER PER HOUR

[illegible]	41.05	61.3	58.26
[illegible]	13	20.4	18.10
[illegible]	16.0	19.16	11.51
[illegible]	42.68	63.82	56.18
[illegible]	347.0	472.0	322.6

QUANTITY OF AIR

[illegible]	48.7	38.0	50.0
[illegible]	0.67	0.86	0.81
[illegible]	1680.0	2090.0	1513.0
[illegible]	1680.0	2090.0	1513.0
[illegible]	168.0	209.0	151.3
[illegible]	5.63	4.71	3.66
[illegible]	8.62	8.89	6.79
[illegible]	0.825	0.825	0.834

GAS

[illegible]	[illegible]	17.65	22.57
[illegible]	[illegible]	96.87	84.84
[illegible]	[illegible]	83.07	77.04
[illegible]	[illegible]	84.30	80.56
[illegible]	[illegible]	0.06893	0.07061
[illegible]	[illegible]	0.3244	0.3227
[illegible]	[illegible]	7.52	10.60
[illegible]	[illegible]	41210.0	37934.0
[illegible]	[illegible]	32950.0	27400.0
[illegible]	[illegible]	37950.0	23870.0
[illegible]	[illegible]	36700.0	25870.0
[illegible]	[illegible]	3670.0	2387.0
[illegible]	129.7	121.0	119.2

GAS ANALYSIS BY VOLUME

Carbon dioxide, CO_2	11.80	12.04	13.2
[illegible]	13.65	12.79	11.4
[illegible]	0.08	0.40	0.2
[illegible]	13.20	12.76	13.4
[illegible]	0.80	0.17	0.4
[illegible]	60.10	57.34	61.0

GAS ANALYSIS BY WEIGHT

Carbon dioxide, CO_2	19.67	20.30	22.15
Carbon monoxide, CO	16.62	15.62	11.73
Oxygen, O	0.78	1.10	0.69
Hydrogen, H	1.01	1.16	1.01
Marsh gas, CH_4	0.59	0.11	0.24
Nitrogen, N, by difference	63.73	63.73	64.19

EFFICIENCY

Grate efficiency, per cent	78.77	82.65	67.00
[illegible]	92.20	82.10	58.80
[illegible]	69.58	58.24	46.80
[illegible]	64.70	53.27	62.75

EFFICIENCY BASED ON 100 PER CENT GRATE EFFICIENCY

[illegible]	[illegible]	[illegible]	[illegible]

COST OF GASIFICATION

[illegible]	$7.25	$7.25	$4.28
[illegible]	3.78	6.325	5.91
[illegible]	1.90	2.06	1.495

FIRING

Method of firing	Hand	Hand	Hand
Frequency of firing		Hour	
Average intervals between firings	2 hrs. 50 min.	2 hrs. 40 min.	2 hrs. 20 min.

HEAT BALANCE

DEBIT

[illegible]	13040.0	13010.0	12359.0
[illegible]	8.0	10.6	9.4
[illegible]	1.0	0.8	0.6
[illegible]	—	0.2	0.2
[illegible]	1.0	2.2	2.6
[illegible]	8.0	3.7	10.2

CREDIT

[illegible]	1603	10.87	1567	12.1	1242	10.1
[illegible]	1310	8.87	1550	11.9	1770	14.3
[illegible]	9090	61.50	7685	59.0	5276	42.7
[illegible]	2770	18.76	2220	17.0	4059	32.9
[illegible]	105.0		121.0		119.6	
Radiation and conduction, by difference	−1850.0		−96.0		−110.6	
Total						

CHAPTER 7.

Results of Tests.

28.- Numerical Values.-- The numerical values of the various computations are tabulated as items on the accompanying form. The results are arranged in ascending order of fuel sizes and not in the oreder of tests as carried out.

29.- Curves.-- From the results obtained curves were plotted, using as abscissae the average fuel size expressed in fractions of an inch. The values used as ordinates for the respective curves were, cold gas efficiency based on the high heating value of the gas and 100% grate efficiency, cold gas efficiency based on the low heating value of the gas and 100% grate efficiency, cold gas efficiency based on the high heating value of the gas and normal grate efficiency, water decomposed per pound of dry coal, weight of gas per pound of dry coal, H_2 by volume in gas, and CO_2 by volume in gas. Another curve was drawn having pounds of gas per pound of dry coal as abscissae and high heating value per cubic foot of gas from analysis as ordinates.

CHAPTER 8.

Conclusions.

From the data available from this series of tests the following conclusions may be drawn:-

30.- One.-- The cold gas efficiency, based on the high heating value and the operating grate efficiency, varies almost inversely as the size of the fuel. This is accounted for by the varying areas of incandescent fuel in contact with the gases, and also by the fact that the length of gas passages thru the fuel bed increases as the size of the fuel decreases, thus increasing the time of contact of the gas with the fuel. Thus in the case of the finest fuel used the gas is the richest and the efficiency of the producer is correspondingly high.

31.- Two.-- The percentage of CO_2 increases with the size of the fuel. The efficiency varies correspondingly, provided the hydrogen content remains constant. This might have been presupposed from an analysis of the conditions for the different fuels, as outlined in conclusion one. In some plants, apparatus is kept on hand for the occassional CO_2 sampling of the gas during the day, in order to determine how the producer is operating. This may, or may not be an indicator of the working efficiency of the producer, as the above shows.

32.- Three.-- The weight of water decomposed per pound of dry coal varies almost inversely as the size of the fuel. This could be true only if the proportion of hydrogen remained practically the same for each test. Plate F shows that this condition was fulfilled, therefore, since the weight of gas per pound of coal varies almost inversely as the size of the fuel, the above conclusion may be drawn.

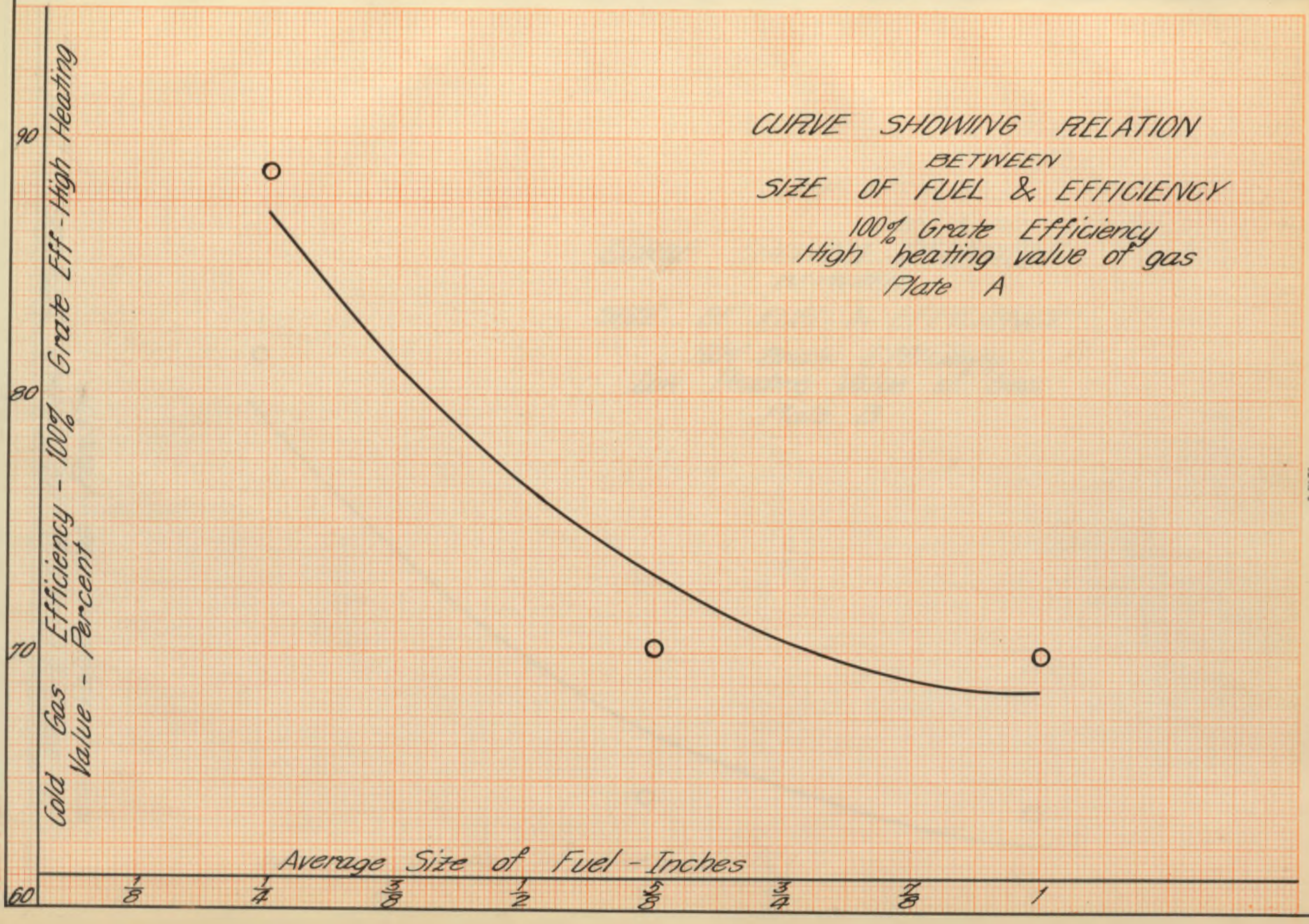
33.- Four.-- It is interesting to note that if the curves with the varying sizes of fuel as abscissae, and the cold gas efficiency, pounds of water decomposed per pound of coal, and weight of gas per pound of coal, as ordinates, are superimposed one upon the other, their relative axes corresponding, the three curves, each very nearly a straight line, will lie almost parallel.

34.- Five.-- The heating value per cubic foot of the gas decreases with an increase in the size of the fuel. This is due to a lower per cent of CO when the larger sizes are employed without a proportionate increase in the hydrogen content.

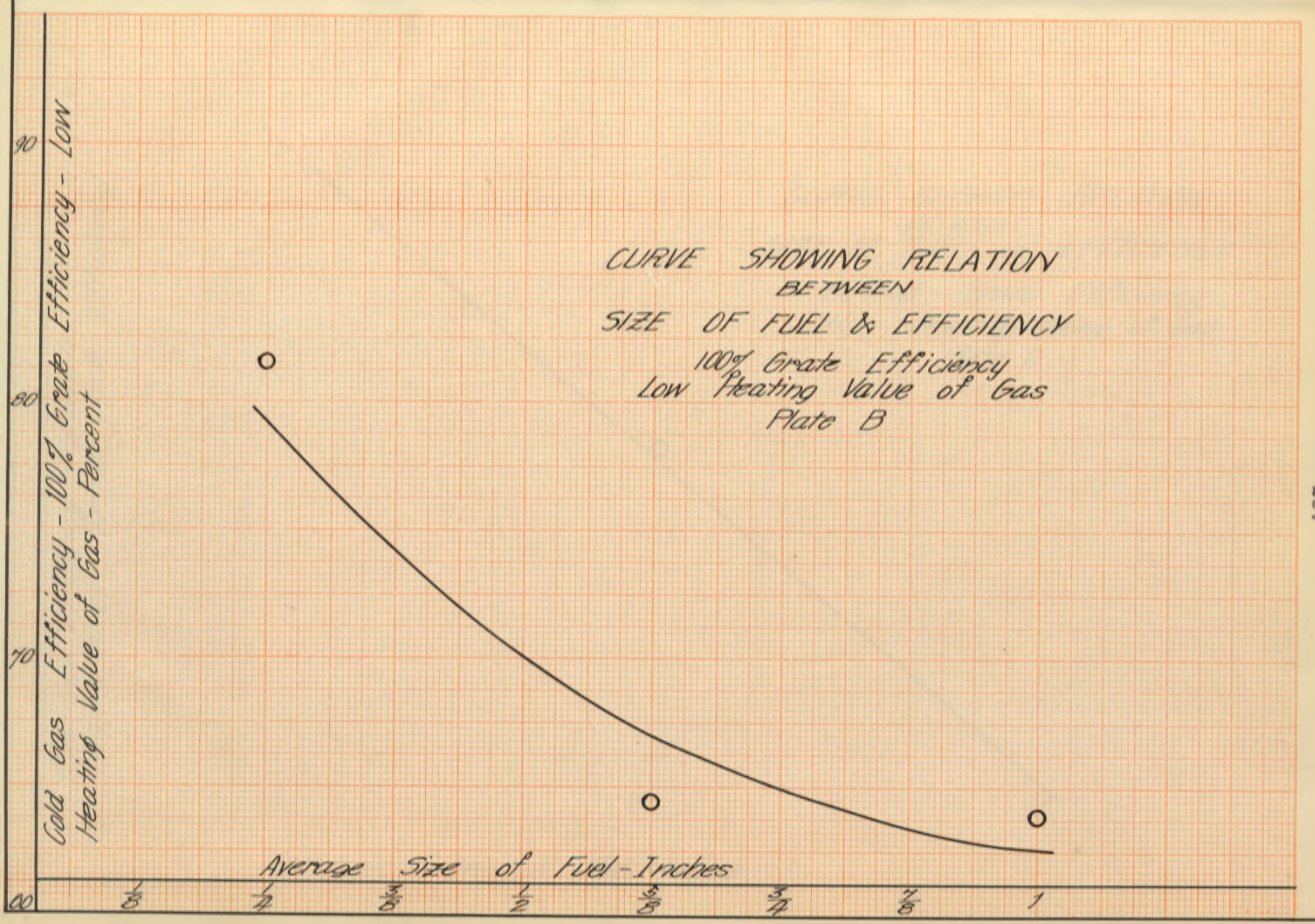
The result of a constant decomposition of water is shown by an increase in the temperature of the gas and a decrease in the amount of CO generated. This increase in the sensible heat of the gas decreases the cold gas efficiency of the plant

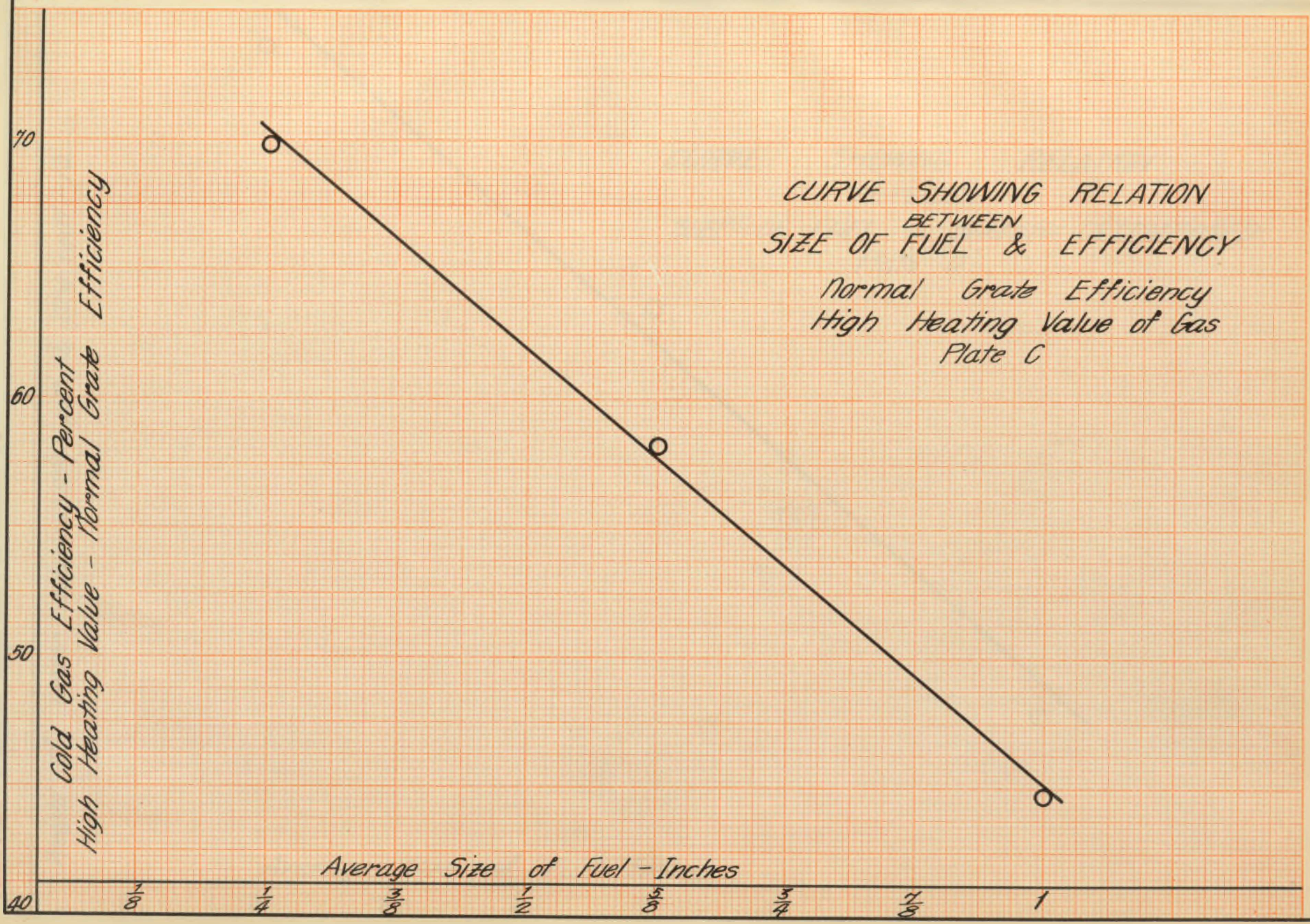
35.- Six.-- In these tests the difference in the coal analyses was not great enough to appreciably effect the results, or warrant any doubt as to the relative value of the tests. A decrease in the quality of the coal would possibly tend to lower the points on the curve, although this would probably be due to increased difficulties of operation, resulting from an increased tendency on the part of the poorer fuels to clinker.

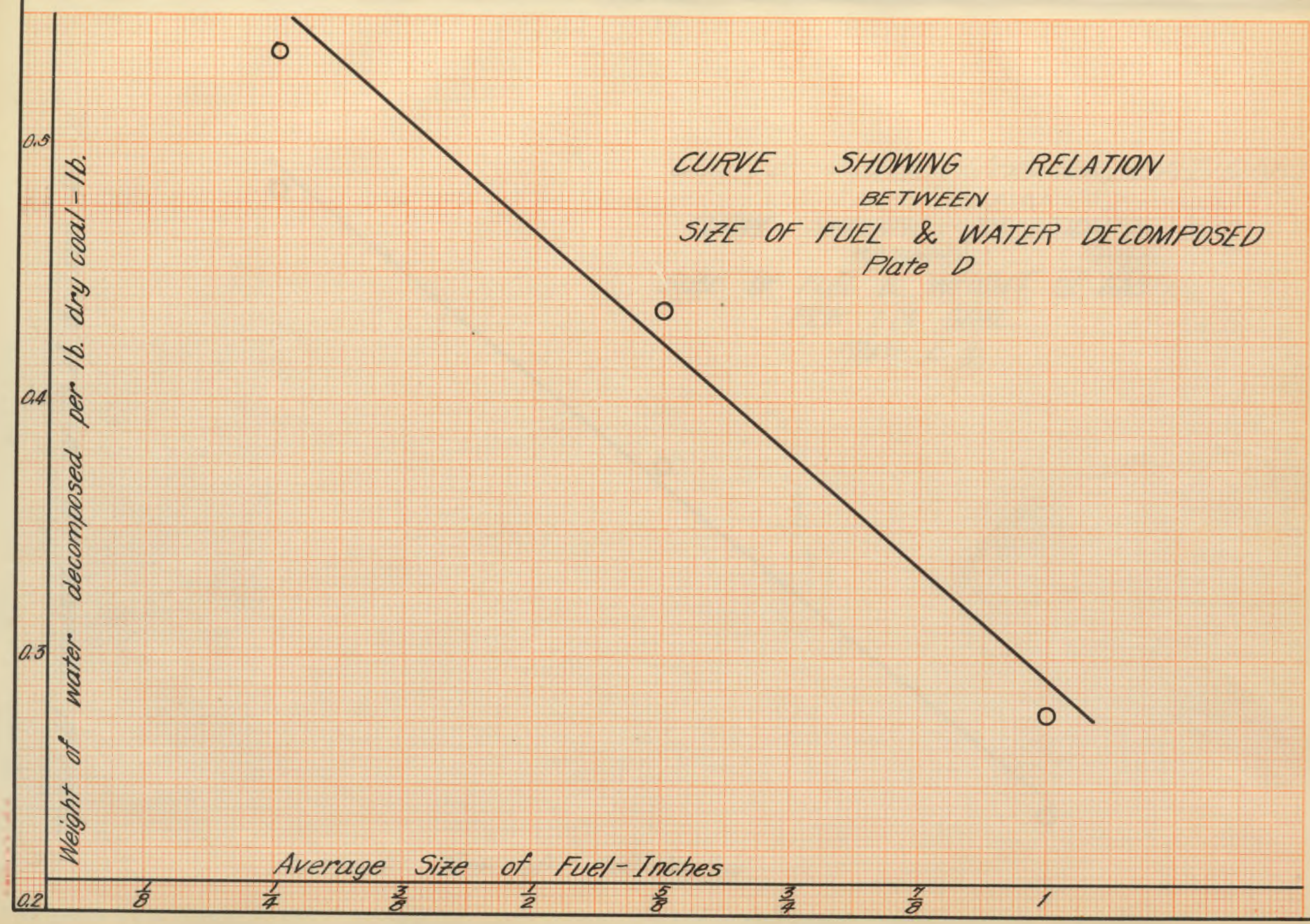
36.- Seven.-- With the larger sizes of fuel the large amount of CO_2 formed necessitates no little attention upon the part of the operator, in order to keep the temperature in the producer within the most economical operating limits. This difficulty is not so pronounced with the medium sizes, and is still less pronounced when the smaller sizes are employed. However, in the latter case there is a tendency for the fine particles of fuel to be carried over with the gas, clogging up the scrubbing apparatus, thus reducing the draft thru the fuel bed and decreasing the gas supply.

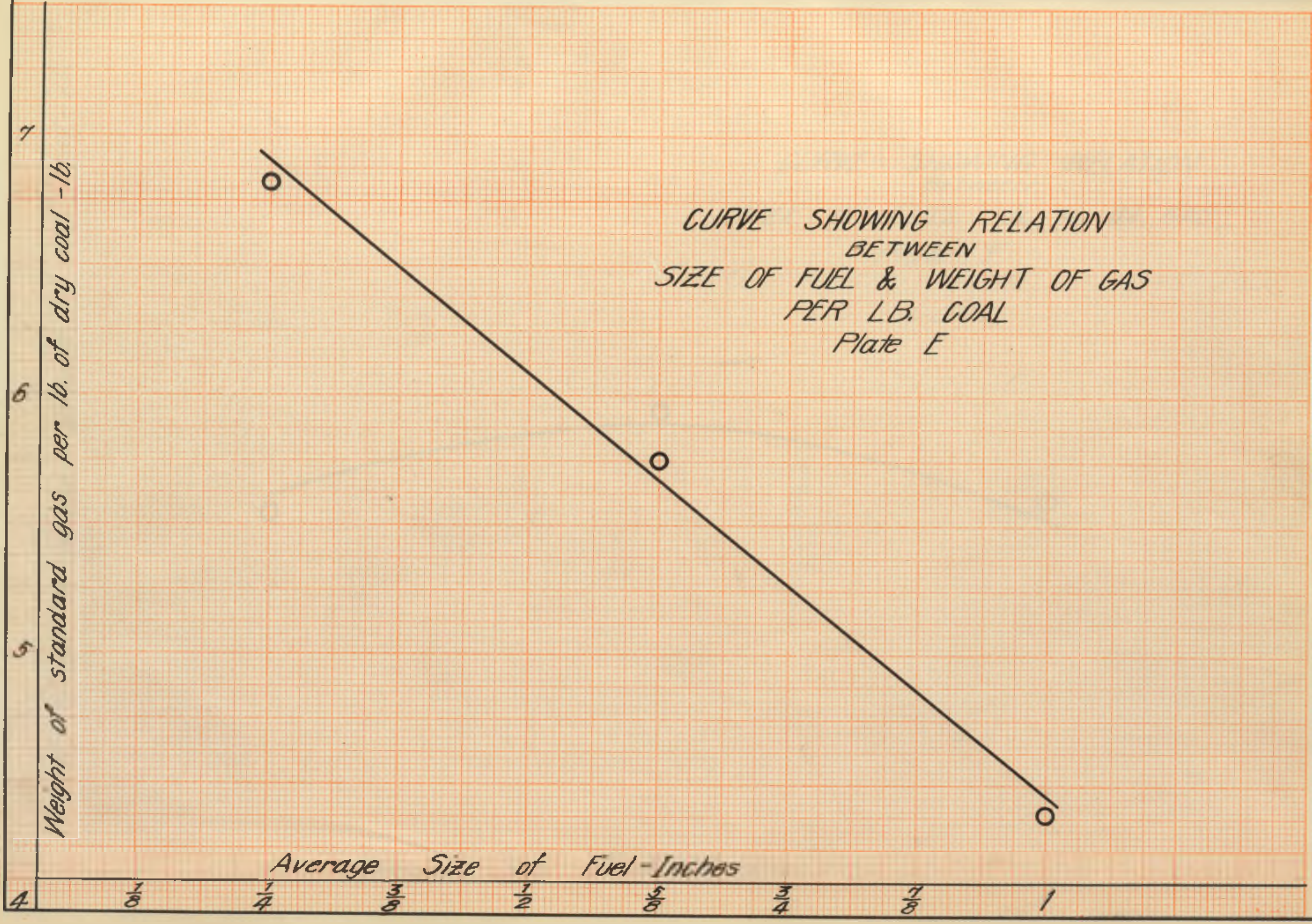


CURVE SHOWING RELATION
BETWEEN
SIZE OF FUEL & EFFICIENCY
100% Grate Efficiency
High heating value of gas
Plate A
Cold Gas Efficiency - 100% Grate Eff - High Heating Value - Percent
Average Size of Fuel - Inches
90
80
70
60
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1

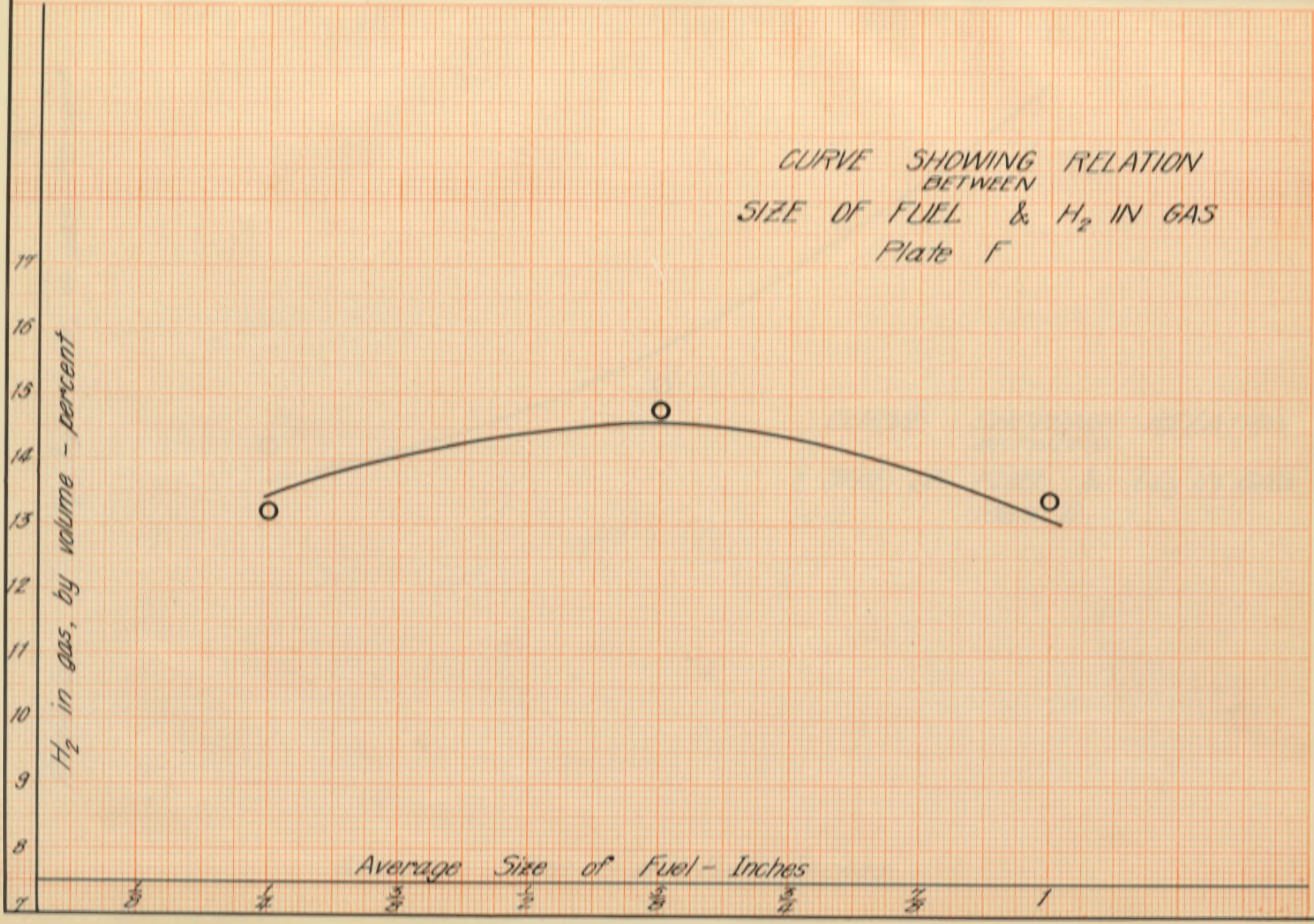

CURVE SHOWING RELATION
BETWEEN
SIZE OF FUEL & EFFICIENCY
100% Grate Efficiency
Low Heating Value of Gas
Plate B
Cold Gas Efficiency - 100% Grate Efficiency - Low
Heating Value of Gas - Percent
90
80
70
60
Average Size of Fuel - Inches
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1

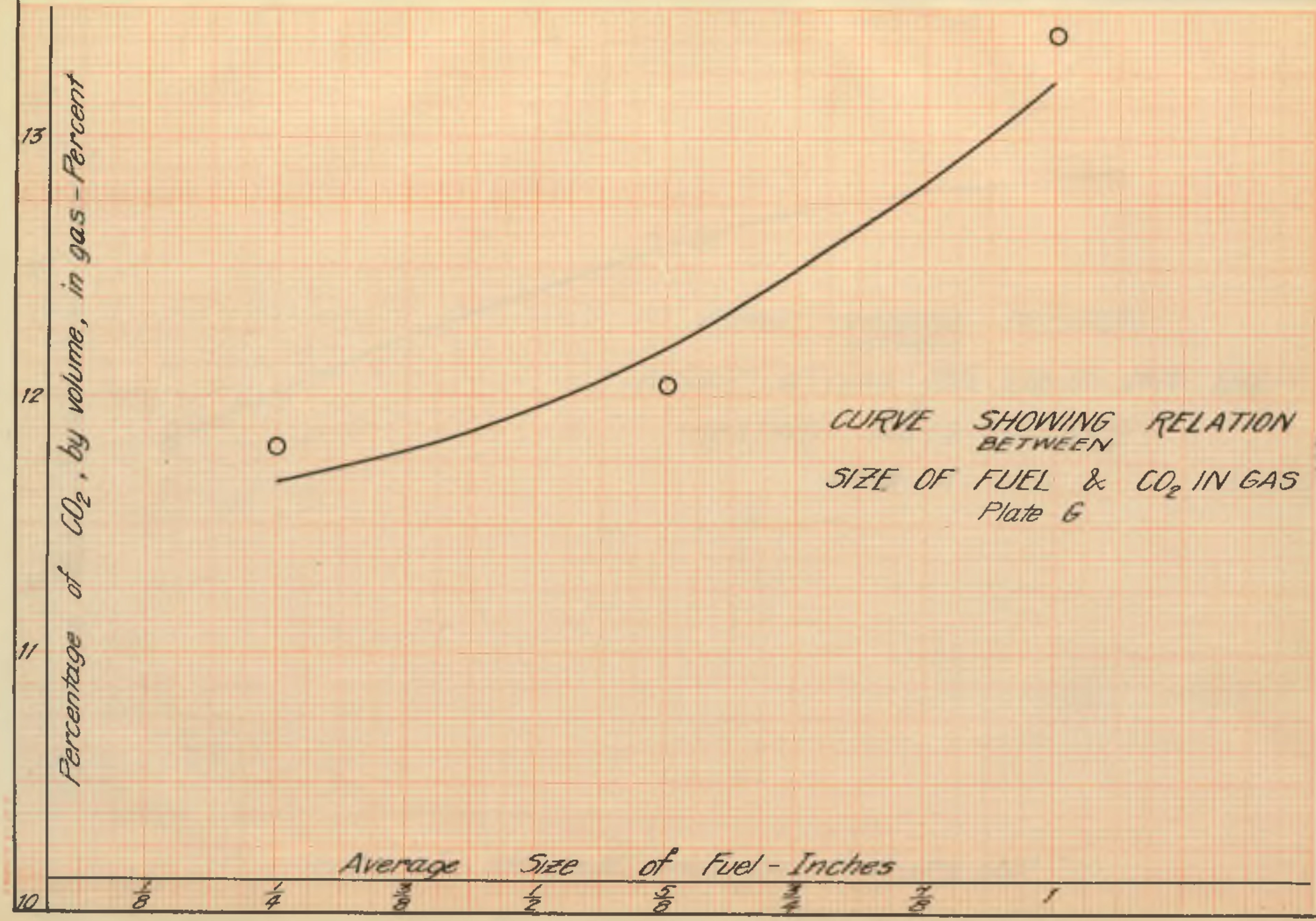

CURVE SHOWING RELATION
BETWEEN
SIZE OF FUEL & EFFICIENCY
Normal Grate Efficiency
High Heating Value of Gas
Plate C
Cold Gas Efficiency - Percent
High Heating Value - Normal Grate Efficiency
70
60
50
40
Average Size of Fuel - Inches
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1

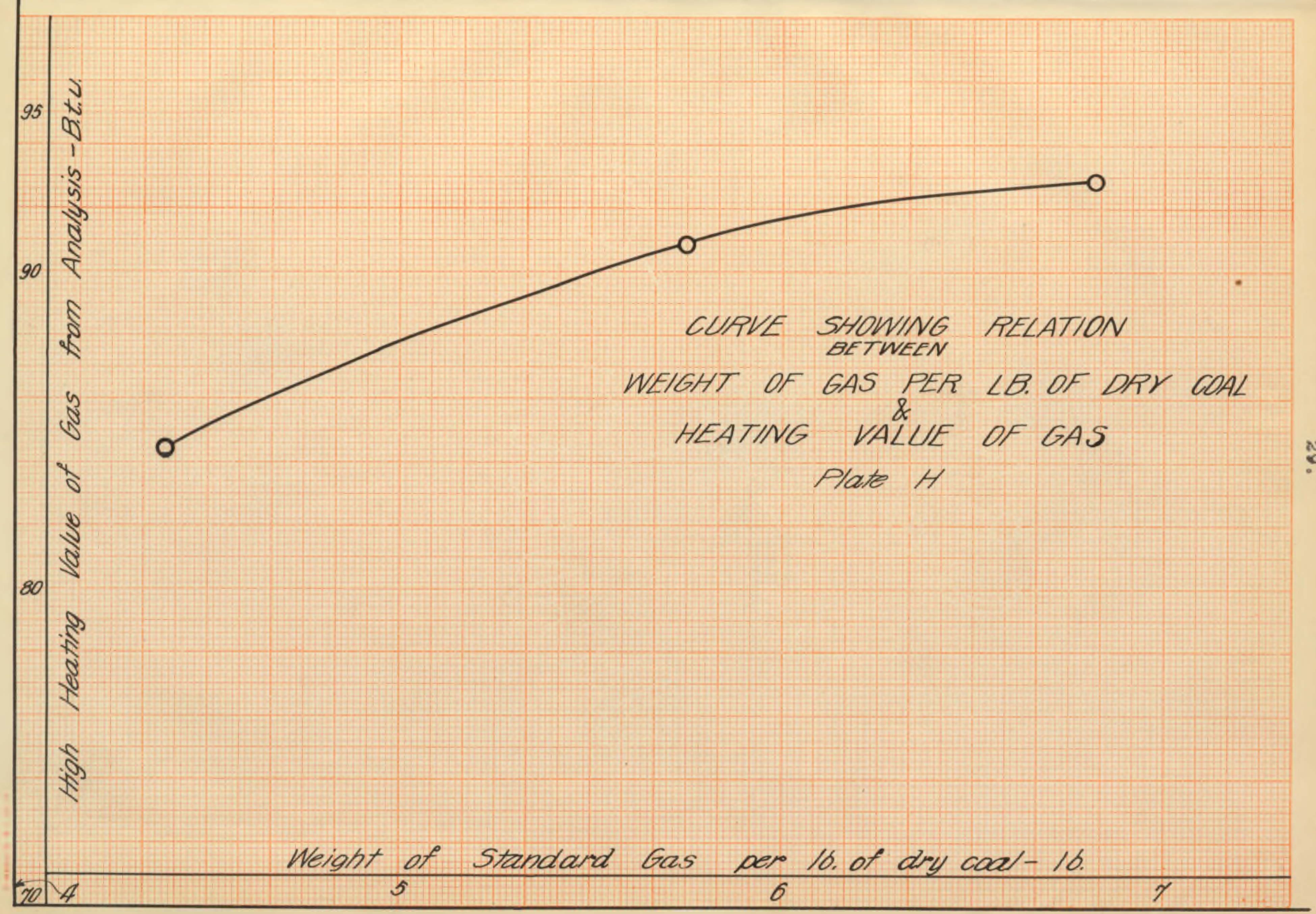

CURVE SHOWING RELATION
BETWEEN
SIZE OF FUEL & WATER DECOMPOSED
Plate D
Weight of water decomposed per lb. dry coal - lb.
0.5
0.4
0.3
0.2
Average Size of Fuel - Inches
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1



CURVE SHOWING RELATION
BETWEEN
SIZE OF FUEL & WEIGHT OF GAS
PER LB. COAL
Plate E
Weight of standard gas per lb. of dry coal - lb.
7
6
5
4
Average Size of Fuel - Inches
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1


CURVE SHOWING RELATION
BETWEEN
SIZE OF FUEL & H_2 IN GAS
Plate F
H_2 in gas, by volume - percent
7
8
9
10
11
12
13
14
15
16
17
Average Size of Fuel - Inches
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1


CURVE SHOWING RELATION BETWEEN
SIZE OF FUEL & CO_2 IN GAS
Plate 6
Percentage of CO_2, by volume, in gas - Percent
Average Size of Fuel - Inches
10
11
12
13
1/8
1/4
3/8
1/2
5/8
3/4
7/8
1



CURVE SHOWING RELATION BETWEEN WEIGHT OF GAS PER LB. OF DRY COAL & HEATING VALUE OF GAS
Plate H
High Heating Value of Gas from Analysis - B.t.u.
95
90
80
70
Weight of Standard Gas per lb. of dry coal - lb.
4
5
6
7