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OPERATING DETAILS OF GAS PRODUCERS

BY

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OPERATING DETAILS OF PRODUCER-GAS INSTALLATIONS.

By R. H. Fernald.

INTRODUCTION.

In 1900, as far as available records show, there were only two producer-gas power installations in the United States.

In June, 1915, the number probably exceeded 1,000. Of this number, some 84.5 per cent comprised small plants using anthracite, and only about 15 per cent of the total number utilized bituminous coal and lignite. In addition to these, two plants used wood, and three or four used oil.

In the main, however, the larger sized units are operating on bituminous coal and lignite.

During the early years of these plants little success was anticipated from the use of bituminous coals and lignites, but in 1904 and 1905 it was fully demonstrated at the Government testing station at St. Louis that these fuels could be utilized to excellent advantage. However, although many producer-gas plants in daily operation are using bituminous coal and lignite, many power-plant men are still skeptical regarding the successful commercial use of these fuels.

PRESENT STATUS OF PRODUCER-GAS PLANTS.

In this connection the author can offer no clearer idea of the present status of the producer-gas power plant than is presented in his letter of March 4, 1915, to the prime movers committee of the National Electric Light Association in response to general queries from the committee. The text of the letter follows:

In response to your request for a brief summary of the producer-gas situation, I take pleasure in submitting herewith a brief outline of some of the more important phases of this development and in answering the queries that you have put to me.

1. *General classification of gas producers.*—Producers for power purposes can be broadly classified as (*a*) up-draft, (*b*) down-draft, (*c*) double-zone.

In the up-draft plant the pressure in the gas generator may be greater or less than that of the atmosphere. If it is greater than that of the atmosphere, the plant is known as an up-draft pressure plant. If it is less than that of the atmosphere, the plant is commonly called an up-draft suction plant, although this reduction of pressure in the gas generator of the larger plants is now usually produced by means of an exhauster instead of by the suction stroke of the engine.

2. *Producers for anthracite coal.*—Little difficulty has been experienced in handling good grades of anthracite coal in gas producers. Occasionally some trouble is experienced owing to the character of the ash or to a low ash-fusing temperature. In the main, however, this fuel has been found satisfactory. For most sections of the country the price of anthracite is relatively too high to warrant its use in plants of large capacity. It is, therefore, largely utilized in plants not exceeding 500 horsepower. As far as I know little has been done in this country with gas producers for the utilization of anthracite screenings or material from the culm pile.

Anthracite coal may be utilized to good advantage in plants of either the up-draft or the down-draft type. Inasmuch as it is comparatively free from tar, anthracite is commonly used in the up-draft producer of either the suction or the pressure type. A single installation of 4,000 horsepower of down-draft producers is using anthracite at $11.30 a ton in preference to bituminous coal for which the plant was designed. Although the company owns bituminous mines, it places a value of $8 a ton on its books for the bituminous coal. On this basis of $8 a ton for the bituminous coal and $11.30 a ton for the anthracite, a year's operation shows financially in favor of the anthracite. Outside of two or three installations, the individual anthracite plants of this country do not exceed a few hundred horsepower.

3. *Bituminous coal.*—Satisfactory gas producers have been designed for the use of both bituminous coals and lignites of good quality. There is comparatively little difficulty in handling on a commercial scale such plants, provided the fuel is low in ash, has a fairly high ash-fusing temperature, and does not give serious trouble from caking and clinkering. Unfortunately these restrictions are too exacting to fit our common practice in the United States with low-priced fuel. The European situation, where they are able to specify rather definitely the characteristics of the coal, is very different.

My answer, therefore, to your query as to whether producers have been successfully designed for the use of bituminous coals and lignites is "yes" for bituminous coals and lignites of high grades.

I do not say "no" for other grades of bituminous coals and lignites, but I realize that low-grade fuel, high in ash and prone to clinker troubles, is not regarded in the majority of cases as worth the time and effort required. Bituminous coals and lignites of good grade may be successfully used in the up-draft producer if adequate equipment is installed for scrubbing the gas and removing the tar, in the down-draft producer of the continuous type, and in the double-zone producer.

The largest single generator in the United States with which I am familiar is one of 250 square feet of fuel-bed area, burning between 3,000 to 4,000[a] pounds of Illinois bituminous coal per hour. I see no reason why single-shell producers of this type should not be built four times this capacity.

4. My estimate of the horsepower capacity of gas producers installed in the United States for power purposes is as follows:

For anthracite coal:	
Plants of more than 500 horsepower rating, horsepower	40,000
Plants of less than 500 horsepower rating, horsepower	95,000
For bituminous coal, horsepower	130,000
For lignite, horsepower	15,000

My estimate of the annual fuel consumption of these plants is, roughly:

Anthracite coal, short tons	240,000
Bituminous coal, short tons	400,000
Lignite coal, short tons	60,000

[a] These figures were reported at the time of making the installations. The latest reports (June, 1915) give the fuel-bed area as 210 square feet and the average fuel consumption as 2,750 pounds per hour.

5. In response to your query regarding the slow progress in the development of the bituminous-coal producer, I name the following as among the reasons that immediately suggest themselves:

(*a*) The low price of our fuels. The time has seemingly not yet arrived when there is sufficient demand for reduced operating costs to warrant the investment necessary for the production of producer-gas units of sufficient size to seriously compete with the efficient steam-turbine units of the present day.

(*b*) As a corollary to *a*, the cost of the labor involved and the reduced capacity limit producers to the utilization of fuels of good grade. As soon as the cost of fuel is sufficiently high to warrant the use of high ash, low-grade material the design of a producer for this purpose will be speedily forthcoming.

(*c*) Additional difficulties are satisfactory gas cleaning, tar removal or recovery, elimination of sulphur, and the prevention of serious clinkering. All of these difficulties can, I believe, be obviated.

(*d*) The fact that, up to the present time, no gas engine has been developed of sufficient size to enter into serious competition with the recent steam-turbine units of 30,000 kilowatt and 35,000 kilowatt capacity.

PRODUCER-GAS PLANTS IN EUROPE.

In considering the many phases of this problem you will, I believe, be interested to know the trend of European producer-gas practice to-day. I therefore append a few notes gleaned from my inspection last summer in the interest of the United States Bureau of Mines.

We find in Europe a demand for a gas producer to handle all grades of fuel, especially those grades usually sent to the dump. This demand has brought to the European market the revolving, eccentric-grate producer. Among the most important advantages claimed for these producers is automatic ash removal. Dependent on this primary advantage rest the following claims for the revolving grate:

1. Low labor cost for handling ashes.
2. More uniform and more complete combustion.
3. Operation for months without interruption.
4. Ability to handle much more fuel per square foot of fuel-bed area.
5. Less space per 1,000 cubic feet of gas produced or per horsepower of plant.
6. Freedom from dust and the usual excessive heat and dirt during removal of ashes.
7. Production of a gas of nearly uniform quality.
8. Reduction in the cost of upkeep.

If in addition to rotating the grate the grate be placed slightly off center, a feature is introduced that is probably of far greater value in handling high-ash, clinkering fuels than the mere rotation of the grate.

Experience with European fuels has shown that even with the eccentric revolving grate and the usual producer shell construction clinker troubles are not entirely eliminated when poor-grade fuel with low ash-fusing temperature is used. A further important feature—probably the most important single item—for overcoming clinkering and the tendency of the ash to fuse with the producer lining is the water jacketing of the part of the producer shell surrounding the hot zone.

These revolving grate producers are reported to gasify two to three times as much fuel per square foot of fuel-bed arèa per hour as can be gasified in corresponding updraft producers with fixed grates.

Claims of very low percentages of carbon in the ash are also made for this type of producer, the reported record for one installation being 5 per cent carbon, or 0.47 per cent of the fuel gasified.

The claims advanced regarding the steam requirements for clinkering coals used in producers with water jackets around the hot zone are to the effect that not over one-quarter as much steam is required as in the jacketless type with fixed grate. The figures given for comparison are 1 pound of steam per pound of fuel for the fixed-grate jacketless producer and 0.29 pound for the revolving eccentric-grate producer. Results with United States coals in fixed-grate jacketless producers indicate that 1 pound of steam per pound of coal is rather high for plants of good size. Seven-tenths of a pound is nearer the figure, although there are undoubtedly many plants, indifferently operated, that are not below the 1-pound rate.

Representatives of companies handling eccentric revolving-grate producers say that they handle coal containing 45 to 55 per cent ash with perfect ease and are satisfied that these producers can meet the conditions required for American high-ash caking coals.

In Europe we also find a great deal of attention given to the by-product gas plant. These plants are not of a few horsepower capacity, but the installations range from 5,000 to 30,000 horsepower. One company alone reports the installation of by-product recovery producer-gas plants using a total of 3,000 tons of fuel per day and aggregating approximately 300,000 horsepower. The capacity and purpose of a few of the larger installations are as follows:

Capacity and purpose of a few of the larger European producer-gas plants.

Installation No.	Fuel capacity per day.	Purpose of plant.	Installation No.	Fuel capacity per day.	Purpose of plant.
	Tons.			*Tons.*	
1	320	Recovery of by-products from waste fuels. Gas used for firing boilers and for power.	5	135	Power, forge, and plate furnaces, fire-clay kilns, etc.
			6	125	Power and firing caustic pots.
2	270	Central distributing station.	7	120	Evaporating brine
3	250	Power and chemical purposes, calcining ore, etc.	8	120	Power and chemical furnaces.
			9	100	Firing chrome furnaces.
4	150	Special plant for the recovery of by-products. Gas used for firing colliery boilers.	10	100	Chemical furnaces.

The majority of these plants are used for power development and gas heating; the recovery of by-products, such as sulphate of ammonia, tar, etc., are secondary factors in the operation of the plant. On the other hand, there are several installations in which power is the secondary factor, the plant being run primarily for the valuable by-product, sulphate of ammonia, which brings a commercial return of $50 to $60 a ton.

A few plants are operated for the by-products alone. In certain districts in which the manufacturing and industrial interests do not offer a market for the gas the so-called "by-products" become the main products and the true by-product, producer gas, is thrown away. This condition of affairs is peculiarly true in regions in which the fuel runs high in nitrogen. It is reported that an extensive plant of this character is soon to be erected in Africa.

Peat seems to be peculiarly adapted to the requirements for the production of sulphate of ammonia, and several commercial by-product plants using this fuel are now in operation in Europe. Among these are two plants in Italy using, respectively, 140 and 90 tons of peat per day.

One of the most interesting plants visited last summer was a by-product coke plant, in which the coke-oven gas was the main product and the coke the by-product, combined with a by-product producer-gas plant. The coke-oven gas was turned into the city mains for general use. In order to obtain all this gas for sale to the city, a distinct central producer-gas plant was installed, as the poorer grade gas, which was not available for general city use, was entirely satisfactory for heating the coke ovens. The originator of this combined method says: "The great advantage of this system is the fact that coke breeze and low-grade fuel generally can be used in the producers without lowering the efficiency of the plant." The producer plant consists of five units, each of 20 tons capacity a day. The coke from the ovens, which is regarded as a by-product, finds a ready market for blast-furnace work, and it is estimated that the by-products from the producer plant, sulphate of ammonia and pitch, practically pay the cost of operation of the producer-gas installation. The coal used in the producers is double-screened nut and contains no dust. It is a fine-looking coal and is reported to be high in oils.

The several companies manufacturing by-product gas plants believe that there is a large field for such plants in the United States if the fuels used be carefully selected. They regard our caking coals as bad for this type of plant.

SLAGGING GAS PRODUCER.

The blast-furnace type or slagging gas producer has appeared at regular intervals in Europe and investigations along this line have also been conducted in this country both by commercial interests and the United States Bureau of Mines. In spite of the many claims that no such producer can operate with any commercial success, we find at a colliery in Deutsch-Luxemburg a wonderfully interesting installation consisting of four slagging producers. These producers are approximately 10 feet in internal diameter and gasify 60 tons of fuel each per 24-hour day. The first of these producers was installed about two years ago and required much study and many changes. At the present time [March 4, 1915] these producers are working on 10 per cent ash fuel, but the company anticipates utilizing material containing 20 to 30 per cent ash. Several different companies are reported to be using these slagging producers, and the fact that this type of producer has a real commercial position is shown by the catalogue of one of the large producer manufacturers of Germany, which, among several other classifications, lists its producers as—

(1) Producers with rotating grates.
(2) Slagging producers.
(3) Flat-grate producers.
(4) Step-grate producers.

Considerable interest is also manifested abroad in the use of wood refuse and similar material in gas producers. At the present time, however, these plants are of small size.

The interest of engineers in Europe is also more or less centered on the possibilities of powdered fuel and questions relating to low-temperature distillation. The principal purpose of this latter problem is to procure a clean smokeless fuel for the unlimited number of fireplaces and at the same time to recover from the original fuel large percentages of oils, motor spirits, and ammonia.

In conclusion, I believe that the time is not distant when the price of our coals must necessarily materially increase. When this time does come we will look much more seriously on the important problems connected with our fuel conservation. We will find it imperative to use high-ash low-grade fuels which, in many cases, will have a low ash fusing temperature. Transportation of this high ash material will be out of the question and its conversion into gas at the mines will result. Even though large gas engines are not forthcoming, the economic use of grades of material that can not be utilized directly under steam boilers will warrant large installations for the production of producer gas and its use for steam generation for large turbo-generator units with long-distance electric transmission.

PRODUCER-GAS PLANT COMPARED WITH STEAM TURBINE.

The steam turbine naturally lent itself to central-station service. It was a unit easily understood by steam-engine operators in so far as practical operation is concerned; it could be readily erected without radical changes in the boiler-room equipment; and it rapidly met the demand for large central-station units.

The producer-gas plant was an untried factor; it met with strong opposition from the older steam-plant operators, who saw possibilities of being forced out of their positions; its installation meant a complete renovation of the entire plant, with the replacing of the steam boiler by the producer unit. Large units of this type did not materialize, with the natural result that even to-day the producer-gas power plant is not the large central-station unit, although it occupies a strong position among the isolated plants and the small central stations.

Methods of operation vary greatly with local conditions and especially with the personal inclination or opinion of the plant superintendent. This variation is, perhaps, perfectly natural, owing to the newness of producer-gas power, the absence of experienced producer-gas engineers, the absence of cooperation among the operators of these independent isolated plants, and the absence of well-defined commercial investigations.

With this lack of a common interest on the part of the owners or operators of these plants—an interest that has of late tended to place central-station operation on somewhat uniform basis—no standards for comparison of plant operations have appeared and little has been known by the superintendent of one plant regarding the relative efficiency of operation of his own installation and that of another plant of similar type operating under similar conditions.

Several unsuccessful attempts have been made by various organizations to collect data relating to these important matters, but unfortunately little or no information could be had.

Appreciating the value of such data in connection with the many problems of fuel conservation and its investigations into the use of producer-gas power, the Bureau of Mines decided (1) that an effort should be made to procure operating details from a small number of representative producer-gas plants using scrubbed gas either for power or heating purposes; (2) that primarily data from plants using bituminous coals and lignites should be sought, but that data from a few of the larger anthracite plants and the oil and wood plants should be included.

With these points in mind, data sheets were sent to the owners of a limited number of plants, and for the most part the response has been highly gratifying. Returns of a positive character were received from 39 installations.

Although, as might be expected, a great deal of indefiniteness exists regarding many of the operating details, and few, if any, cost data are available, it is believed that in the following pages sufficient detailed information is presented to provoke wholesome discussion on the part of those interested in this form of power; to stimulate responses to future requests from the Bureau of Mines, and to serve as a basis for comparison by the different operators of similar plants.

CHARACTER OF FUEL USED IN GAS PRODUCERS.

Owing to the agitation of the Bureau of Mines for several years past concerning the use of high-ash and low-grade fuels, it was hoped that several producer-gas installations would report the use of grades of fuel hitherto regarded as of little commercial value. However, an inspection of several plants in 1913 showed rather conclusively that on the whole the grade of fuel used in producer-gas installations has been steadily rising, and, in the main, the fuel used to-day is decidedly superior to that used six or eight years ago.

Although from the standpoint of the engineers of the Bureau of Mines this condition is to be regretted, it is perhaps perfectly natural, as the tendency of the operators of such plants is to reduce manual labor to a minimum. A feeling of assurance by the management of guaranteed reliability of service is also commercially important in determining the quality of fuel to be used. It is not strange, then, that the highest grade fuel obtainable at a reasonable price is, in nearly every instance, the one adopted.

A rather poor grade of bituminous coal was originally used in a plant of considerable size, but owing to the amount of labor required in operating, the purchasing agent was finally persuaded by the plant superintendent to substitute a high-grade coal at a much higher price per ton.

Such excellent results were at once obtained and the labor cost was so materially reduced that the purchasing agent, who had formerly believed in purchasing the cheapest coal to be had, immediately substituted the high-grade coal throughout the boiler plant as well as the producer plant. The superintendent felt that the greatest service the producer plant had rendered was in improving the grade of fuel used in the steam plant. He stated that he realized that his company was not working toward fuel conservation, but he felt that reliability of service was the uppermost requirement in his plant. He said that he would be glad to use a lower grade fuel at a less cost per ton if he could be shown plants with similar exacting commercial requirements successfully operating on such fuel.

Such comments are, for the most part, typical of the present situation. It is, however, gratifying to note here and there exceptions to this tendency. One notable example may be seen in Texas in a plant that uses lignite screenings as the regular fuel for the gas producers. The manager finds these screenings, costing much less than run-of-mine lignite, an excellent producer fuel. He has given a standing order for this material, but has considerable difficulty in procuring enough of it.

As far as is reported, no other operator in that vicinity feels any assurance of success with such screenings as they are generally regarded as inferior fuel.

The high character of the fuels generally used for producer-gas installations is made apparent by the data in the table following.

Grade of fuel used in different types of gas producers.

PRODUCERS USING BITUMINOUS COAL.

Plant No.	Ash.	Sulphur.	Heating value per pound as fired.
	Per cent.	*Per cent.*	*B. t. u.*
24	3.7	0.5	11,540
8	6.9	1.6	12,270
12	7.4	.5	12,296
17	10.1	3.4	12,522
23	6.7	2.2	13,741
28	....	....	13,750
37	....	....	14,000
33	7.0	1.5	14,370
39	5.0	.9	14,500
27	7.9	1.2	14,535
22	4.8	.5	14,769
3	7.3	.8	14,800
35	5.5	1.0	14,834
25	7.0	2.0	....
20	4.7	1.0	....

PRODUCERS USING LIGNITE.

11	7.9	1.0	5,560
4	6.9	.6	7,440
11	8.2	.4	7,070
31	6.0	....	11,400

PRODUCER USING WOOD.

26	....	....	5,400

Most lignite contains 30 to 40 per cent water, but, as indicated above, it does not necessarily run high in ash. As regards true fuel conservation, there is seemingly little being done in the United States by the operators of producer-gas plants.

TESTS OF LOW-GRADE FUEL.

It is, perhaps, important again to emphasize the possibilities from high-ash coals. Although it is fully appreciated that commercial conditions make reliability of operation and plant capacity imperative, it is the belief of the author that many of these plants could utilize relatively cheap, poor grades of fuel with an assurance of both reliability and capacity and a net financial gain. The most difficult problem seems to be that of procuring thoroughly competent men for the careful supervision of such installations. The tabulated figures following, showing the results of Bureau of Mines tests, indicate the possibilities of using in gas producers the fuels represented.

Results of fuel tests, showing adaptability of certain fuels for use in gas producers.

Source of fuel.	Variety or size of fuel.	Ash.	Moisture.	Quantity of fuel, as fired, consumed in producer per brake horsepower-hour.
		Per cent.	*Per cent.*	*Pounds.*
New Mexico	Run of mine	19.63	3.62	1.10
Tennessee	do	20.57	3.55	1.45
Iowa		20.70	16.69	1.56
Wyoming		20.72	9.44	1.70
Do	Run of mine	21.73	8.65	1.83
Illinois	Bone	23.12	8.67	2.88
Brazil, South America	Run of mine	23.44	10.96	2.02
West Virginia	Bone	28.08	2.91	1.26
Pennsylvania	Washery refuse	30.35	2.68	2.34
Do	do	31.89	2.25	2.76
West Virginia	Bone	43.74	.47	1.65

If these figures are compared with the results on page 25, it will readily be seen that even after due allowance has been made for the difference between the operation of a testing station and that of the average commercial plant, the possibilities from these high-ash fuels warrant thoughtful consideration by the progressive managers of commercial installations.

The manager of a large steel plant in England realizes that his ability to maintain the high-grade qualities of the steel, for which his company has been so long noted, and at the same time to reduce the cost of manufacture to a point below that of his competitors depends on a reduction in the cost of generating power. He is, therefore, seriously attacking the immense refuse heaps that have been accumulating for years at the colliery connected with the steel plant. The material from these refuse heaps is passed through a crusher and then to a washer where approximately one-half of the nonconbustible material is removed. The washed fuel, containing approximately 25 per cent of noncombustible material is then utilized in rotary eccentric-grate producers, to the entire satisfaction of the company and with a reduction in the cost of the product of the plant.

In sharp contrast is a plant of several thousand horsepower previously mentioned. This plant is operated in the interests of a large corporation in the United States, which owns extensive bituminous-coal mines not distant from the plant. The operating company sends its own bituminous coal to the market and uses Pennsylvania anthracite at a cost of over $11 per ton in its producer-gas plant. Owing to the lower labor charge when anthracite is used, the records of the plant show, for periods of a year or more, that the cost of operation with bituminous coal, if charged on the books at $8 per ton, is considerably more than with anthracite coal. Although at the prices indicated, the anthracite fuel seems to give the better results, it is a question of no little importance as to whether refuse material from the company's mines might not, even with higher labor costs, prove the least expensive fuel, especially as the plant has ample spare producer capacity.

DATA ON FUEL USED AT COMMERCIAL PLANTS.

The Bureau of Mines sent form letters to numerous producer-gas plants, inquiring as to the character of fuel used, the reasons, if any, for having changed fuels, the reasons why certain plants did not use local fuels, and the necessity for a low sulphur content in the coal. The responses may be briefly summarized as follows, the numbers being those assigned to the replies as received. The figures for fixed carbon, volatile matter, moisture, sulphur, and ash are percentages:

Summary of replies to queries regarding operation of producer-gas plants.

Up-Draft Plants.

Plants using anthracite.

1. Fuel, buckwheat. Low-sulphur coal necessary, as high-sulphur coal causes back-firing.

9. Fuel, buckwheat. Pea coal has been used. Buckwheat is fully as cheap and works nearly as well. Low-sulphur coal not necessary for successful operation.

16. Fuel, buckwheat, from $\frac{3}{8}$-inch down. Analysis follows:

Fixed carbon	82.47
Volatile matter	5.29
Moisture	.....
Ash	12.29

This plant formerly used gas-house coke, but the anthracite works with greater ease, as the coke clinkered badly and gave trouble from tar in the engines.

19. Fuel, Pennsylvania No. 1 buckwheat. Low-sulphur coal regarded as necessary to prevent clinkering.

20. One 200-horsepower producer uses pea anthracite, and one 250-horsepower producer uses run-of-mine bituminous coal. The pea anthracite is used in the spare producer, the other producer having been modified for the use of coke, which is a by-product from the gas department.

36. Fuel, No. 1 buckwheat. Pea anthracite formerly used. Buckwheat costs less and seems to give about the same results.

Plants using bituminous coal.

3. Fuel, Pocohontas slack. Analysis follows:

Fixed carbon	73.60
Volatile matter	17.70
Moisture	1.45
Ash	7.25
Sulphur (separately determined)	.80
British thermal units in coal, as fired	14,800

Formerly used Alabama coal. Unsatisfactory. Too much tar. Caused preignition and variable gas quality. Peat is mined in the vicinity. Was tried, mixed with coal, and did fairly well, but gave an offensive, sickening gas. No ill effects from sulphur in coal, except possibly in causing coal-pile fires.

5. Fuel, bituminous coal from Puritan mines, Cambridge, Ohio, ¾-inch lump. Have experimented with other coals, but the above meets requirements best. Other coal is mined in the vicinity, but it is too high in sulphur. Low-sulphur coal is required, as the sulphur fumes cause distress.

12. Fuel, No. 2 washed nut bituminous coal that passes over a ¾-inch and through a 2½-inch screen. The proximate analysis is:

Fixed carbon	54.83
Volatile matter	29.91
Moisture	7.90
Ash	7.36
Sulphur (separately determined)	.48
British thermal units in coal as fired	12,296

Low-sulphur coal is regarded as essential in the operation of this plant to prevent sulphur fumes throughout the factory and a sulphur coating on the manufactured product as the gas is used for annealing.

17. Fuel, Hocking Valley coal in nut sizes passing over 1-inch and through 2-inch screens. The two grades used show—

Fixed carbon	51.67	57.60
Volatile matter	38.26	34.20
Moisture	9.24	4.99
Ash	10.07	3.21
Sulphur (separately determined)	3.42	.73
British thermal units in coal as fired	12,522	13,658

The second fuel is reported to give not enough gas and to be too high in by-products.

21. Owing to the fact that the gas is used in connection with furnaces and the products of combustion are discharged into the room, considerable irritation of the lungs and throat is experienced, which seems to cause ill health among the employees unless the percentage of sulphur in the fuel is kept low. The fuel used contains less than 1 per cent sulphur.

25. Fuel, Hocking Valley bituminous nut coal. The analysis follows:

Fixed carbon	47.01
Volatile matter	36.67
Moisture	9.30
Ash	6.97
Sulphur (separately determined)	1.98

The company used anthracite for the first two years, but on the addition of new producers changed to bituminous coal, with a saving due to the difference in price. They find that the present plant operates more easily on bituminous coal than the former producers did on anthracite.

33. The analysis of the fuel used follows:

Fixed carbon	69.2
Volatile matter	21.3
Moisture	2.5
Ash	7.0
Sulphur (separately determined)	1.5
British thermal units in coal on dry basis	14,760

37. Fuel, bituminous, Westmoreland (Pa.) run-of-mine coal, showing 14,200 British thermal units on the dry basis. Anthracite coal is mined within 50 miles, but the bituminous coal works more freely and is less expensive.

39. Fuel, New River and Pocahontas (W. Va.) coal reduced to extreme fineness before received. Typical analysis of the New River coal follows:

Fixed carbon	73.6
Volatile matter	20.4
Moisture	1.04
Ash	4.96
Sulphur (separately determined)	.91
British thermal units in coal as fired (approximately)	14,500

Considerable carbon in ash at times because of uneven burning of fuel bed. Have used Pocahontas. No difference noted in general operation between Pocahontas and New River. Some wood is available in the vicinity, but the high cost of procuring it and the uncertainty as to successful gasification in the producers installed prevent its use. No effects, ill or otherwise, have been noted from sulphur.

Plants using lignite.

4. Fuel, Texas, screened, large-lump lignite. Analysis of coal as received:

Fixed carbon	27.02
Volatile matter	36.92
Moisture	29.20
Ash	6.86
Sulphur (separately determined)	.58
British thermal units in coal as received	7,442

Obtain better gas with coal of low-sulphur content.

11. Fuel, lignite screenings from two mines, showing a proximate analysis as follows:

	Mine 1.	Mine 2.
Fixed carbon	17.50	12.13
Volatile matter	47.55	48.18
Moisture	27.21	31.81
Ash	8.21	7.88
Sulphur (separately determined)	.44	1.03
British thermal units in coal as fired	7,073	5,561
British thermal units in coal on dry basis	9,717	8,153
British thermal units in coal combustible	10,952	9,217

Formerly this plant used lignite lump, but the cheaper grade gives satisfactory results. This cheaper fuel is regarded by the mine operators as of lower grade than the lignite lump. It is lower in heat value and is also of a grade not usually marketable. It works with slightly less ease than the lump lignite, but as it costs less and is really worked with little difficulty it is regarded as a very satisfactory fuel. This lignite is mined in the vicinity of the plant. Low-sulphur fuel is not regarded as essential for successful operation.

38. Fuel, lignite, pea-screenings, near Centralia, Wash. Several other Washington lignites have been tried, but all cost more and were no better or not so good on account of hotter fire and more clinker. The present fuel is of lower grade and highest in ash but works better.

Plants using wood.

13. Fuel, waste hardwood in lengths of 1 foot or less, and about 1 to 3 inches in diameter, together with some bark and sawdust. This hardwood runs about 35 to 60 per cent moisture as used. During the early operation of the plant sticks 1½ to 3 feet long were used, but some difficulty was experienced with arching of the fuel bed and the formation of pockets that burned out the gas.

26. Fuel, cypress refuse from the hog machine. Brought about 1 mile from the mill. Chips and sawdust also used. The wood as fired yielded 5,400 British thermal units, and on dry basis 10,000 British thermal units. Other fuels tried in this plant are: Anthracite, bituminous coal, coke breeze, and pine hog. Coal or coke was found inferior to the wood refuse, as the cypress hog gives a more constant quality of good gas. It works with greater ease and costs less than the other fuels. Low sulphur content is regarded as important because of the deleterious action of H_2SO_4 on the producer plant and engine.

DOWN-DRAFT PLANTS.

Plants using bituminous coal.

8. Fuel, Big Muddy (Ill.) run-of-mine coal. Analysis follows:

Fixed carbon	50.92
Volatile matter	32.80
Moisture	9.40
Ash	6.88
Sulphur (separately determined)	1.56
British thermal units in dry coal	13,553

Satisfactory in price and results. Is regarded as high grade. Makes good gas with little clinker. No trouble has been experienced on account of sulphur.

20. One 200-horsepower producer uses pea anthracite and one 250-horsepower producer uses run-of-mine bituminous coal with—

Fixed carbon	76.80
Volatile matter	17.11
Moisture	1.39
Ash	4.70
Sulphur (separately determined)	1.01

The pea anthracite is used in the spare producer, the other producer having been modified for the use of coke, which is a by-product from the gas department.

22. Uses Pocahontas slack. Analysis follows:

Fixed carbon	81.41
Volatile matter	13.23
Moisture	.54
Ash	4.82
Sulphur (separately determined)	.50
British thermal units in slack as fired	14,769

Experiments have been made with other fuels, but no other fuel has been used for any length of time. The lower the sulphur the better the results.

23. Fuel, West Virginia bituminous coal run through a 4-inch crusher.

Fixed carbon	53.89
Volatile matter	36.01
Moisture	3.45
Ash	6.65
Sulphur (separately determined)	2.22
British thermal units in coal as fired (average of 49 cars)	13,741

This company has used other West Virginia coals and Indiana coal but finds the present coal gives a larger producer output. It is of higher grade than the other fuels tried, higher in carbon, lower in ash, and works with greater ease. It costs more than the other fuels.

24. Fuel, bituminous southwestern Illinois coal, 1½ to 7 inches. Analysis follows:

Fixed carbon	55.51
Volatile matter	31.78
Moisture	9.02
Ash	3.69
Sulphur (separately determined)	.52
British thermal units in dry coal	12,805

Run-of-mine coal from the same mine and a few other similar Illinois coals have been used. The run-of-mine coal was changed because of too much slack, as a more uniform grade of coal is preferred. The present fuel is regarded as of higher grade than that previously used, although it comes from the same mine. It is freer from dirt and of more suitable size for producer use. It operates with greater ease. It costs more per ton at the mine. Low sulphur is not essential but is preferred.

27. Fuel, Pennsylvania run-of-mine bituminous coal. The average analysis of the coal in four cars follows:

Fixed carbon	76.94
Volatile matter	13.70
Moisture	1.47
Ash	7.89
Sulphur (separately determined)	1.18
British thermal units in coal as fired	14,535

When this particular grade of coal can not be procured a coal yielding 13,365 British thermal units is substituted. The latter fuel is higher in volatile matter, ash, and sulphur, and lower in fixed carbon. It is not necessary to run the fires quite as hot as with the former fuel on account of the higher volatile matter. The second coal costs less than the first. Low sulphur content is regarded as essential. On account of corrosion the 3-inch steel economizer tubes last only about 18 months.

28. Fuel, West Virginia Pocahontas coal, running from dust to 0.75 inch in size. As fired it yields 13,500 to 14,000 British thermal units, and on the dry basis it yields 14,000 to 14,500 British thermal units.

29. Fuel, Virginia bituminous run-of-mine coal and slack. Washed slack has been used, but a change was made to the fuel first mentioned because no more washed slack could be purchased. The present fuel is regarded as of lower grade, although it works better in the producer and costs less.

35. Fuel, Berwyn and White Scalp level, South Fork (Pa.) coal. Analysis:

Fixed carbon	77.0
Volatile matter	17.0
Moisture	.5
Ash	5.5
Sulphur (separately determined)	1.0
British thermal units in coal as fired	14,834

This is a higher-grade coal and costs more than that previously used. The change was made as better results can be obtained with the present coal, as it works with greater ease and does not cake or clinker. Low sulphur content is regarded as necessary in order to eliminate the action of sulphuric acid.

DOUBLE-ZONE PLANTS.

Plants using bituminous coal.

2. Fuel, New Mexico bituminous chestnut coal. Costs less than coal previously used in steam plants. Low-sulphur coal not necessary.

8. Fuel, Big Muddy (Ill.) run-of-mine coal. Analysis follows:

Fixed carbon	50.92
Volatile matter	32.80
Moisture	9.40
Ash	6.88
Sulphur (separately determined)	1.56
British thermal units in coal on dry basis	13,553

Satisfactory in price and economy. It is regarded as high grade. Makes good gas with little clinker. No trouble has been experienced on account of sulphur.

Plants using lignite.

31. Fuel, lignite, size about 3-inch cubes.

Fixed carbon, approximately	40
Volatile matter	34
Moisture	18
Ash	6
British thermal units in coal as fired	11,400

POUNDS OF FUEL PER SQUARE FOOT OF FUEL-BED AREA PER HOUR.

One of the most important commercial items connected with the design and the operation of gas producers is the determination of the number of pounds of fuel consumed per square foot of fuel-bed area per hour. This rate of fuel consumption varies radically with different types of plants and with different grades and different types of fuel and has led to much difficulty in designing and in rating producers. Early work in this country followed European practice almost entirely and thereby occasioned much trouble in connection with the rating of pioneer plants, and brought about the ultimate failure of many of them. Under certain European conditions fuels of a definite grade are specified, so that high rates of fuel consumption may be obtained. It is not impossible to obtain similar rates of consumption under corresponding circumstances in this country, but as selected fuels are seldom obtainable except for special tests, it has been found that in general in the United States the rate of fuel consumption per square foot of fuel-bed area does not average much over one-half the consumption originally guaranteed by early manufacturers. This fact has, of course, led to a decided modification in the design of many plants.

Although the possible rate of burning high-grade fuel may be relatively high, much depends on the method of operation and the character of the fuel as to the actual commercial results obtained. Certain types of fuel lend themselves more readily to high rates of fuel consumption than others, and with a given fuel the rate of burning will vary with the nature of the gas-generating process, the down-draft plant consuming practically twice as much fuel per square foot of fuel-bed area per hour as the up-draft. In 1911 the writer[a] stated that down-draft plants were in operation that consumed more than 40 pounds of lignite per square foot of fuel-bed area per hour, and that up-draft producers could gasify comparatively large quantities of fuel per hour for relatively short periods, but that in actual operation with ordinary grades of fuel it was doubtful whether the consumption in the up-draft plants would exceed 15 to 16 pounds per square foot of fuel-bed area per hour. The normal figure at that time was stated to be much nearer 10 pounds, and it was said that 10 pounds would prove to be a high figure for fuels having a large percentage of ash or a sulphur content that tended to produce serious clinkering. It is interesting to compare the figures mentioned with the figures from several plants in commercial operation at the present time, as furnished by the owners or operators of the plants. Such figures are presented in the pages following.

FUEL CONSUMPTION OF UP-DRAFT PLANTS USING ANTHRACITE COAL.

The fuel-consumption figures for certain plants using anthracite coal follow:

Fuel consumption of up-draft gas producers using anthracite coal.

Plant No.	Horsepower of each gas generator.	Area of fuel bed.	Fuel as fired per square foot of fuel-bed area per hour.	
			As rated.	As actually operated.
		Square feet.	*Pounds.*	*Pounds.*
14	75	7.1	18.0	....
9	160	12.6	16.0	12.7
34	250	38.5	7.8	....
18	300	42.5	8.7	....
19	300	44.2	6.8	7.3
36	300	44.2	8.5	4.5
16	400	56.6	9.0	....
Average	....	....	10.7	....

[a] Fernald, R. H., and Smith, C. D., Résumé of producer-gas investigations: Bull. 13, Bureau of Mines, 1911, p. 45.

The average consumption of the seven plants listed, on the basis of the manufacturers' rating, was 10.7 pounds per square foot of fuel-bed area. The number of plants reporting operating figures for anthracite coal is not enough to permit the presentation of averages, although it is probable that the average figure for commercial operation for up-draft plants using anthracite as a fuel is not far from the average given on the basis of the manufacturers' rating.

FUEL CONSUMPTION OF UP-DRAFT PLANTS USING BITUMINOUS COAL.

Figures covering fuel consumption of gas producers using bituminous coal follow:

Fuel consumption of up-draft gas producers using bituminous coal.

Plant No.	Horsepower of each gas generator.	Area of fuel bed.	Fuel as fired per square foot of fuel-bed area per hour.	
			As rated.	As actually operated.
		Square feet.	*Pounds.*	*Pounds.*
37	200	23.7	7.0	7.0
3	200	25.0	10.0	7.6
33	250	28.3	10.6	7.6
17	250	33.1	10.0	13.7
12	200 300	24.0 42.0	10.4 9.5	7.4
25	300 400	40.0 50.0	9.1 8.0	8.5
39	370	50.2	10.0	6.1
21	650 1,000	50.0 78.0	....	8.7
5	1,000	70.9	7.0	7.1
12	2,500	210.0	14.3	13.1
Average	....	....	10.4	8.7

For the up-draft plants operating on bituminous coal the range of actual operating rates of fuel consumption seems to be from approximately 6 to more than 13.5 pounds per square foot of fuel-bed area per hour. This marked difference might, on first thought, be supposed to be due to differences in the character of the fuels, but an examination of the records submitted shows that actually the higher-grade fuel is used in the plant reporting the low rate of fuel consumption per square foot of fuel-bed area per hour.

The coal used in the plant reporting the 6-pound rate averaged 14,500 British thermal units as fired and contained 5 per cent ash and 0.9 per cent sulphur, whereas the coal used in the plant reporting the 13.7-pound rate averaged 12,520 British thermal units and contained 10.1 per cent ash and 3.4 per cent sulphur, and the coal in the plant reporting the 13.1-pound rate averaged 12,300 British thermal units and contained 7.4 per cent ash and 0.5 per cent sulphur.

The inference is that the plant with the 6-pound rate was operated much below the capacity of the producer.

Although there seems to be little direct relation between the rated fuel consumption for the individual plants and the number of pounds of fuel actually burned per square foot of fuel-bed area, the average figures check within reasonable limits and indicate that approximately 8.5 pounds per square foot of fuel-bed area per hour with good-grade bituminous coal is a reasonable figure for an up-draft producer gas plant.

FUEL CONSUMPTION OF UP-DRAFT PLANTS USING LIGNITE.

The figures for fuel consumption in gas producers using lignite follow:

Fuel consumption of up-draft gas producers using lignite.

Plant No.	Horsepower of each gas generator.	Area of fuel bed.	Fuel as fired per square foot of fuel-bed area per hour.	
			As rated.	As actually operated.
		Square feet.	*Pounds.*	*Pounds.*
4	100	19.6	11.5	11.5
7	100	20.4	....	8.6
11	250	38.5	....	14.8
38	300	41.3	10.0	8.5
Average	....	....	10.8	10.8

The returns cited for lignite in up-draft plants indicate that approximately 11 pounds of lignite is burned per square foot of fuel-bed area per hour in plants of this type.

Tests at the Government testing station at St. Louis in 1904–1906 indicated that a higher average rate may easily be obtained with lignite in up-draft plants.

FUEL CONSUMPTION OF UP-DRAFT PLANTS USING WOOD.

Figures for fuel consumption in gas producers using wood follow:

Fuel consumption of up-draft gas producers using wood.

Plant No.	Horsepower of each gas generator.	Area of fuel bed.	Fuel as fired per square foot of fuel-bed area per hour.	
			As rated.	As actually operated.
		Square feet.	*Pounds.*	*Pounds.*
13	150	50.3	12.0	....
26	{200 280	33.3 50.3 }	14.0	14.5

FUEL CONSUMPTION OF DOWN-DRAFT PLANTS USING BITUMINOUS COAL.

Figures showing fuel consumption in certain plants using bituminous coal follow:

Fuel consumption of down-draft gas producers using bituminous coal.

Plant No.	Horsepower of each gas generator.	Area of fuel bed.	Fuel as fired per square foot of fuel-bed area per hour.	
			As rated.	As actually operated.
		Square feet.	*Pounds.*	*Pounds.*
22	250	17.4	14.4	14.4
27	250	17.4	17.0	....
35	250	20.4	14.7	14.7
28	375	38.5	13.0	....
28	500	50.0	12.5	....
8	800	36.0	33.4	18.4
23	1,500	60.0	27.5	23.5
24	1,500	60.0	20.0	16.7
Average	....	....	19.1	17.5

For the down-draft plants of the double-generator type the figures reported are perhaps not sufficient to warrant conclusive deductions, but when compared with data from other sources they make apparent that the average fuel consumption per square foot of fuel-bed area per hour is nearly correct.

FUEL CONSUMPTION IN DOWN-DRAFT GAS PRODUCER USING LIGNITE.

Figures procured a few years since from a plant using lignite in 1,100-horsepower units of the down-draft double-generator type indicated a normal fuel rate of 33 pounds per square foot of fuel area per hour for 16 hours a day, and the unusual rate of 48 pounds for 8 hours a day. This instance, however, is too exceptional to be regarded as representative of general practice.

FUEL CONSUMPTION OF DOUBLE-ZONE PLANTS USING BITUMINOUS COAL.

Figures showing fuel consumption of double-zone gas producers using bituminous coal follow:

Fuel consumption of double-zone gas producers using bituminous coal.

Plant No.	Horsepower of each gas generator.	Area of fuel bed.	Fuel as fired per square foot of fuel-bed area per hour.	
			As rated.	As actually operated.
		Square feet.	*Pounds.*	*Pounds.*
2	250	29.3	24.0	10.3
8	500	47.0	17.0	....

As operating returns were received for only one double-zone plant, no definite direct deductions can be made, but a review of the results of tests of such a plant indicates the rate of fuel consumption under test conditions to be not far from 15 pounds per square foot of fuel-bed area per hour with bituminous coal and 23 pounds with lignite.

CONCLUSIONS REGARDING COAL CONSUMPTION.

A study of the operating reports submitted indicates that the average rate of fuel consumption in producer-gas plants is considerably higher than a few years ago. This betterment is due, perhaps, to two reasons—first, a more efficient operation of the plants themselves, and, second, an increasing tendency to use higher grade fuel. The first result is to be commended, but the second should be deplored.

Although too much stress must not be laid on the following values, the deductions from the operating figures supplied above, coupled with personal observation of many other plants, seem to indicate the following approximate values for fuel consumption per square foot of fuel-bed area per hour as representative of good general commercial practice.

Figures for fuel consumption in gas producers representing good general practice.

Kind of plant.	Fuel consumption per square foot of fuel-bed area per hour with—							
	Anthracite coal.		Bituminous coal.		Lignite.		Peat.	Wood.
	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.	Average.
Up-draft using—	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Fuel as fired	10.0	14.0	8.5	14.0	12.0	17.0	15.0	14.0
Fuel dry	10.0	13.5	8.0	13.0	8.5	12.0	12.0	....
Down-draft using—								
Fuel as fired	....	....	17.5	23.5	26.5	31.5	35.5	....
Fuel dry	....	....	16.5	22.0	18.5	22.0	25.5	....
Double-zone using—								
Fuel as fired	....	....	13.5	18.5	21.5	27.0	....	....
Fuel dry	....	....	12.5	17.5	15.0	19.0	....	....

POUNDS OF FUEL PER HORSEPOWER-HOUR.

Producer-gas investigations of the United States Geological Survey and of the Bureau of Mines, conducted with plants not above the average in efficiency, showed the following approximate fuel consumption per brake horsepower per hour:

Results of producer-gas investigations, showing fuel consumption per brake horsepower per hour with different fuels.

Condition of fuel.	Fuel consumption per brake horsepower-hour with—						
	Bituminous coal.			Lignite.			Peat.[a]
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Fired	1.3	2.0	0.8	2.0	2.8	1.5	2.6
Dry	1.2	1.8	.8	1.63	2.02	1.35	2.0

[a] One sample only of peat.

Although these figures were procured during the progress of regular tests, the conditions outlined in previous reports of the Bureau of Mines indicate clearly that equally good results should be readily obtained in the average commercial producer-gas plant. With this in mind, the following results, reported by the operators and owners of several plants, are of peculiar interest:

Results of operation of producer-gas plants showing fuel consumed per brake horsepower-hour with different fuels.

Plant No.	Horsepower of each gas generator.	Total horsepower of plant.	Heat value of fuel as fired.	Fuel fired per brake horsepower-hour.	
				Rating.	Operating.
ANTHRACITE COAL.					
			B.t.u.	*Pounds.*	*Pounds.*
14	75	150		1.67	
19	300	300		1.00	1.30
36	300	300		1.25	1.30
16	400	400		1.25	
18	300	600		1.23	
9	160	640		1.25	1.50
34	250	1,500		1.20	1.25
Average				1.26	1.34
BITUMINOUS COAL.					
29	200	200		1.10	1.00
20	250	250		1.25	
3	200	400	14,800	1.25	2.40
37	200	400	14,000		1.65
17	250	500	12,520	1.30	
33	250	500	14,370	1.20	1.00
27	250	500	14,535	1.10	
22	500	500	14,770	1.00	1.20
12	200 300	1,000	12,300	1.30	1.40
35	250	1,000	14,835	1.20	1.00
39	370	1,100	14,500	1.37	1.80
25	300 400	1,400		1.10	1.40
2	250	1,500		2.80	2.00
28	375 500	1,750	13,750	1.29	1.00
8	500 800	4,200	12,270	1.60	1.20
23	1,500	6,000	13,740	1.10	1.15
24	1,500	9,000	11,540	.80	
Average				1.30	1.40
LIGNITE.					
4	100	100	7,440	2.25	2.50
7	100	100			2.40
38	300	300			2.00
31	200	400	11,400	1.50	3.00
Average					2.48
WOOD.					
13	150	150		4.00	
26	200 280	1,040	5,400	2.50	3.33

A more direct comparison between the results of commercially operated plants and those obtained at the Government testing station may be had by an inspection of the following tabulation:

Comparative results of operating producer-gas plants by the Government and by commercial companies.

Operator.	Fuel consumed per brake horsepower-hour with—										
	Anthracite.			Bituminous coal.			Lignite.			Peat.[a]	Wood[a]
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Average.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Bureau of Mines	......	......	......	1.3	2.0	0.8	2.0	2.8	1.5	2.6	......
Commercial plants	1.3	1.5	1.3	1.4	2.4	1.0	2.5	3.0	2.0	......	3.3

[a] One sample only used.

Figures showing the heat value of the fuel and the actual consumption of fuel as fired per horsepower-hour for different plants follow:

Heat value of fuel used at different gas producers and fuel consumption per horsepower-hour.

Plant No.	Heat value of fuel.	Fuel fired per horsepower-hour.	Plant No.	Heat value of fuel.	Fuel fired per horsepower-hour.
	B. t. u.	*Pounds.*		*B. t. u.*	*Pounds.*
4	7,440	2.50	37	14,000	1.65
31	11,400	3.00	33	14,370	1.00
8	12,270	1.20	22	14,770	1.20
12	12,300	1.40	3	14,800	2.40
23	13,740	1.15	35	14,835	1.00
28	13,750	1.00			

It is at once evident that there is no direct relation between the independent results obtained by different operators and the heat value of the fuel used. This lack of relationship is to be expected, as individual plant conditions are so radically different and producer-gas power is relatively so new that some plants are necessarily much more efficiently operated than others, a fact convincingly borne out by a personal inspection of a large number of plants. Even plants owned by the same corporation, situated in the same district and using the same general grades of fuel, may bear little relation to each other in the results obtained. In one plant after the power used had been changed from steam to producer gas the cost per ton of finished product was reduced to less than one-half of the former cost, whereas in another plant controlled by the same company the cost per ton of finished product was practically doubled after a similar introduction of producer gas. The difference in the two results seems to have been due to the difference in the methods of the superintendents in charge. One superintendent was a live, wide-awake man who believed it essential to have his power plant kept in perfect condition for the successful manufacture of his product. As a result, he has never shut down for want of power.

The other superintendent felt that the power plant ought to take care of itself. The appearance of the plant testified plainly to his expressed views and serious shutdowns were frequent.

DEPTH OF FUEL BED.

Data supplied by various producer-gas companies regarding the depth of fuel bed used follow:

Data regarding depth of fuel bed used in various producer-gas plants.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Grate area.	Approximate quantity of fuel burned per hour.	Depth of bed.
	Square feet.	*Pounds.*	*Feet.*
14	7.1	125	4
9	12.6	160	2.5
6	13.6	....	3
36	44.2	200	6
32	38.5	....	2.75
34	38.5	300	2
19	44.2	300	10
16	56.6	500	4

PLANTS BURNING BITUMINOUS COAL.

37	23.7	165	2
3	25.0	190	3
39	50.2	300	1.5
25	40.0	340	2.5
25	50.0	425	2.5
21	50.0	435	1.75
17	33.1	450	4
5	70.9	500	3
21	78.0	680	1.75
12	210.0	2,750	6.5

PLANTS BURNING LIGNITE.

15	....	....	4
4	19.6	225	2
38	41.3	350	6.5
11	38.5	570	1.5

PLANTS BURNING WOOD.

13	50.3	605	8
26	50.3	725	7

Data regarding depth of fuel bed used in various producer-gas plants—Continued.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Grate area.	Approximate quantity of fuel burned per hour.	Depth of bed.
	Square feet.	*Pounds.*	*Feet.*
29	....	220	5
22	17.4	250	5
27	17.4	295	6
35	20.4	300	12
28	50.0	625	6
8	36.0	1,200	8.5
23	60.0	1,400	9

DOUBLE-ZONE PLANTS.

PLANT BURNING BITUMINOUS COAL.

2	29.3	310	12

PLANT BURNING LIGNITE.

31	....	....	8

COMPOSITION OF GAS.

The composition of producer gas varies with the type of producer, the methods and skill used in operating it, the uniformity and regulation of the air and steam supply, the kind and quality of fuel used, the depth of fuel bed, the distribution of the fuel, and the uniformity in size of the fuel. The variations in the composition of producer gas under different operating conditions are readily shown by the following results of analyses of the gas produced in different plants.

Results of analyses of gas from different types of gas producers.

[Results represent per cent by volume.]

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	CO	CH_4	C_2H_4	H_2	CO_2	O_2	N_2
14	24.0	....	....	12.0	3.5	0.2	60.3
19	21.4	....	....	19.0	7.5	.3	51.8
Average	22.7	....	....	15.5	5.5	.3	56.0

PLANTS BURNING BITUMINOUS COAL.

Plant No.	CO	CH_4	C_2H_4	H_2	CO_2	O_2	N_2
37	27.5	2.2	0.7	6.5	2.9	0.2	60.0
17	25.0	4.3	.0	14.6	5.2	.9	50.0
39	21.8	2.8	.0	11.3	6.4	.4	57.3
25	23.6	4.4	.0	14.2	4.9	1.3	51.6
21	24.0	4.6	.0	11.6	4.6	.0	55.2
Average	24.4	3.7	.1	11.6	4.8	.6	54.8

Results of analyses of gas from different types of gas producers—Continued.

UP-DRAFT PLANTS—Continued.

PLANTS BURNING LIGNITE.

Plant No.	CO	CH_4	C_2H_4	H_2	CO_2	O_2	N_2
38	16.2	5.0	0.0	25.0	6.9	1.3	45.4
11	[a] 21.0	....	....	....	6.6	2.5	....
11	[b] 9.8	....	....	....	16.6	3.2	....

PLANT BURNING WOOD.

26	13.6	8.0	0.0	4.0	12.9	0.0	61.7

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

35	24.0	1.6	0.0	14.3	2.0	0.2	57.9
8	21.2	3.0	.0	9.3	5.0	.3	61.2
24	25.6	.0	1.0	13.6	5.0	.0	54.8
Average	23.6	1.5	.3	12.4	4.0	.2	58.0

DOUBLE-ZONE PLANTS.

PLANT BURNING BITUMINOUS COAL.

8	23.2	2.8	0.0	11.0	6.2	1.1	55.7

PLANT BURNING LIGNITE.

31	10.4	3.8	0.0	17.2	15.4	0.4	52.8

OIL-GAS PLANTS.

PLANTS BURNING CRUDE OIL.

Plant No.	CO	CH_4	H_2S	C_xH_y	H_2	CO_2	O_2	N_2
10	10.2	6.1	0.0	3.8	10.6	6.1	0.0	63.2
30	7.4	12.7	3.1	2.6	....	4.5	....	69.3

[a] No steam. [b] With steam.

The averages of several typical analyses of producer gas from the Bureau of Mines testing plant and the averages of the figures presented for plants in commercial operation are given below. Attention is called to the fact that the analyses may not be strictly comparable, because methods of analyses may have differed slightly.

Average results of analyses of producer gas from Bureau of Mines testing plants and from commercial plants.

[Results represent per cent by volume.]

UP-DRAFT PLANTS.

Constituent.	Gas from anthracite coal.		Gas from bituminous coal.		Gas from lignite.		Gas from peat.[a]		Gas from wood.[a]	
	Bureau of Mines.	Commercial plants.	Bureau of Mines.	Commercial plants.	Bureau of Mines.	Commercial plants.	Bureau of Mines.	Commercial plants.	Bureau of Mines.	Commercial plants.
Carbon monoxide (CO)	....	22.7	18.28	24.4	21.00	....	21.0	....	....	13.6
Methane (CH_4)	....	.0	3.12	3.7	2.20	....	2.2	....	....	8.0
Ethylene (C_2H_4)	....	.0	.18	.1	.40	....	.4	....	....	.0
Hydrogen (H_2)	....	15.5	12.90	11.6	18.50	....	18.5	....	....	4.0
Carbon dioxide (CO_2)	....	5.5	9.84	4.8	12.40	....	12.4	....	....	12.9
Oxygen (O_2)	....	.3	.04	.6	.00	....	.0	....	....	.0
Nitrogen (N_2)	....	56.0	55.64	54.8	45.50	....	45.5	....	....	61.7

[a] One sample only.

DOWN-DRAFT PLANTS.

Constituent.	Gas from anthracite coal.		Gas from bituminous coal.		Gas from lignite.		Gas from peat.		Gas from wood.	
	Bureau of Mines.	Commercial plants.	Bureau of Mines.	Commercial plants.	Bureau of Mines.	Commercial plants.	Bureau of Mines.	Commercial plants.	Bureau of Mines.	Commercial plants.
Carbon monoxide (CO)	....	....	19.1	23.6	15.0	....	14.8	....	....	....
Methane (CH_4)	....	....	1.1	1.5	1.7	....	1.5	....	....	....
Ethylene (C_2H_4)	....	....	.0	.3	.0	....	.1	....	....	....
Hydrogen (H_2)	....	....	11.4	12.4	13.3	....	13.3	....	....	....
Carbon dioxide (CO_2)	....	....	7.6	4.0	11.5	....	12.9	....	....	....
Oxygen (O_2)	....	....	.2	.2	.2	....	.6	....	....	....
Nitrogen (N_2)	....	....	60.6	58.0	58.3	....	56.8	....	....	....

HEAT VALUE OF GAS.

Figures showing the heat value of the gas from different fuels determined from the average of a large number of tests reported by the Bureau of Mines and also from the figures submitted by the operators of plants in commercial operation are presented below:

Average heat values of gas from different fuels when used in various types of gas producers.

[Figures represent British thermal units per cubic foot of gas.]

UP-DRAFT PLANTS.

Location of gas producer.	Gas from anthracite coal.		Gas from bituminous coal.		Gas from lignite.		Gas from peat.		Gas from wood.	
	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
Bureau of mines testing station	....	....	152	176	158	188	[a] 175	....	....	....
Commercial plants	138	....	151	175	157	185	....	....	[a] 133	....

[a] One sample only.

Average heat values of gas from different fuels when used in various types of gas producers—Continued.

DOWN-DRAFT PLANTS.

Location of gas producer.	Gas from anthracite coal.		Gas from bituminous coal.		Gas from lignite.		Gas from peat.		Gas from wood.	
	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
Bureau of mines testing station	....	....	110	123	111	127	[a] 115	[a] 119	....	....
Commercial plants	....	....	123	130	....	....	....	....	....	....

DOUBLE-ZONE PLANTS.

Location of gas producer.	Gas from anthracite coal: Average.	Gas from anthracite coal: Maximum.	Gas from bituminous coal: Average.	Gas from bituminous coal: Maximum.	Gas from lignite: Average.	Gas from lignite: Maximum.	Gas from peat: Average.	Gas from peat: Maximum.	Gas from wood: Average.	Gas from wood: Maximum.
Bureau of mines testing station	....	....	....	....	....	....	....	....	....	....
Commercial plants	....	....	([b])	....	118	....	....	....	....	....

OIL-GAS PLANTS.

Location of gas producer.	Gas from anthracite coal: Average.	Gas from anthracite coal: Maximum.	Gas from bituminous coal: Average.	Gas from bituminous coal: Maximum.	Gas from lignite: Average.	Gas from lignite: Maximum.	Gas from peat: Average.	Gas from peat: Maximum.	Gas from wood: Average.	Gas from wood: Maximum.
Bureau of mines testing station	....	....	....	....	....	....	....	....	....	....
Commercial plants	....	....	....	[c] 215	[c] 230	....	....	....	....	....

[a] Two samples only.
[b] Tests indicate this figure to be approximately 115.
[c] Figures represent two plants burning crude oil.

CUBIC FEET OF GAS PER POUND OF FUEL.

Tabulated data showing the quantity of producer gas available from various fuels used in the different types of plants follow:

Average quantities of gas produced from different fuels in different types of gas producers.

[Figures represent cubic feet of standard (60° F. and 30 inches of mercury) gas per pound of fuel.]

UP-DRAFT PLANTS.

Location of gas producer.	Gas from bituminous coal.				Gas from lignite.				Gas from peat.			
	As fired.		Dry.		As fired.		Dry.		As fired.		Dry.	
	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
Bureau of mines testing station	61	101	65	104	36	46	46	53	[a] 30	......	[a] 38	......
Commercial plants	75	96	......	......	......	......	......	......	......	......	......	......

DOWN-DRAFT PLANTS.

Location of gas producer.	Bituminous coal, as fired: Average.	Bituminous coal, as fired: Maximum.	Bituminous coal, dry: Average.	Bituminous coal, dry: Maximum.	Lignite, as fired: Average.	Lignite, as fired: Maximum.	Lignite, dry: Average.	Lignite, dry: Maximum.	Peat, as fired: Average.	Peat, as fired: Maximum.	Peat, dry: Average.	Peat, dry: Maximum.
Bureau of mines testing station	65	80	68	82	36	44	52	61	[b] 29	[b] 31	[b] 40	[b] 44
Commercial plants	79	82	......	......	......	......	......	......	......	......	......	......

[a] One sample only. [b] Two samples only.

TIME BETWEEN FUEL CHARGES AND WEIGHT OF FUEL CHARGES.

Figures showing the time between fuel charges and the weight of fuel charges in the various types of plants follow:

Time between fuel charges and weight of fuel charges in different types of gas producers.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Horsepower of each gas generator.	Average fuel burned per hour.	Length of service per day.	Time between fuel charges.	Weight of fuel charge.
		Pounds.	*Hours.*	*Hours.*	*Pounds.*
6	150	....	24	1 to 6	200
9	160	160	24	.5	200 to 600
32	250	....	3 to 7	2	400
18	300	190	11	24	1,800 to 2,400
19	300	300	24	6	1,000 to 1,500
36	300	200	10	10	2,000
1	350	....	5 to 24	.5	175

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Average fuel burned per hour.	Length of service per day.	Time between fuel charges.	Weight of fuel charge.
3	200	190	24	1	165
37	200	165	10	.5	80
17	250	450	....	4	1,500
33	250	215	14	.75	250
39	370	300	24	.17	100
21	{ 650 1,000	435 680 }	10	.13	100
12	2,500	2,750	24	2.5	7,000

PLANTS BURNING LIGNITE.

Plant No.	Horsepower of each gas generator.	Average fuel burned per hour.	Length of service per day.	Time between fuel charges.	Weight of fuel charge.
4	100	225	8	2	500 to 800
7	100	175	11	1	175
15	100	....	14	2 to 3	200 to 300
11	250	570	24	.33	190
38	300	350	24	2 to 3	900

PLANT BURNING WOOD.

Plant No.	Horsepower of each gas generator.	Average fuel burned per hour.	Length of service per day.	Time between fuel charges.	Weight of fuel charge.
26	{ 200 280 }	....	24	0.5	280

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Average fuel burned per hour.	Length of service per day.	Time between fuel charges.	Weight of fuel charge.
29	200	....	24	0.5	110
27	250	295	10	.25	50
35	250	300	10	.17	50
28	{ 375 500 }	625	24	.17	100
8	800	1,200	24	.25	....
23	1,500	1,400	24	.09	....

DOUBLE-ZONE PLANTS.

PLANT BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Average fuel burned per hour.	Length of service per day.	Time between fuel charges.	Weight of fuel charge.
2	250	310	24	1 to 1.5	700

TIME BETWEEN POKINGS OF FUEL BED.

Tabulated data showing the time between pokings of the fuel bed in the various types of plants are presented below:

Time between pokings of fuel bed in different types of gas producers.

Plant No.	Area of fuel bed.	Depth of fuel bed.	Approximate amount of fuel burned per hour.	Time between pokings.
UP-DRAFT PLANTS.				
PLANTS BURNING ANTHRACITE COAL.				
	Square feet.	*Feet.*	*Pounds.*	*Hours.*
14	7.1	4	125	1
9	12.6	2.5	160	.75
6	13.6	3	....	3 to 6
36	44.2	6	200	10
34	38.5	2	300	1
19	44.2	10	300	8
1	....	....	....	1
16	56.6	4	500	6
PLANTS BURNING BITUMINOUS COAL.				
37	23.7	2	165	10
3	25.0	3	190	.33
25	40.0	2.5	340	4
21	50.0	1.75	435	.75
17	33.1	4	450	1
33	28.3	....	215	2
5	70.9	3	500	1
21	78.0	1.75	680	.75
12	210	6.5	2,750	12
PLANTS BURNING LIGNITE.				
15	....	4	....	1
7	20.4	....	175	12
4	19.6	2	225	2
11	38.5	1.5	570	12
PLANTS BURNING WOOD.				
13	50.3	8	605	0.25
26	50.3	7	725	.16
DOWN-DRAFT PLANTS.				
PLANTS BURNING BITUMINOUS COAL.				
29	....	5	220	1
22	17.4	5	250	(a)
27	17.4	6	295	.5 to 1
35	20.4	12	300	3
8	36.0	8.5	1,200	(a)
23	60.0	9	1,400	.5
DOUBLE-ZONE PLANTS.				
PLANT BURNING BITUMINOUS COAL.				
2	29.3	12	310	1
PLANT BURNING LIGNITE.				
31	....	8	....	4

[a] Not poked.

TROUBLE FROM HOLES AND CHANNELS IN FUEL.

Data supplied by owners or operators regarding trouble from holes and channels in the fuel bed in the various types of plants are presented below. The numbers preceding each paragraph refer to plant numbers assigned by the author:

Data regarding holes and channels in full bed.

UP-DRAFT PLANTS.

Plants burning anthracite coal.

1. Causes back-firing trouble.
6. Little trouble from holes and channels.
9. Little trouble, because we use sufficient producer capacity.
14. Not serious. Holes easily closed.
16. Considerable stoking required at times.
19. No trouble.
20. Permit gas to burn in producer.
32. Shut the engine down.
34. Make weak gas.
36. No trouble.

Plants burning bituminous coal.

3. Cause poor gas and clinker.
5. Little trouble.
12. No trouble when producers have proper attention.
17. No trouble.
21. Cause much trouble.
25. No trouble.
33. Not appreciable.
37. Cause weak gas.
39. Serious. Necessitating laborious work to keep the fire even throughout the bed.

Plants burning lignite.

4. Occasional, but never serious.
7. Destroys gas.
11. No trouble. Dropping fuel on fire keeps it down.
38. Very little. Never have this trouble, as little work keeps the fuel bed in fine shape.

Plants burning wood.

13. Permit unfixed oxygen to reach top of fuel bed, causing burning.
26. No trouble.

DOWN-DRAFT PLANTS.

Plants burning bituminous coal.

8. No trouble.
20. Permits gas to burn in producer.
22. No trouble.
23. Do not let them occur.
24. Readily noticeable on recording calorimeter. Believed to have affected results seriously.
27. Fire must be closely watched and fuel charged lightly.
28. No trouble.
29. Considerable. At times had to shut plant down.
35. No trouble.

DOUBLE-ZONE PLANTS.

Plants burning bituminous coal.

2. Quite serious.
8. No trouble.

METHODS OF OVERCOMING VARIATIONS IN QUALITY OF GAS.

Data supplied by owners or operators regarding methods of overcoming variations in the quality of the gas yielded by the various types of gas producers follow:

Data regarding methods used for overcoming variations in gas quality in various types of gas producers.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding methods used to overcome variations in quality of gas.
14......	75	None.
6.......	150	Variation of steam feed.
9.......	160	None.
20......	200	Suction producer, none; pressure producer, gasometer.
32......	250	Change setting of mixing valve on engine.
19......	300	Automatic vapor control and proper cleaning methods.
36......	300	Automatically controlling steam supply to producer.
16......	400	Producer automatically regulated.
		PLANTS BURNING BITUMINOUS COAL.
3.......	200	Gas holder.
37......	200	By keeping fires regular gas quality varies but very little.
17......	250	None.
33......	250	Do.
39......	370	None, except best possible attention to producer fuel bed.
25......	300, 400	Hand regulation of air temperature admitted to ash bed.
21......	650, 1,000	None, except to reprimand gasmen.
5.......	1,000	Keep bed tight, uniform, and free from air pockets.
12......	200, 300, 2,500	Gas quality checked by recording calorimeter.
		PLANTS BURNING LIGNITE.
4.......	100	Change mixture at engine.
7.......	100	Adjustment of levers.
15......	100	More or less free air.
11......	250	Mixing valves on engines. Gas constant except when cleaning fires.
38......	300	None. Little variation.
		PLANT BURNING WOOD.
26......	200, 280	None.
		DOWN-DRAFT PLANTS.
		PLANTS BURNING BITUMINOUS COAL.
29......	200	Close attention to fire.
35......	250	Keep fires and scrubbers clean.
28......	375, 500	20,000-cubic foot gas holder.
22......	500	None, except with fires in generators and mixing in gas holders.
8.......	800	Water gas run to regulate temperature of fires.
23......	1,500	None other than holder.
24......	1,500	Mixture of gas from different producers. Careful watching of fires.
		DOUBLE-ZONE PLANTS.
		PLANT BURNING BITUMINOUS COAL.
2.......	250	None.

Data regarding methods used for overcoming variations in gas quality in various types of gas producers—Continued.

DOUBLE-ZONE PLANTS—Continued.

PLANT BURNING LIGNITE.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding methods used to overcome variations in quality of gas.
31......	200	Change mixing valves on engine.

OIL-GAS PLANT.

PLANT BURNING CRUDE OIL.

10......	400	Variations so slight that governor handles them easily.

METHODS OF CLEANING GAS GENERATORS.

The owners and operators of producer-gas plants were asked to describe briefly their method of cleaning the gas generator; they were requested to state the time and the number of men required for cleaning each unit. Brief abstracts of the replies received are tabulated below.

Data regarding methods of cleaning gas generators in various types of producer-gas plants.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE.

Plant No.	Horse-power of each gas generator.	Total horse-power of plant.	Remarks of owner or operator regarding methods used to clean gas generator.
14......	75	150	Coal and ash pulled through doors above grate; clinkers removed from walls by bar through poke hole; 3 hours' time of 1 man.
6.......	150	450	Half close valve between producer and gas main; remove all ashes between grates and fire with hoe and poker; poke fire down and add fresh fuel; 1 hour's time of 1 man.
9.......	160	640	Draw ash and clinker, allowing fire to settle down to grate; one-half hour's time of 1 man.
32......	250	500	After shutting down at 6 p. m., ashes raked out at water seal; 1 hour's time of 1 man.
19......	300	300	Ash removed from center of fire by rocking grate operated by compressed-air cylinder; fine ash is barred from lining and raked out; 2 hours' time of 1 man.
36......	300	300	Bar lining; shake grate; 1 hour's time of 1 man.
1.......	350	700	Raked out from bottom; 2 to 3 hours' time of 2 men.
16......	400	400	Ash is taken out at two intervals in 24 hours; 1 to 2 hours' time of 1 man.

PLANTS BURNING BITUMINOUS COAL.

3......	200	400	Air and steam cut off for a couple of days; ash and coal removed through water seal; 3 hours' time of 1 man.
37......	200	400	All free ash is removed from bed, leaving fire bridged; bed is then broken down and producer filled; 1½ hours' time of 2 men.
17......	250	500	Shaking the grates and pulling the ashes; three-fourths of an hour's time of 1 man.
39......	370	1,100	Remove sufficient ash from water seal to let bed down to normal level; work loose bed down to new level with poke bars; break clinkers off walls and smash fine with chisel bars and heavy hammers; 12 hours' time of 3 men is the minimum.
25......	300 400	1,400	(*a*) Clean by hand-operated rotary table; (*b*) clean by air-driven shaking grate; 5 minutes' time of 1 man; clean when running.
21......	650, 1,000	3,650	Not much of this to do.
5.......	1,000	4,000	Draw ashes till bed drops 1 foot; poke fire till solid; 1½ hours' time of 1 man.
12......	2,500	2,500	Twenty minutes to 1 hour's time of 1 man.

Data regarding methods of cleaning gas generators in various types of producer-gas plants—Continued.

UP-DRAFT PLANTS—Continued.

PLANTS BURNING LIGNITE.

Plant No.	Horse-power of each gas generator.	Total horse-power of plant.	Remarks of owner or operator regarding methods used to clean gas generator.
4	100	100	Burn low; rake and clean everything out; 6 hours' time of 2 men.
15	100	100	If run 3 days, 24 hours per day, take out everything; if run 14 hours a day, clean every day; for 3 days' run, 3 hours' time of 1 man.
11	250	500	Bar fires, and take out ashes, working around producer several times to prevent fire dropping; if gas becomes weak, stop a while; 1¼ hours' time of 2 men.
38	300	300	Run fuel bed down till 3 or 4 feet deep; open hoppers and all poke holes and draw out fire below; fire is kindled by layer of shavings and fine wood on grates about 12 inches deep; cover with layer of 4 inches of good dry coal; after well lighted, fill with coal; close hoppers and poke holes, starting gas washer for draft; 10 hours' time of 2 or 3 men.

PLANTS BURNING WOOD.

13	150	150	Producer cleaned daily by removal of ashes; scrubber pit cleaned every hour or so to avoid tar clogging the main; work done by 1 man.
26	200, 280	1,040	Beds lowered by removing ash once a month through water seal; 3 hours' time of 2 men.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

29	200	200	Dig out from bottom and punch down from top; 15 minutes' time of 1 man.
27	250	500	Let producer stand from Saturday till Monday; spray fire with water on top for 15 minutes; let stand for 1 hour; clean everything out; recharge with 2,000 pounds of coke; 10 hours' time of 2 men.
35	250	1,000	Fuel and ash are cleaned out every 2 weeks and new fires started; 4 hours' time of 6 men.
28	375,500	1,750	Clinker sometimes very hard and must be broken with bar from above; 6 to 10 hours' time of 8 men for each pair of producers.
22	500	500	All ash, refuse, and clinkers removed; 5 hours' time of 3 men.
8	800	3,200	Set is cut out; cooled with water; ashes removed; clinker cut down; 8 hours' time of 4 men.
23	1,500	6,000	Water sprayed through charging door directly after run till fire is cooled; coke withdrawn; ashes follow; 4 men, 3 days, 10 hours each.
24	1,500	9,000	Power-gas producer: Put fire out; remove clinker, coke, and ash; 2 to 4 days' time of 3 to 5 men. Heating-gas producer: Throw fire to one side; clean grate; throw fire back; repeat for other side; 1 to 2 hours' time of 1 man.

DOUBLE-ZONE PLANTS.

PLANTS BURNING BITUMINOUS COAL.

2	250	250	Not necessary to shut down to clean.
8	500	500	See procedure under "Down-draft plants."

OIL-GAS PLANT.

PLANT BURNING CRUDE OIL.

30	....	....	Raise stack valve, shut off blower, remove coke, close door, turn on blast, adjust oil, and lower stack; 10 minutes' time of 1 man.

SERIOUS CLEANING TROUBLES.

Data furnished by owners and operators regarding cleaning troubles in the different types of gas producers are presented in the tabulation following:

Data regarding cleaning troubles in various types of gas producers.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Horsepower of each gas generator.	Total horse-power of plant.	Remarks of owner or operator regarding cleaning troubles.
14......	75	150	None.
6.......	150	450	None. Only care is to guard against too much intake air.
9.......	160	640	Not to allow ashes and clinker to work up along walls.
32......	250	500	None.
19......	300	300	None.
16......	400	400	Taking out too many ashes, allowing bed to drop too low.
			PLANTS BURNING BITUMINOUS COAL.
3.......	200	400	Little trouble. If bed hangs it may burn man in falling.
37......	200	400	Occasional difficulty in breaking down the bridge; then must drive the bar through with the sledge.
39......	370	1,100	Impossibility of properly breaking up and settling clinker so as to maintain even fire.
5.......	1,000	4,000	None.
12......	2,500	2,500	None.
			PLANTS BURNING LIGNITE.
15......	100	100	Clinker.
11......	250	500	None unless fire is allowed to drop.
38......	300	300	None. Same lining in producer for 5 years. Cleaning out hard mixture of tar and ash deposit in gas collector and scrubber inlet pipe is dirty work and takes a little time.
			PLANTS BURNING WOOD.
13......	150	150	Filling of gas main by tar. This is burned out occasionally. To be done away with by improved gas cleaner.
26......	200, 280	1,040	Tar.
			DOWN-DRAFT PLANTS. PLANTS BURNING BITUMINOUS COAL.
29......	200	200	Poor gas and sometimes trouble with clinkers.
27......	250	500	Producer can not be cleaned while running.
35......	250	1,000	Heat and dirt.
28......	375, 500	1,750	Hard clinker.
22......	500	500	Chopping down clinker.
8.......	800	3,200	None.
23......	1,500	6,000	None.
24......	1,500	9,000	Hard clinker. . Loss of coke and thin fire to start next run.
			DOUBLE-ZONE PLANT. PLANT BURNING BITUMINOUS COAL.
8.......	500	500	None.
			OIL-GAS PLANT. PLANT BURNING CRUDE OIL.
30......	....	....	The rapidity with which generator must be cleaned. Reserve gas supply limited.

TIME BETWEEN PERIODS OF DRAWING PRODUCER FIRES.

The following tabulation gives data regarding time between periods of drawing producer fires in the various types of gas producers:

Data regarding time between periods of drawing producer fires in various types of gas producers.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Horsepower of each gas generator.	Total horsepower of plant.	Remarks of owner or operator regarding time between periods of drawing producer fires.
14	75	150	20 days.
20	200	....	45 days.
32	250	500	Present fire, 8 months; previous fire, 4 years.
19	300	300	Once a year.
36	300	300	Indefinite.
1	350	700	14 days. One producer each week.
16	400	400	Not drawn.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Total horsepower of plant.	Remarks
3	200	400	365 days.
37	200	400	10 days.
33	250	....	2 days.
39	370	1,100	Fires not drawn except for repairs.
21	650, 1,000	3,650	12 months.
5	1,000	4,000	Every third day.
12	2,500	2,500	6 months to 1 year.

PLANT BURNING LIGNITE.

Plant No.	Horsepower of each gas generator.	Total horsepower of plant.	Remarks
4	100	100	120 days.
38	300	300	About once a year.

PLANT BURNING WOOD.

Plant No.	Horsepower of each gas generator.	Total horsepower of plant.	Remarks
26	200, 280	1,040	3 months or more.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Total horsepower of plant.	Remarks
29	200	200	3 months.
20	250	....	45 days.
27	250	500	6 days; necessary to cut unit out when coke is 80 to 90 per cent burned out and producer badly clinkered.
35	250	1,000	12 days.
28	375, 500	1,750	14 days.
22	500	500	Weekly.
8	800	3,200	10 to 15 days.
23	1,500	6,000	13 to 17 days.
24	1,500	9,000	15 to 21 days.

DOUBLE-ZONE PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Total horsepower of plant.	Remarks
2	250	250	Do not draw fires.
8	500	500	10 to 15 days.

PLANT BURNING LIGNITE.

Plant No.	Horsepower of each gas generator.	Total horsepower of plant.	Remarks
31	200	....	2 years.

OIL-GAS PLANT.

PLANT BURNING CRUDE OIL.

Plant No.	Horsepower of each gas generator.	Total horsepower of plant.	Remarks
30	....	....	Every 8 hours.

METHODS OF SCRUBBING AND CLEANING GAS.

Data supplied by owners and operators regarding methods of scrubbing and cleaning the gas in the various types of gas producers follow.

Data regarding methods of scrubbing and cleaning gas in various types of gas producers.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE.

Plant No.	Horse-power of each gas generator.	Replies from owners or operators.
6	150	Counter flow wet coke tower scrubber and excelsior dry scrubber.
20	200	Coke.
34	250	Water spray dripped through coke.
19	300	Static washer.
36	300	Static scrubber. Centrifugal tar extractor.
1	350	Wood cross sections through which water flows.
16	400	Coke between 1 and 2 inches with water sprays.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horse-power of each gas generator.	Replies from owners or operators.
3	200	Latticed spray scrubbers, rotary tar extractors and purifiers.
37	200	Rotary water-jet scrubber.
17	250	Smith type "F" tar extractors connected in series.
33	250	Preliminary wet scrubber, counter current. Rotary scrubber and dry scrubber.
39	370	Cooled in first pass of wet scrubber, passed through wooden checker work which is sprayed with water. Passed through centrifugal tar extractor to holder.
25	300, 400	Cooling, spraying, and tar extracting. Wood centrifugal tar extractor on one plant and Smith static tar extractor on the other.
21	650, 1,000	Saaler washers. Four coolers with water spray. No filling in coolers.
5	1,000	Buffalo scrubber. No dry scrubber used. Gas for heating purposes and not for engines.
12	200 300 2,500	Smith type "F" spun-glass tar extractors.

PLANTS BURNING LIGNITE.

Plant No.	Horse-power of each gas generator.	Replies from owners or operators.
4	100	Cooling with water and passing through mechanical scrubber.
11	250	Gas passes through baffles of 2-inch by 4-inch timbers placed on edge, set close together, 14 feet high. Four streams of water flush each scrubber. Gas then passes through tar extractor.
38	300	Spray scrubber and mechanical gas washer (tar extractor).

PLANTS BURNING WOOD.

Plant No.	Horse-power of each gas generator.	Replies from owners or operators.
26	200, 280	Static scrubber, centrifugal tar extractor.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horse-power of each gas generator.	Replies from owners or operators.
29	200	Cooled with water spray. Passed through coke with water running over it and down through 6 or 8 feet of straw.
27	250	Scrubbers, 28 inches in diameter by 14 feet, each with seven water sprays. Each exhauster has 16 sprays, throwing water at 40 pounds' pressure against first impeller running at 3,500 revolutions per minute.
35	250	Passed through wet and dry scrubber, coke and excelsior.
28	375, 500	Passed through wet scrubber and then exhauster and dry scrubber. One wet scrubber filled with excelsior, other with coke. Both dry scrubbers filled with excelsior.
22	500	Cooling in boiler, wet scrubber and dry scrubber.
8	800	Static wet scrubbers with water sprays, dry scrubber with excelsior.
23	1,500	Gas runs down center of cooler through spray, up inside of shell, through sprays and through a rotary scrubber.
24	1,500	Plant A—through vertical boiler, spray cooler, and centrifugal scrubber. Plant B—gas is not clean except from one producer. Special use. Cooled centrifugal tar scrubber and dry cleaner.

Data regarding methods of scrubbing and cleaning gas in various types of gas producers—Continued.

DOUBLE-ZONE PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horse-power of each gas generator.	Replies from owners or operators.
2	250	Wet scrubber.
8	500	Static wet scrubber with water sprays. Dry scrubber with excelsior.

PLANT BURNING LIGNITE.

Plant No.	Horse-power of each gas generator.	Replies from owners or operators.
31	200	Water spray.

OIL-GAS PLANTS.

PLANTS BURNING CRUDE OIL

Plant No.	Horse-power of each gas generator.	Replies from owners or operators.
10	400	Static scrubber filled with baffles cleaning gas to about 1½ grains per cubic foot. Buffalo Forge centrifugal scrubber cleaning to about 0.02 grain per cubic foot. Used 2 years without sign of need of change.
30	....	Gas is forced through three turns, 10 inches by 18 feet, against a gravity flow of water running over baffle plates.

TIME BETWEEN RENEWALS OF SCRUBBER MATERIAL.

The owners and operators questioned furnished little information relating to the time between changes in the scrubber material used in the producer-gas installations. The few plants that reported indicated the periods to be as follows:

Time between renewals of scrubber material in various types of producer-gas plants.

UP-DRAFT PLANTS.

Plants burning anthracite coal.

Plant No.	Time between renewals of scrubber material, months.
20	12
16	12
6	[a] 24 to 36 [b] 3 to 6
9	6
34	48
Plants burning bituminous coal.	
33	8
12	2 to 5
21	3
Plant burning lignite.	
11	Never.
Plant burning wood.	
26	Never.

[a] Coke. [b] Excelsior.

DOWN-DRAFT PLANTS.

Plants burning bituminous coal.

Plant No.	Time between renewals of scrubber material, months.
29	6 to 12
35	a 12 b 0.5
22	c 2 d 0.5
8	1¼
24	1 to 1½

a Coke. b Excelsior. c Top. d Bottom.

OPINIONS REGARDING SCRUBBING AND CLEANING RESULTS.

The various owners and operators were asked whether the scrubbing and cleaning results in their producers were satisfactory, and if not, why. The data obtained on this point are presented below:

Data regarding satisfactoriness of scrubbing and cleaning results in various types of gas producers.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding satisfactoriness of scrubbing and cleaning results.
6	150	Satisfactory.
9	160	Do.
20	200	Do.
32	250	Do.
34	250	Do.
19	300	Do.
36	300	Do.
1	350	Fairly.
16	400	Satisfactory.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding satisfactoriness of scrubbing and cleaning results.
3	200	Satisfactory.
37	200	Very satisfactory.
33	250	Not satisfactory. Considerable tar remains in gas and clogs engine valves.
39	370	As satisfactory as ever observed in pressure up-draft producer using bituminous coal.
25	300,400	Satisfactory.
21	650,1,000	Does very well, though gas carries tar after cleaning.
5	1,000	For heating purposes; not for gas engines.
12	200 300 2,500	Entirely satisfactory.

PLANTS BURNING LIGNITE.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding satisfactoriness of scrubbing and cleaning results.
4	100	Satisfactory.
7	100	Do.
11	250	Satisfactory. Tar gives no trouble whatever in engine.
38	300	Satisfactory. Except occasional cleaning each 3 to 4 months. Tar is of soft paraffin nature, but contains a resinal substance, and when dry is hard to remove.

PLANTS BURNING WOOD.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding satisfactoriness of scrubbing and cleaning results.
13	150	Not satisfactory. Are preparing more complete arrangements to recover acids and tars for utilization and for elimination of condensed matter in gas mains.
26	200,280	Not satisfactory. On account of moisture and tar.

Data regarding satisfactoriness of scrubbing and cleaning results in various types of gas producers—Continued.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding satisfactoriness of scrubbing and cleaning results.
29......	200	Reasonably satisfactory. Slight trouble from tar.
27......	250	Does not remove lampblack.
35......	250	Not satisfactory. Considerable dirt and dust get by.
28......	375, 500	Pipes have to be cleaned out occasionally.
22......	500	Not entirely satisfactory. Soot and lampblack not completely removed.
8.......	800	Satisfactory.
23......	1,500	Entirely satisfactory.
24......	1,500	Plant A—satisfactory; plant B—new outfit; good so far (5 months).

DOUBLE-ZONE PLANTS.

PLANTS BURNING BITUMINOUS COAL.

2.......	250	Not satisfactory. Does not remove tar.
8.......	500	Satisfactory.

PLANT BURNING LIGNITE.

31......	200	Satisfactory.

OIL-GAS PLANTS.

PLANTS BURNING CRUDE OIL.

10......	400	No tar.
30......	....	Not satisfactory. Very difficult to get out the floating carbon.

MANNER IN WHICH TAR GIVES TROUBLE.

Data obtained from the operators and owners in response to a query as to the way in which tar gave trouble are presented in the tabulation following:

Data regarding tar troubles in various types of gas producers.

UP-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horse-power of each gas generator.	Statement of owner or operator regarding tar troubles.
3.......	200	No operating trouble.
37......	200	Clogs the governor valve on engine.
33......	250	Choking and sticking of engine valve.
39......	370	Clogs mains, fitings, engine regulators, and inlet valve passages. Frequent cleaning of all gas piping required.
25......	300, 400	No trouble.
21......	650, 1,000	Most in gas house in handling. Have little trouble where gas is used.
5.......	1,000	Chokes pipes between cooling tower and washers.
12......	200 300 2,500	No trouble at all.

Data regarding tar troubles in various types of gas producers—Continued.

UP-DRAFT PLANTS—Continued.

PLANTS BURNING LIGNITE.

Plant No.	Horse-power of each gas generator	Statement of owner or operator regarding tar troubles.
4	100	No serious trouble.
11	250	No trouble at all.
38	300	No trouble with any part of engine except governor valve chamber and mixing valve chamber. Must be cleaned every 3 months.

PLANTS BURNING WOOD.

Plant No.	Horse-power of each gas generator	Statement of owner or operator regarding tar troubles.
13	150	Clogging mains.
26	200, 280	In long gas lines to engine and admission valves.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horse-power of each gas generator	Statement of owner or operator regarding tar troubles.
29	200	Makes engine valve stick and causes some trouble in exhauster.
27	250	Produced only when starting new fire. Clogs ports in exhauster.
35	250	Clogs scrubbers.
28	375, 500	No trouble.
8	800	Do.
23	1,500	Do.
24	1,500	Labor for cleaning water seal, stopping sprays in cooler and scrubber. Small amount collects at burners in few months, interfering with the seating of mushroom valves on the line.

DOUBLE-ZONE PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horse-power of each gas generator	Statement of owner or operator regarding tar troubles.
2	250	Sticking intake valves.
8	500	No trouble.

PLANT BURNING LIGNITE.

Plant No.	Horse-power of each gas generator	Statement of owner or operator regarding tar troubles.
31	200	On valves of engines.

OIL-GAS PLANT.

PLANT BURNING CRUDE OIL.

Plant No.	Horse-power of each gas generator	Statement of owner or operator regarding tar troubles.
30	....	Causes throttle, poppet, and inlet valves and stack to choke.

TROUBLE CAUSED BY LAMPBLACK.

Data supplied by owners and operators regarding trouble caused by lampblack follow:

Data regarding trouble from lampblack in various types of producers.

UP-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator	Remarks of owner or operator regarding trouble caused by lampblack.
3	200	Stops water outlet in spray scrubbers.
37	200	By collecting in and reducing area of gas mains.
33	250	Lampblack mixing with tar.
39	370	No trouble observed. If any, it is mixed with tar.
25	300, 400	No trouble.
21	650, 1,000	Choking flues in producers and coolers.
12	200, 300, 2,500	No trouble.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

27	250	Mixes with oil and gums engine valves.
35	250	Clogs scrubbers.
28	375, 500	Deposits in pipes.
22	500	In engine cylinder. Deposits on inlet valves.
8	800	No trouble.
24	1,500	Do.

DOUBLE-ZONE PLANT.

PLANT BURNING BITUMINOUS COAL.

8	800	No trouble.

OIL-GAS PLANTS.

PLANTS BURNING CRUDE OIL.

10	400	Gradually chokes gas line and soots up gas valves. Requires cleaning every 6 months; 10-hour job.
30	....	Clogs gas main. Works by piston rings and mixes with lubricating oil.

RELATION OF TAR OR LAMPBLACK IN ENGINE TO COST OF LUBRICATION.

In response to a query as to whether the cost of engine lubrication is materially increased by the presence of tar or lampblack in the engine, the following information was supplied:

Data regarding relation of lampblack in gas-producer engine to cost of lubrication.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator in response to the query: "Is the cost of engine lubrication increased by the presence of tar or lampblack?"
		UP-DRAFT PLANTS.
		PLANT BURNING ANTHRACITE COAL.
9......	160	No.
		PLANTS BURNING BITUMINOUS COAL.
3......	200	No.
33......	250	Yes.
39......	370	Not determined.
25......	300, 400	No.
21......	650, 1,000	Not greatly.
5......	1,000	Yes.
		PLANT BURNING LIGNITE.
4......	100	No.
		PLANT BURNING WOOD.
26......	200, 280	Yes.
		DOWN-DRAFT PLANTS.
		PLANTS BURNING BITUMINOUS COAL.
29......	200	No.
22......	500	Not materially.
8......	800	No.
23......	1,500	Yes.
24......	1,500	Think not.
		PLANT BURNING LIGNITE.
38......	300	No. No lampblack ever seen.
		DOUBLE-ZONE PLANTS.
		PLANTS BURNING BITUMINOUS COAL.
2......	250	No.
8......	500	Do.
		PLANT BURNING LIGNITE.
31......	200	Yes.
		OIL-GAS PLANTS.
		PLANTS BURNING CRUDE OIL.
10......	400	No.
30......	....	No. Use cheap oil.

BURNER TROUBLE CAUSED BY TAR AND LAMPBLACK.

Data supplied by owners and operators regarding trouble from tar or lampblack clogging the gas burners in the various types of gas producers follow; the number at the beginning of each paragraph indicates the plant that supplied the information:

5. None.
9. None.
12. None.
13. Burner is piece of 8-inch iron pipe; clogged sometimes; cleaned once per month.
17. Latest burner gives no trouble.
22. None.
24. No trouble. Remove some lump tar from burners about once each two months.
25. Gas so cleaned that no trouble is experienced.
30. None.
32. None.
35. Burners clog.
38. None.

TROUBLE FROM SULPHUR IN PRODUCER GAS.

Data regarding trouble from sulphur in producer gas as experienced by the various owners and operators follow:

Data regarding trouble from sulphur in gas of various types of gas producers.

UP-DRAFT PLANTS.

Plant No.	Horsepower of each gas generator.	Replies from owners or operators.
		PLANTS BURNING ANTHRACITE COAL.
9	160	None.
20	200	Do.
18	300	Trouble; by clogging passages where velocity of flow is changed and by eating out sheet-steel parts.
19	300	None.
		PLANTS BURNING BITUMINOUS COAL.
3	200	Cuts water-cooled valves.
37	200	None.
17	250	When producer has stood over for 20 hours sulphur is noticed by men at furnaces.
25	300, 400	None.
21	650, 1,000	Trouble.
5	1,000	Trouble; causes distress among employees.
12	2,500	Trouble; high sulphur gives unpleasant fumes in factory.
		PLANTS BURNING LIGNITE.
11	250	Exhaust valve seats become pitted.
38	300	None, except that engine exhaust has deteriorated roof metal work, guy ropes, etc.

DOWN-DRAFT PLANTS.

Plant No.	Horsepower of each gas generator.	Replies from owners or operators.
		PLANTS BURNING BITUMINOUS COAL.
29	200	None.
20	250	Do.
35	250	Do.
28	375, 500	Do.
22	500	Trouble; acts on valves and pipes, and particularly on exhaust.
8	800	No serious trouble.
23	1,500	None.
24	1,500	Do.

PROPORTION OF SULPHUR ALLOWABLE IN FUEL.

The owners and operators were asked as to what percentage of sulphur could be present in the gas-producer fuel without causing inconvenience to the workmen. Summarized data supplied in the replies follow:

Data regarding percentage of sulphur allowable in fuel for producer-gas plants.

UP-DRAFT PLANTS.

PLANT BURNING ANTHRACITE COAL.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding percentage of sulphur allowable in gas-producer fuel.
19......	300	1.5 to 1.75 per cent.

PLANTS BURNING BITUMINOUS COAL.

17......	250	3 per cent.
33......	250	2 per cent.
21......	650, 1,000	Not over 1 per cent.
12......	2,500	1.5 per cent.

PLANT BURNING LIGNITE.

38......	300	Do not know per cent, but have seen sulphur plainly visible on fuel and had no trouble.

DOUBLE-ZONE PLANTS.

PLANTS BURNING BITUMINOUS COAL.

2.......	250	1 per cent has never caused trouble; none higher used.
8.......	500	Approximately 1.5 per cent.

AUXILIARY POWER USED.

Many producer plants require a small amount of auxiliary power for the operation of tar extractors, blowers, pumps, exhausters, air compressors, etc. This total auxiliary power varies with the different conditions of plant operation and is, as a rule, less for plants operating with anthracite coal than for plants using tar-producing fuels. An idea of the amount of auxiliary power required may be had from the data presented in the table following, which shows the amount installed and the amount actually used.

Auxiliary power used at various producer-gas plants.

UP-DRAFT PLANTS.

Plant No.	Fuel used.	Total horsepower of plant.	Total horsepower of installed auxiliaries.	Proportion of total plant horsepower— Installed in auxiliaries.	Actually used by auxiliaries.
				Per cent.	*Per cent.*
38	Lignite	300	6.0	2.0	1.3
3	Bituminous coal	400	4.0	1.0	1.0
37	do	400	18.0	4.5	3.3
16	Anthracite coal	400	15.0	3.75	
11	Lignite	500	25.0	5.0	5.0
33	Bituminous coal	500	30.0	6.0	6.0
32	Anthracite coal	500	10.0	2.0	
18	do	600	15.0	2.5	1.3
12	Bituminous coal	1,000	17.0	1.7	1.7
26	Wood	1,040	70.0	6.7	1.9
39	Bituminous coal	1,100	165.0	15.0	6.2
25	do	1,400	113.0	8.0	3.9
34	Anthracite coal	1,500	10.0	0.7	0.7
12	Bituminous coal	2,500	65.0	2.6	2.6
5	do	4,000	105.0	2.6	2.0
Average				4.3	2.8

DOWN-DRAFT PLANTS.

Plant No.	Fuel used.	Total horsepower of plant.	Total horsepower of installed auxiliaries.	Installed in auxiliaries.	Actually used by auxiliaries.
29	Bituminous coal	200			3.0
20	do	250	5.0	2.0	
22	do	500	10.0	2.0	2.0
27	do	500	48.0	9.5	5.0
35	do	1,000	100.0	10.0	10.0
8	do	3,200	170.0	4.0	2.9
23	do	6,000	160.0	2.7	2.0
24	do	9,000	450.0	5.0	1.7
Average				5.0	3.8

So much depends on the details of the installation, the number of hours of service per week, and the commercial demands regarding reliability that there may be little relation between the actual auxiliary requirements of different plants. A summary of the data presented in the preceding table follows:

Summary of data regarding auxiliary power used at various producer-gas plants.

Kind of plant.	Proportion of total plant power— Installed in auxiliaries. Maximum.	Minimum.	Average.	Actually used by auxiliaries. Maximum.	Minimum.	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Up draft	15.0	0.7	4.3	6.2	0.7	2.8
Down draft	10.0	2.0	5.0	10.0	2.0	3.8

TROUBLE FROM PRODUCER AUXILIARIES.

Data regarding serious trouble with producer auxiliaries were requested from the various owners and operators. A summary of the information furnished follows:

Data regarding trouble from auxiliaries used with gas producers.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding serious trouble with producer auxiliaries.
14	75	No trouble.
6	150	Do.
9	160	Do.
20	200	Do.
32	250	Do.
18	300	When fan-type exhausters were used on outlet of producer they were eaten away by sulphurous compounds.
19	300	No trouble.
36	300	Do.
16	400	Do.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding serious trouble with producer auxiliaries.
3	200	No trouble.
37	200	Do.
33	250	Trouble; scrubber gets choked with tar.
39	370	Tar extractors become clogged and passages of scrubbers using excessive power cause high pressures at top of producers, causing gas to leak around poke hole, causing distress to operators. Further, under such conditions flues in fire develop rapidly when pressure is relieved at time poke holes are opened for inspection.
25	300, 400	No trouble.
21	650, 1,000	Do.
5	1,000	Do.
12	2,500	No trouble except that due to mechanical defect in steam engine driving the gas pump.

PLANTS BURNING LIGNITE.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding serious trouble with producer auxiliaries.
4	100	No trouble.
15	100	Do.
11	250	Do.
38	300	Do.

PLANTS BURNING WOOD.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding serious trouble with producer auxiliaries.
13	150	No trouble.
26	250	Do.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding serious trouble with producer auxiliaries.
29	200	No trouble.
20	250	Do.
27	250	Trouble on starting new fires a little coal tar is produced, clogging exhauster. Cleaned every 3 weeks.
35	250	No trouble.
28	375, 500	Do.
22	500	Do.
8	800	Do.
23	1,500	Do.
24	1,500	Do.

Data regarding trouble from auxiliaries used with gas producers—Continued.

DOUBLE-ZONE PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding serious trouble with producer auxiliaries.
2.......	250	No trouble.
8.......	500	Do.

PLANT BURNING LIGNITE.

31......	200	No trouble.

OIL-GAS PLANTS.

PLANTS BURNING CRUDE OIL.

10......	....	No trouble.
30......	....	No trouble; wash water pump collects tar on runner shaft.

TIME REQUIRED TO BRING GAS PRODUCERS TO FULL GAS PRODUCTION AFTER STAND-BY.

A summary of the information furnished by owners and operators regarding the time required to bring the various types of producers to condition of normal demand after a stand-by follows:

Data regarding time required to bring various types of gas producers to condition of normal demand after a stand-by.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding time required for producer to reach full production after stand-by.
6.......	150	1 hour after 18 hours.
32......	250	½ hour after 14 hours.
34......	250	3 hours Monday forenoon.
18......	300	½ hour after 13 hours.
19......	300	1 hour after 14 hours.
36......	300	40 minutes after 14 hours.
1.......	350	½ hour.

PLANTS BURNING BITUMINOUS COAL.

3.......	200	½ hour after 12 hours.
37......	200	1 hour after 14 hours.
17......	250	1 hour to come in on main line after 10 hours.
33......	250	1 hour after 12 hours.
39......	370	1 to 2 hours after 12 hours.
25......	300, 400	1 hour after 12 hours.
21......	650, 1,000	¾ hour after 13 hours.
5.......	1,000	1½ hours after 24 hours.
12......	2,500	½ hour to 1 hour after 14 hours.

Data regarding time required to bring various types of gas producers to condition of normal demand after a stand-by—Continued.

UP-DRAFT PLANTS—Continued.

PLANTS BURNING LIGNITE.

Plant No.	Horsepower of each gas generator.	Remarks of owner or operator regarding time required for producer to reach full production after stand-by.
4	100	20 minutes after 12 hours.
7	100	1 hour after 12 hours.
11	250	2 hours after 12 hours.
38	300	20 minutes to ½ hour after 8 hours; 1 hour to 1½ hours after 1 week.

PLANT BURNING WOOD.

26	200, 280	½ hour after 24 hours to 1 week.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

29	200	Service continuous.
27	250	Can start engine in 15 minutes after 12 hours, but takes about 1 hour to get to working well.
23	1,500	4 hours after 32 hours.
24	1,500	30 minutes to 1 hour after 12 hours.

DOUBLE-ZONE PLANTS.

PLANTS BURNING BITUMINOUS COAL.

2	250	½ hour after 18 hours.
8	500	1 hour after 16 hours.

OIL-GAS PLANT.

PLANT BURNING CRUDE OIL.

30	....	Producer shows good efficiency after 10 minutes' operation.

STAND-BY FUEL.

Many controversies have arisen regarding the stand-by losses in producer-gas plants. What this percentage may be under test and what it is under commercial operating conditions are two widely different values. Several writers on the subject are in the habit of allowing per stand-by producer hour from 3 to 6 per cent of the fuel charged in the producer per operating hour.

An attempt was made to procure figures covering commercial operation in several plants but the returns were so greatly at variance that no deductions of value could be presented. The figures reported show stand-by percentages ranging from 3 to 33.

QUANTITY OF WATER USED BY PRODUCER PLANTS.

The quantity of water actually required in the operation of a producer-gas plant and the quantity used by the plants reporting seem to bear little relation to each other. This variance is largely due to the fact that most of the plants reporting seem to have ample water supply in close proximity so that the water cost is small.

Obviously, the quantity of water required in both the generation of the gas and in the cleaning process will vary according to the type of producer plant, the character of the fuel used, the method of operation, and the efficiency of the scrubbing devices.

QUANTITY OF VAPORIZER WATER USED.

The quantity of vapor used by the gas generators per pound of fuel fired was not reported by the operators queried. Previous investigations have indicated that for up-draft plants this figure usually runs from 0.7 to 1 pound of water for the vaporizer to each pound of anthracite coal fired. With bituminous coals, lignites, peats, wood, and other fuels the quantity of water required by the vaporizer will vary greatly with the percentage of moisture contained in the fuel. With bituminous coals in up-draft plants this figure seems to be not far from that required for anthracite coals. The average for 20 bituminous coals taken at random shows 0.7 pounds of water per pound of coal.

On the other hand, a series of investigations with one grade of fuel in an up-draft plant showed the quality of the gas to vary little for a range of vaporizer consumptions from 0.7 pound to 1.12 pounds.

In using peat it has been found that if the peat contains 25 or 30 per cent moisture no steam is necessary in the operation of the plant.

In one plant in this country operating on lignite the supply of available water is seriously limited. The moisture contained in the lignite is, however, sufficient to more than make up the vaporization requirements so that in the process of cooling the gases enough water vapor is condensed to more than offset the losses. This plant is, therefore, actually increasing its water supply during operation.

During a series of tests with a down-draft producer at the Pittsburgh station of the Bureau of Mines, the average consumption of water by the vaporizer was as follows:

Consumption of water by vaporizer in down-draft producer of Bureau of Mines.

Fuel.	Water per pound of fuel as fired, pounds.
Bituminous coal	0.23
Lignite	.00
Peat	.00

QUANTITY OF SCRUBBER WATER USED.

The quantity of water required for scrubbing the gas in the operation of a producer-gas plant is reported by different writers as follows:

(*a*) 1 gallon per 40 cubic feet of gas washed.

(*b*) 3.3 gallons per brake horsepower-hour.

(*c*) 10 to 15 pounds per pound of fuel used in the gas generator.

If these quantities are reduced to the basis of cubic feet of water required per 1,000 cubic feet of gas washed the range is as follows:

(*a*) 3.3 cubic feet per 1,000 cubic feet of gas.

(*b*) 6 cubic feet per 1,000 cubic feet of gas.

(*c*) 2.6 to 3.9 cubic feet per 1,000 cubic feet of gas.

The latter figures indicate an average of approximately 4 cubic feet of water required for scrubbing 1,000 cubic feet of gas.

During the operation of the testing station of the Bureau of Mines the quantities of scrubber water averaged approximately as follows:

9.7 cubic feet per 1,000 cubic feet of gas with the up-draft plant, including the centrifugal tar extractor.

10.5 cubic feet per 1,000 cubic feet of gas with the down-draft plant.

Figures supplied by the operators of several plants are as follows:

Quantities of scrubber water used in different gas producers.

Plant No.	Fuel.	Operation.	Quantity of scrubber water per pound of fuel.
			Pounds.
37	Bituminous coal	Up-draft	76
17	do	do	26
39	do	do	67
25	do	do	36
25	do	do	31
22	do	Down-draft	116
8	do	Down-draft and double-zone.	95

If these figures are reduced to cubic feet of water per 1,000 cubic feet of gas washed by assuming that 1 pound of bituminous coal is equivalent to 61, 90, and 83 cubic feet of gas for up-draft, down-draft, and double-zone producers, the values are as follows:

Quantities of scrubber water used per 1,000 cubic feet of gas scrubbed.

Plant No.	Water per 1,000 cubic feet of gas scrubbed, cubic feet.
37	19.9
17	6.8
39	17.5
25	9.5
25	8.1
22	20.6
8	16.9
Average	**14.2**

The range between the temperature of the water entering and that of the water leaving the scrubber seems to depend more on the quantity of water available than on any predetermined temperature as the proper one for the water leaving the scrubber.

The prevailing temperature for the water entering the scrubber is 50° to 90° F., and for the water leaving it 75° to 200° F., the average being about 110° F.

The temperature rise recorded for the different plants is as follows:

Rise in temperature of scrubber water at different plants.

Plant No.	Temperature rise, °F.
14	45
3	8
37	10
15	50
1	155
26	37
39	44
25	45
21	70
22	15
8	55
2	10
10	40

QUANTITY OF WATER REQUIRED TO COOL ENGINE.

The quantity of water required in engine cooling is reported by various writers as follows:

(*a*) For single-acting engines, 5 to 7 gallons per horsepower-hour.

(*b*) For large double-acting engines, 4.5 to 5.5 gallons per horsepower-hour for cylinders, stuffing boxes, valves, etc., and 1.75 to 2.25 gallons per horsepower-hour for pistons and pistons rods; or a total ranging from 6.25 to 7.75 gallons per horsepower-hour.

(*c*) Twenty-five to fifty pounds per brake horsepower-hour, or 3 to 6 gallons.

(*d*) For a producer-gas engine, single-acting and of less than 200 horsepower, the normal consumption of water per brake horsepower-hour at full load is 5.5 gallons for cooling the engine.

(*e*) For engines of 2 to 1,000 horsepower, for cylinder covers and stuffing boxes, 5.5 to 6.5 gallons; pistons and rods, 2 to 2.5 gallons; boxes, seats, and exhaust valves, 1 to 1.75 gallons. Total, 9 to 11 gallons per brake horsepower-hour.

(*f*) With a temperature range of 90° F., 45 pounds or 5.5 gallons will be required per horsepower-hour. In large engines the consumption is smaller, or about 4.25 gallons. To be on the safe side the cooling water may be estimated at 5.5 to 8 gallons.

If the various values be reduced to the common basis of cubic feet of water per horsepower-hour, the figures are as follows:

Quantity of engine-cooling water required in various plants on basis of cubic feet per horsepower-hour.

Report.	Cooling water per horsepower-hour, cubic feet.
a	0.67 to 0.93
b	.83 to 1.03
c	.40 to .80
d	.73 to .73
e	1.20 to 1.47
f	.67 to 1.07
Average	.75 to 1.00

The Bureau of Mines figures show an average of 0.82 cubic foot per horsepower-hour for a three-cylinder, single-acting engine of 250 horsepower.

The wide variation in practice is shown by the following figures from plant operators:

Quantity of engine-cooling water required at different producer-gas plants.

Plant No.	Cooling water per horsepower-hour, cubic feet.
37	3.36
25	2.80
35	2.56
22	1.01
8	2.18
8	2.56

The inlet temperatures reported for the cooling water range from 50° to 90° F. and the outlet temperatures from 86° to 160° F., the average being about 115° F.

LUBRICANTS USED.

The quantity of oil required per horsepower-hour varies with the character of the installation and the method of operation. For full load, 24-hour service, the proportion per horsepower-hour is of course greater than for a plant running under light load for a 9-hour or 10-hour day. Some of the figures given by the engine manufacturers for the quantity of engine oil required are as follows:

1. For a 200-horsepower engine, the oil amounts to 1.25 gallons per 10-hour day, or 0.625 gallon per 1,000 horsepower-hours.

2. For a 65-horsepower engine, the oil used is $\frac{1}{2000}$ gallon per brake horsepower-hour, or 0.500 gallon per 1,000 horsepower-hours.

3. For a 100-horsepower engine, inclosed crank case, 0.5 gallon per 10 hours, or 0.500 gallon per 1,000 horsepower-hours.

4. For a 140-horsepower engine, inclosed crank case, 1 gallon per 10 hours, or 0.715 gallon per 1,000 horsepower-hours.

5. For a 125-horsepower engine, inclosed crank case, 1 quart per 10 hours, or 0.200 gallon per 1,000 horsepower-hours.

The average of these quotations is 0.508 gallon per 1,000 horsepower-hours. The plant operators reported their commercial requirements to be as follows:

Quantity of oil used in lubricating engines in various gas producers.

Plant No.	Horsepower of engines.	Length of service per day.	Cylinder oil used per 1,000 horse-power-hours.	Engine oil used per 1,000 horse-power-hours.	Other lubricants used per 1,000 horse-power-hours.
		Hours.	*Gallons.*	*Gallons.*	*Gallons.*
4	100	8	2.0		
7	100				1.25
14			1.8	1.3	
3	40, 160	16	2.8		
16	190	24		1.0	
11	500	24	1.25		
9	80, 160, 200, 375	12	1.5	3.0	
12	200, 500	24		1.26	
39	300	24	.75	.4	.8
25	750	10	.5	.17	.07
21	125		.13	.4	.1
35	150, 250, 300, 600		.5	1.0	
22	500	10	.5	.6	.14
23	500, 1,000	10	.4	.6	
24	300, 2,000	24	2.7	5.3	.7
2	115, 300, 750	24	.25	.5	
30		24	1.25		
Average			1.17	1.11	.51

The average of a number of returns from the operators of reciprocating steam engines indicates the consumption of cylinder oil and engine oil to be approximately the same and to equal 0.13 gallon each per horsepower-hour. On this basis the oil consumption of gas engines seems to be approximately eight or nine times as much as that of reciprocating steam engines. This difference is perhaps not surprising, as the lubricating requirements of the gas engine are much more severe than those of the steam engine, but the ratio seems rather high.

PREIGNITIONS AND THEIR CAUSES.

Data supplied by owners and operators regarding preignitions and their causes follow. The numbers preceding each paragraph refer to plant numbers assigned by the author.

Are preignitions frequent and troublesome.—To what do you attribute them?

Up-Draft Plants.

Plants burning anthracite coal.

1. Yes. Carbon deposits.
6. No.
9. No. Most trouble from too high compression.

14. No. Excessive hydrogen.
16. No.
18. No.
19. No.
20. No. Excessive hydrogen.
32. No.
34. No. Hydrogen.
36. No.

Plants burning bituminous coal.

3. No, if good coal is used and valves are tight. Hydrogen, bad gas, and leaky valves.
12. No.
21. None.
25. No. Overhanging fire or hot particles of carbon from lubrication.
33. No.
37. No.
39. No.

Plants burning lignite.

4. Yes; at times. Carbon deposits, etc.
7. No.
11. Only for first hour after starting. Excessive hydrogen.
15. No.
38. Very seldom. To a hot spot or "chimney" in producer forming high hydrogen or to small particles of tar being sucked off governor valve and holding fire in cylinder. Stopped by throttling gas valve and then sweeping cylinder with air.

Plants burning wood.

26. Sticking valves from tar.

Down-Draft Plants.

Plants burning bituminous coal.

8. No.
20. No. Excessive hydrogen.
22. Yes. Dirt, incandescent points, too rich mixture.
23. No.
24. No.
27. Had trouble for a while, but seldom now . Holes or channels in fires.
28. After water gas run and when air inlet valve leaks. Too rich gas.
29. No. Do not have any.
35. No. Carbon.

Double-Zone Plants.

Plants burning bituminous coal.

2. No.
8. No.

Plants burning lignite.

31. At times. Sticking valves.

OIL-GAS PLANTS.

Plants burning crude oil.

10. No. Very little. Small portions of lampblack carrying a spark.
30. No. Excess hydrogen under high compression.

CHANGING OR CLEANING IGNITERS.

The time interval for reliable use of engine igniters is of course more or less dependent on the constituents of the gas, the degree of cleanliness, the amount of sulphur, the engine construction, and the care in operation. The table following indicates the reported practice in this connection:

Data regarding changing cr cleaning of igniters in gas producers.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Period of operation each day.	Period before igniter is cleaned or changed.
	Hours.	
14......	24	Cleaned each month; lasts 4 years.
19......	24	2 months.
16......	24	¾ month.
6.......	24	¼ month.
9.......	24	½ month.
1.......	5-24	1½ months.
34......	24	¼ month.
18......	11½	Do.

PLANTS BURNING LIGNITE OR BITUMINOUS COAL.

4.......	8	⅔ month.
7.......	11	2 months.
3.......	24	¼ month.
37......	10	½ month.
33......	14	Do.
12......	24	¼ to ½ month.
39......	24	2 months.
25......	10	8 months.
21......	10	2 months.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

29......	24	Years.
27......	10	¼ month.
35......	10	½ month.
22......	10	4 months.
8.......	24	2 months.
23......	24	3 months.

DOUBLE-ZONE PLANTS.

PLANTS BURNING BITUMINOUS COAL OR LIGNITE.

31......	24	1 month.
2.......	24	Do.

GAS PRESSURES AND DISTANCES FOR GAS DELIVERY.

It is interesting to note that in practically all of these plants the gas is delivered at a short distance from the producer. The reports from 36 plants show a range of distances of 15 to more than 3,000 feet. Twenty-four plants deliver their gas at distances not exceeding 100 feet and only 5 deliver gas to a distance exceeding 500 feet.

None of these plants carries gas at any considerable pressure. The range seems to be from a slightly less than atmospheric to 2¼ pounds higher than atmospheric. In the majority of instances the positive pressure ranges from 1 to 8 ounces.

RECOVERY OF BY-PRODUCTS FROM WASTE LIQUORS FROM SCRUBBERS, WASHERS, ETC.

To the query regarding recovery of by-products from waste liquors from scrubbers, washers, etc., the answers were all "None recovered" with the exception of four. Two operators report a special effort to procure the tar; one stated that he recovered the by-products, but gave no further information, and the fourth reported "Not yet."

COMMERCIAL USE MADE OF TAR PRODUCED.

The various owners and operators were asked what commercial use was made of the tar produced in their plants and what price was received for it. The data supplied are presented below. The numbers preceding each paragraph refer to plant numbers assigned by the author.

2. None.

3. None.

4. None.

5. None.

7. None.

9. No tar.

11. No market for tar from lignite.

12. Fired under boilers in main boiler plant. Saves 5 tons of coal per day, equal to $10.

13. Distilled for wood oil, creosote, and pitch.

14. None recovered.

17. Run back into producer.

21. Burned under boiler to make steam for use in gas plant.

23. No tar.

24. Mixed with coal and burned in hand-fired boiler. Not satisfactory.

25. Utilized in steam-boiler plant. The tar from one of the producers returns to the producer and is gasified.

26. Returned to producer by spreading on fuel.

28. None.

30. None.

35. None.

37. Burned under boiler.

38. One barrel per day goes to Puget Sound with scrubber water. Formerly burned with fuel oil under boilers, but caused some trouble on account of water. Will soon sell it or burn it again. Worth about $1.10 per barrel if burned under boiler.

39. Originally provision was made for introducing the tar into the producer combustion zone, but the tar was too stiff to handle.

COMMERCIAL UTILIZATION OF CARBON RESIDUE FROM OIL-GAS PRODUCERS.

Only two replies were received to the query, Is the carbon residue from oil-gas producers commercially utilized, and if so, how? Plant 10 reported that the residue was used under boilers, and plant 30 reported that it was used as fuel in blast furnaces.

ENRICHMENT OF PRODUCER GAS.

The various owners and operators were asked whether they knew of any plants that enriched the producer gas. Replies to this inquiry indicated that the enriched producer gas was used to some degree, but not generally. Three or four companies were reported to be using this enriched gas for illuminating purposes. One plant enriched the producer gas with gasoline vapor for use in brazing.

TEMPERATURE REQUIRED AT FURNACE.

Data received from the various owners and operators regarding the temperature required at the furnace follow.

10. About 1,400° F.
12. 950 to 1,050° F. in leers.
13. 650° F.
17. 1,700° F.
21. 1,300 to 2,200° F.
24. As high as 1,500° F.
25. 1,500 to 2,000° F.

SPARE CAPACITY AND POWER ACTUALLY AVAILABLE.

Practically the same general rules that govern the installation of spare boiler units in steam plants control the installation of spare producer units. The principal points that have to be considered are reliability of plant and continuity of service.

The need of reserve boiler units is, however, much greater under normal operating conditions on account of the necessity of frequent boiler cleaning. Although the intermittent type of producer must be cleaned at regular intervals, depending in length on the percentage of ash in the fuel, the continuous type may be run for years without the fires being drawn if clinker troubles are not excessive.

An examination of the data at hand shows no relation between the daily hours of service and the installation of spare units. Of the plants from which reports were received, ranging in capacity from

100 to 9,000 horsepower, about one-third have reserve units of 20 to 50 per cent of the total installed power.

Ten years ago most gas producers for power purposes were overrated in capacity.

This overrating was the natural result of the blind use of European figures and became for a time a serious matter. Although the rating of such plants is far more conservative to-day, still an examination of the operating reports of 27 plants reveals the fact that approximately one-third of them have considerably less than 100 per cent of their capacity available. One instance is reported in which only 60 per cent of the rated capacity could be realized. The average percentage of available capacity for the plants that are below rating is 75.

On the other hand, 6 of the 27 plants show a capacity considerably above normal rating. The maximum is 155 per cent, and the average for the 6 is 132 per cent.

USES OF PRODUCER-GAS PLANTS.

To indicate the varied applications of producer gas and producer-gas power a brief tabulation is presented giving the information received from the 39 companies that reported. The numbers preceding the paragraphs refer to plant numbers.

1. Lights and power (5 to 24 hours per day).
2. Commercial lighting and power (24 hours per day).
3. Manufacture of acid phosphate (24 hours per day).
4. City water company (8 hours per day).
5. General factory purposes; also drying molds and covers.
6. Light and power (24 hours per day).
7. Milling flour (11 hours per day).
8. Induction motor drive (24 hours per day).
9. Lighting and power (24 hours per day).
10. Street and house lighting, ice making, refrigeration, etc. (16 hours per day).
11. Grinding cottonseed cake into meal for export.
12. Motor drives (24 hours per day, 6½ days per week). Gas also used for leers in glass bottling factory.
13. For heating wood-distillation retorts (22 to 24 hours per day).
14. For operating blowing engines and for oprating pyrites furnace (24 hours per day.
15. Light and power (14 hours per day).
16. Mining and concentrating iron ore (24 hours per day).
17. Hardening and annealing.
18. Machine shop, electric power (11½ hours per day).
19. Factory lighting and power, motor-driven ammonia compressor for raw-water ice making (summer, 24 hours per day; winter, 8 to 16 hours).
20. Electric lighting and power (24 hours per day).
21. Driving machinery by rope transmission from engine to line shaft (10 hours per day); also forge, annealing, and hardening.
22. Manufacturing (10 hours per day).

.3. Manufacture of plate glass, power (24 hours per day, 5½ days per week).

24. Excitation of direct-current electric generator, lights and general plant auxiliary; alternating-current motors driving grinding and polishing machines, 1,000 to 1,200 kilowatts on each alternating-current machine. (Continuous, 24 hours per day, 156 hours per week.) Also melting glass in furnaces and glass annealing.

25. Power in manufacturing plant (10 hours per day). Also hardening and annealing.

26. Power by direct drive and also direct-connected to direct-current generators (7 months, 24 hours per day; 5 months part load, 24 hours per day). Exhaust gas used to produce steam at 60 pounds pressure on vaporizers connected to engine exhausts.

27. Factory power.

28. Electric power for phosphate mining. Principal load is motor-driven centrifugal pumps (156 hours per week).

29. Oil mill, electric power (24 hours per day).

30. Pumping (24 hours per day).

31. Electric power (24 hours per day) and concentration of acid.

32. Machine-shop power (10 hours per day) and drying linings in foundry ladles.

33. Electric shop drive (14 hours).

34. Power in paper mill to drive beaters and pumps; also belted generators (24 hours per day, 6 days per week).

35. Power for manufacturing purposes, shops (10 hours per day); also for heating carbonizing furnaces.

36. Power for manufacturing (10 hours per day).

37. Shop power and lighting (9 hours per day).

38. Driving ammonia compressor and electric generator for power and light (45 months, 24 hours per day with not to exceed one stop per 20 to 30 days for cleaning and adjustments in the summer months; 7 to 8 months, 10 to 20 hours per day). Producer has had fires drawn not to exceed five times in five years.

39. Operating motor-driven centrifugal pumps, rotating and shaking screens and elevators, and for lighting purposes. Also conveyors, rotating dry kilns, washers, shops, etc. (24 hours per day).

RESPONSE OF PRODUCER TO SUDDEN CHANGES IN DEMAND.

Following are tabulated data relative to the response of various types of gas producers to sudden changes in demand:

Data regarding response of various types of gas producers to sudden changes in demand.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Horsepower of each gas generator.	Reply of owner or operator to the query, "Does the gas producer respond readily to sudden changes in demand?"
1	350	Yes.
6	150	Yes; for engine load fluctuation. Starting a second engine takes about 20 minutes before gas is strong.
9	160	Reasonably so.
14	75	Load is nearly constant. Believe it would be slow.
16	400	Yes.
18	300	Do.
19	300	Do.
20	200	Do.
32	250	Producer is so large that it instantly covers requirements.
34	250	One alone does not. Good on full number.
36	300	Yes.

Data regarding response of various types of gas producers to sudden changes in demand—Continued.

UP-DRAFT PLANTS—Continued.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Reply of owner or operator to the query, "Does the gas producer respond readily to sudden changes in demand?"
3	200	Yes; if fuel bed is in good shape.
5	1,000	Yes.
12	2,500	Do.
17	250	Do.
21	650, 1,000	No trouble.
25	300, 400	Yes.
33	250	No.
37	200	Yes; as long as fires are kept regular.
39	370	No.
		PLANTS BURNING LIGNITE.
4	100	Yes; when working well.
7	100	Yes.
11	250	Do.
15	100	Do.
38	300	Do.
		PLANTS BURNING WOOD.
13	150	Yes; about 5 minutes required for increase in volume.
26	200, 280	Yes.
		DOWN-DRAFT PLANTS.
		PLANTS BURNING BITUMINOUS COAL.
8	800	Perfectly.
20	250	Yes.
22	500	Have none.
23	1,500	Yes.
24	1,500	Do.
27	250	No.
28	375, 500	Proper care required.
29	200	No.
35	250	Demand is steady.
		DOUBLE-ZONE PLANTS.
		PLANTS BURNING BITUMINOUS COAL.
2	250	Yes.
8	500	Perfectly.
		PLANT BURNING LIGNITE.
31	200	Yes.

PERIOD OF CONTINUOUS OPERATION.

The data following were furnished in answer to a query regarding the period of operation of gas producers.

Period of continuous operation of gas producers.

UP-DRAFT PLANTS.

Plant No.	Horse-power of each gas generator.	Length of service each day.	Time in continuous operation.
PLANTS BURNING ANTHRACITE COAL.			
		Hours.	*Days.*
14	75	24	20
6	150	24	Continuous.
32	250	3 to 7	Do.
34	250	24	Do.
19	300	24	50
36	300	10	Continuous.
1	350	5 to 24	7
16	400	24	330
PLANTS BURNING BITUMINOUS COAL.			
17	250	....	6
33	250	14	2
25	300 400	10	Continuous.
39	370	24	3
21	650 1,000	10	Continuous.
5	1,000	16	6
12	2,500	24	180 to 360
PLANTS BURNING LIGNITE.			
4	100	8	200 to 300
7	100	11	6
15	100	14	3
11	250	24	Continuous.
38	300	24	Do.
PLANTS BURNING WOOD.			
13	150	....	7
26	200 280	24	7

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horse-power of each gas generator.	Length of service each day.	Time in continuous operation.
29	200	24	Continuous.
20	250	24	30
27	250	10	6
35	250	10	6
28	375 500	24	14
22	500	10	6
8	800	24	10 to 15
23	1,500	24	15
24	1,500	24	15 to 20

DOUBLE-ZONE PLANTS.

PLANT BURNING BITUMINOUS COAL.

Plant No.	Horse-power of each gas generator.	Length of service each day.	Time in continuous operation.
2	250	24	Continuous.

PLANT BURNING LIGNITE.

Plant No.	Horse-power of each gas generator.	Length of service each day.	Time in continuous operation.
31	200	24	730

RELIABILITY AND LENGTH OF SERVICE OF PLANTS.

The following queries were included in the general request for information sent to owners and operators of gas producers: Has the plant proved reliable? If not, what is the cause of failure? How many years has the plant been in service? The data supplied follow.

Data regarding reliability and length of service of producer-gas plants.

UP-DRAFT PLANTS.

PLANTS BURNING ANTHRACITE COAL.

Plant No.	Horsepower of each gas generator.	Total horse-power of plant.	Reply of owner or operator to queries.
14......	75	150	Yes. In service 7 years.
19......	300	300	Yes.
6.......	150	450	In service 3 years.
32......	250	500	Yes. In service 8 years.
9.......	160	640	Reasonably so. Have had a few minor troubles, but nothing serious. In service 7 years.
1.......	350	700	No. Too many little things that may happen to cause a shutdown, such as change of quality of gas and poor ignition. In service 3¼ years.
20......	200	....	Yes, after some minor changes.
18......	300	....	Yes. In service 4 years.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Total horse-power of plant.	Reply of owner or operator to queries.
3.......	200	400	Yes, very reliable. Plant competes with a hydroelectric plant that offers current at less than 2 cents per kilowatt-hour. A part of the plant is run with motors, but a majority of it is run from a main line shaft. The manufacturing processes require steady power 24 hours a day, 7 days a week. In service 9 years.
17......	250	500	Yes.
33......	250	....	No. Tar and gas stick valves of engine and choke scrubber and pipes.
39......	370	1,100	No. Irregularity in thermal quality of gas. Choking of gas mains and engine regulators with tar. Engines are undoubtedly rated too high. Improved mixing valves and gas-inlet passages would probably result in increased capacity. However, considerable expense would be involved. Plant has been superseded by 1,000-kilowatt steam turbine installed in 1911. In service 2 years.
25......	300, 400	1,400	Yes. One unit in service 3 years, and one unit 2 years.
12......	200,300,2,500	3,500	Yes. Power units in service 3 years; fuel unit, 1 year.
21......	650, 1,000	3,650	After first year. At first had some trouble on account of tar and with the washing equipment. Since October, 1913, have been using natural gas. In service 4 years.
5.......	1,000	4,000	Producers were operated 3 years continuously and were discontinued, but are still in good condition.

PLANTS BURNING LIGNITE.

Plant No.	Horsepower of each gas generator.	Total horse-power of plant.	Reply of owner or operator to queries.
4.......	100	100	Producer was bought for 100 horsepower, but at present does not have capacity of 90.
7.......	100	....	Yes. In service 5 years.
15......	100	100	No. Unit has not been run during the past 12 months. Failure thought to be due to prejudice on the part of engineer and helpers, or possibly the attention required was too tedious compared with the steam plant.
38......	300	300	Yes. Most trouble and expense has been with exhaust piping. This trouble was overcome by installing two short sections of water-jacketed exhaust pipes connecting into fire-brick lined steel shell placed between the twin engines and containing a stack of cast-iron water-heating spiders, or star-shaped sections, which heat all jacket water from 130° to 200° F. About one-half of this hot water is used for industrial purposes and the balance for humidifying the producer ash-pit air. In service 5 years and 4 months.
11......	250	500	Yes. In service 5 years.

Data regarding reliability and length of service of producer-gas plants—Continued.

UP-DRAFT PLANTS—Continued.

PLANTS BURNING WOOD.

Plant No.	Horsepower of each gas generator.	Total horse-power of plant.	Reply of owner or operator to queries.
13......	150	150	Yes. After finding out how to use wet wood. When plant was first started used up a large quantity of good dry wood on hand. Plant then put on very green wet wood, requiring much reconstruction of method of operation. In service intermittently for 2 years.
26......	200,280	1,040	Yes.

DOWN-DRAFT PLANTS.

PLANTS BURNING BITUMINOUS COAL.

Plant No.	Horsepower of each gas generator.	Total horse-power of plant.	Reply of owner or operator to queries.
29......	200	200	"All my figures have been destroyed, as we gave up the engine 2 years ago and have since had a fire. We are using hydroelectric power altogether and find it much more successful."
20......	250	....	Yes, after some minor changes.
22......	500	500	Yes. In service 7½ years.
35......	250	1,000	Yes. Company is now changing over to hydroelectric power. Producers and engines have been in service over 10 years and for many reasons are not using power economically, owing largely to rapid plant growth and necessarily poor power-plant location.
28......	375,500	1,750	One pair of producers in service 6 years and one pair 2 years.
8.......	800	3,200	Yes. In service 6 years.
23......	1,500	6,000	Yes. In service 4 years.
24......	1,500	9,000	To certain extent. Lack of knowledge of requirements to make good quality gas, including proper grade and kind of coals, grates, steam and air supply, and method of firing and cost of apparatus.

DOUBLE-ZONE PLANT.

PLANT BURNING BITUMINOUS CCAL.

Plant No.	Horsepower of each gas generator.	Total horse-power of plant.	Reply of owner or operator to queries.
2.......	250	250	Fairly. Most trouble from poor grade of coal. In service 2½ years.

PUBLICATIONS ON FUEL TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines is temporarily available for free distribution. Requests for all publications can not be granted, and applicants should limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.

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