Bulletin No. 334 Series Q, Fuels, 8

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

THE BURNING OF COAL WITHOUT SMOKE IN BOILER PLANTS

A PRELIMINARY REPORT

BY

D. T. RANDALL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

CONTENTS.

	Page.
Introduction	5
General conditions in the United States	5
City ordinances for smoke prevention	7
The production of smoke	11
The prevention of smoke in boiler plants	12
Feasibility	12
The principles of smokeless combustion	12
Proper furnace equipment	14
Difficulty in securing perfect combustion	16
Indirect methods of smoke abatement	20
Summary	21
Bibliography	22

THE BURNING OF COAL WITHOUT SMOKE IN BOILER PLANTS.

By D. T. Randall.

INTRODUCTION.

The technologic branch of the United States Geological Survey has been conducting investigations to determine the best method of utilizing the coals of the United States. The law under which this work has been carried on aims to increase the efficiency and to prevent the waste of these fuels, especially such as are used by the United States Government. It is a recognized fact that the more nearly perfect the combustion of any fuel the greater is its efficiency. With perfect combustion there is no smoke. In view of the need for more complete information on the conditions favorable to the burning of coal with economy and without objectionable smoke in boiler furnaces, extended tests have been made at the fuel-testing plants at St. Louis, Mo., and Norfolk, Va. The results of the St. Louis tests are summarized in the present paper,[1] which has been prepared by the author as engineer in charge of smoke-abatement investigations. In addition to this work a number of commercial plants in the larger cities have been inspected to ascertain what are the best methods now in use, and the information thus obtained will be published in a later bulletin.

GENERAL CONDITIONS IN THE UNITED STATES.

The prevention of objectionable smoke in the manufacturing and business centers of large cities is a problem that can not be easily solved. At present no city in which a considerable quantity of bituminous coal is burned is free from smoke. The cities of the East have avoided this problem by a general use of the smaller sizes of anthracite coal. For this reason it is not surprising that the greatest improvement in the methods of burning bituminous coal has been made in the Central and Western States.

Stoves, ranges, house-heating boilers, and hot-air furnaces are as a rule intended for the use of anthracite coal or coke. Whenever bituminous coal is burned in such furnaces all the principles of combustion are violated and smoke results. The supply of anthracite coal is limited, and except for domestic purposes such coal is little used outside of the territory adjacent to the mines. The larger cities of the Eastern States, which consume practically all the available supply of the smaller sizes of anthracite coal for power and heating purposes, now find it necessary to supplement this fuel with a considerable tonnage of bituminous coal. Except the power generated by waterfalls, nearly all the heat and power used in the United States are obtained from the burning of coal. It is evident, then, that for the most part this country must depend on its bituminous coal for manufacturing, railroad, and power-plant purposes. This means that we must improve our usual methods of burning bituminous coal or continue to suffer from the loss in economy and smoke resulting from imperfect combustion.

There are now three general methods of utilizing coal—in steam boiler and other furnaces, in gas-producer plants, and in by-product coke plants. Of these, the last two methods are readily operated to produce heat or power without smoke, but at the present time such plants are not numerous and consume only a small portion of the coal that is used in this country. It is predicted by persons who are enthusiastic regarding the economy and smokelessness of these methods that they will in time be used exclusively for the production of heat and power in all our large cities.

It has been demonstrated at the fuel-testing plants of the Geological Survey that bituminous coal of all grades can be burned in a gas producer without smoke, generating a gas which when used in a gas engine furnishes power with much greater economy than is usual in steam plants. With good grades of coal mined in the Eastern States a horsepower can be generated with about 1 pound of coal. One of the most important facts in connection with the gas-producer plant is that, besides being smokeless, it will utilize coals so high in ash as to be unsuitable for boiler furnaces. The lignite coals of the West are also particularly well adapted for use in the producer, though they are considered much inferior to bituminous coal for boiler furnaces. About fifty producer plants are now in operation in the United States, burning bituminous coal. Interest in such plants is increasing, and many new ones are being planned, ranging in capacity from 500 to 10,000 horsepower each.

That the coal supply is being wasted in many ways is a fact that has been frequently brought to the attention of the public. One waste results from the ordinary methods of manufacturing coke, in which all of the gas from the coal is allowed to escape into the air. This loss has led to the installation of a few by-product coke plants in which coke is made and the resulting gas is piped to points where fuel is needed and there consumed. Other valuable products from the distillation of coal are also obtained. These plants, furnishing both coke and gas as fuel, constitute a considerable factor in the prevention of smoke in the cities near which they are located, as both fuels are burned readily without smoke for domestic purposes and for manufacturing industries requiring heat or power. The convenience and cleanliness of these fuels will probably lead to an increase of their production and use.

It is reported that there are 30 by-product coke plants in this country, with a total of more than 3,000 ovens, using nearly 20,000 tons of coal a day. It is estimated that these plants manufacture daily more than 50,000,000 cubic feet of gas. The following are some of the cities near which they are located: Chicago and Joliet, Ill.; Milwaukee, Wis.; Duluth, Minn.; Detroit and Wyandotte, Mich.; Ensley and Tuscaloosa, Ala.; Chester, Dunbar, Everett, Lebanon, Sharon, and Steelton, Pa.; Wheeling, W. Va.; Buffalo, Geneva, and Syracuse, N. Y.; Cleveland and Hamilton, Ohio.

In many manufacturing plants furnaces that were formerly fired with coal are now using crude oil, natural or manufactured gas, coke, or coal burned on automatic stokers. All these methods are giving good results in preventing smoke.

CITY ORDINANCES FOR SMOKE PREVENTION.

With the knowledge that it can be prevented, there has come an increasing demand from the people of the large cities that smoke shall not be allowed to pollute the atmosphere. This is true not only of the United States, but also of most European countries. For example, the importance of burning bituminous coal economically and without smoke led the Prussian government some time ago to furnish traveling instructors at an expense of about $10,000 a year for the training of firemen throughout the State, licenses being given to competent firemen. There are also in Prussia a number of boiler-supervision societies, which employ skilled firemen to direct the work done by the regular employees of the plants owned by members of the society.

In nearly all cities of the United States efforts are being made to abate the smoke given off by manufacturing, steam-boiler, and domestic furnaces in which bituminous coal is burned. As a result of the demands of the public the ordinances of some of these cities require that all new plants be equipped properly and that old ones be remodeled, and permits are now necessary for the installation of all boilers and furnaces. Most ordinances define the degree of blackness of smoke which constitutes a violation of the law. In general, it may be said that in this country the only excuse recognized for black or dense gray smoke is that the fires are being built or cleaned, but no such excuse is valid in many of our cities. The conditions in a number of the larger cities of the United States are about as follows:

The Baltimore ordinance contains a clause which practically excepts the manufacturing plants of the city. Cases brought into court were dismissed on account of defects in the ordinance, and an attempt is being made by the smoke-abatement league to secure the enactment of one that will be more effective. There are on record about 660 steam plants in Baltimore, not including heating plants. Of this number only 12 are equipped with automatic stokers.

The Buffalo ordinance is not effective, as it simply declares the emission of large quantities of smoke to be unlawful. In addition to the work of the smoke inspector, active efforts to improve the conditions have been made by the Society for Beautifying Buffalo.

The Chicago ordinance makes it unlawful to permit dense smoke to escape from any furnace except for six minutes of each hour during the time when fires are being started or cleaned. Members of the City Club of Chicago have taken an active interest in the suppression of smoke. There has recently been a reorganization in the smoke inspector's office and a committee of engineers has been appointed to assist and advise with that official. The following is a partial list of the equipment installed in Chicago: Plants with chain-grate stokers, 70; with overfeed stokers, 40; with underfeed stokers, 12; with special hand-fired furnaces, 40. In addition to these there are many small plants equipped with steam jets and other appliances.

The Cincinnati ordinance establishes a standard for density of smoke permitted and allows a period not exceeding six minutes in any hour during which the fires are started. During the past year citizens of Cincinnati have formed a smoke-abatement league and by public subscription raised a fund to pay the salary of a smoke inspector working under the league's direction. The city smoke inspector's office has been reorganized and a number of suits regarding fines for allowing stacks to smoke are pending in the courts. Action on other plants has been withheld until these cases are settled. The furnace equipment in Cincinnati is as follows: Down-draft furnaces, 90; other furnaces, 5; inclined-grate stokers (*a*) side feed, 113; (*b*) front feed, 56; (*c*) underfeed, 89; automatic steam jets, hand fired, 48; steam jets, not automatic, hand fired, 247.

The Cleveland ordinance excepts private residences, but dense gray or dense black smoke from other furnaces is declared to be in violation of the law. According to the records of the smoke inspector's office there are about 1,800 boilers in the city, equipped as follows:

Furnace equipment in Cleveland.

	Boilers.	Plants.
Chain-grate stokers	200	40
Inclined-grate stokers	400	164
Underfeed stokers	170	34
Down-draft furnaces	50	....
Automatic steam jets	400	131
Nonautomatic steam jets	125	110
Miscellaneous devices, Dutch ovens, etc	....	50
Smokeless coal used under	500	....

The Detroit ordinance makes it unlawful to allow dense gray or black smoke to escape from any chimney. The smoke inspector is assisted by a committee of the chamber of commerce, and good results are being obtained. It is reported that in 1906 the following new equipment was installed: Mechanical stokers, 108; automatic smoke-prevention devices, 12; steam jets, 16.

The Indianapolis ordinance makes the production of dense gray or black smoke subject to a penalty, private residences being exempt. The efforts toward smoke abatement in this city are confined to the office of the smoke inspector. According to that official's report for the year ending December 31, 1906, the following equipment was in use:

Furnace equipment in Indianapolis.

	Boilers.	Plants.
Underfeed stokers	43	10
Inclined-grate stokers	100	18
Traveling-grate stokers	48	10
Down-draft furnaces	5	....
Smokeless furnaces, brick-arch construction	15	....
Automatic steam jets	65	....
Total number of boilers in operation, reported	828	....

At present there is no effective ordinance in Louisville and no smoke inspector. A movement has been started by a number of citizens to form a smoke-abatement league for the purpose of securing the passage of an ordinance and the organization of a smoke-inspection department. Last year there were in this city, in addition to the hand-fired plants, 13 plants with down-draft furnaces, 11 with chain-grate stokers, 18 with inclined-grate stokers, and 4 with underfeed stokers.

Milwaukee has an effective ordinance and the smoke-inspection department is doing a considerable amount of educational work among the manufacturers. The inspector reports that during 1905 the following installations were made: Underfeed stokers, 32; chain-grate stokers, 2; inclined-grate stokers, 15; down-draft furnaces, 6; automatic steam jets, 44; total, 99.

The ordinance of New York City makes no exception and provides a penalty for the emission of dense black smoke from any furnace. The smoke-abatement committee has been active in bringing offenders against the law into court, and a number of power plants are installing additional equipment to comply with the smoke ordinance. In this city 12,200 stationary boilers are on record, but there is no record of the furnaces and equipment. It is reported, however, that there are 26 plants equipped with stokers of the overfeed type and 2 with stokers of the underfeed type. Many of these stoker plants are exceptionally large.

The Philadelphia ordinance declares the emission of smoke of greater density that the established standard unlawful, except from locomotives or steam craft standing with banked fires, or during a period of ten consecutive minutes when fires may be in process of being cleaned or started. Exception is also made of river craft in continuous transit through the city. The smoke-inspection department is assisted by the efforts of the citizens' committee, which has been active in creating a public sentiment in favor of smoke abatement. The number of boilers in the entire city, as reported by the chief inspector, is 8,194, of which 2,132 are using soft coal. The number of stokers and appliances for abating smoke is 220.

The Pittsburg ordinance declares that the production of dense black or dense gray smoke, except from private residences, is unlawful, but while a new fire is being started or the fires are being cleaned such smoke is allowed for a period of eight minutes in any hour.

The St. Louis ordinance provides a penalty for allowing dense smoke to escape into the air. According to this ordinance it is a good defense if the person charged with the violation shall show to the satisfaction of the jury or of the court that there is no practicable device, appliance, means, or method by which the emission of dense smoke could have been prevented. St. Louis has, in addition to its smoke-inspection department, a smoke-abatement committee maintained by the Civic League. According to the report of the smoke inspector for 1906, there were in the city plants with the following furnace equipment: Steam jets, 550 plants; down-draft furnaces, 264 plants; fire-brick arches, etc., 50 plants; automatic stokers, 19 plants.

An ordinance has recently been passed in Toledo, and the smoke inspector is making an effort to cooperate with the owners of plants in the suppression of smoke. The ordinance makes an exception of private residences, dense gray or black smoke from all other furnaces being a violation of the law.

The law governing the abatement of smoke in Washington and the District of Columbia makes an exception of private residences, but provides a penalty for dense gray or black smoke from all other sources. The law is rigidly enforced and there is but little smoke from bituminous coal.

THE PRODUCTION OF SMOKE.

The term smoke as used in this paper refers to chimney gases that contain small particles of unconsumed carbon, which give the gases a dark color. Smoke may be of any degree of blackness, but what some persons would call smoke is not considered smoke by others.

Smoke is due to a lack of air at the proper temperature at the point where the volatile gases should be burned, the result being that these gases are only partly burned and the carbon is set free. The density of smoke is measured in many ways, but the most satisfactory at present is by means of the Ringelmann charts. These charts are made by drawing black lines at right angles on a white background. The lines are so spaced as to give the effect of different percentages of blackness when placed at a distance of about 50 feet from the observer. The charts are numbered 1, 2, 3, 4, and 5, and represent, respectively, 20, 40, 60, 80, and 100 per cent of black smoke. As a matter of fact, anything but a clean stack will result in a smoky atmosphere. If a stack continuously emits a small amount of smoke, it may, during the course of the day, have given off as much carbon and have had as bad an effect as another stack which has been clear most of the time, but which for three or four periods of five minutes each has emitted a dense black smoke. In localities where bituminous coal is burned exclusively a plant is considered good if the average blackness is equivalent to 5 per cent or less.

The following information, taken from the report of the committee for testing smoke-preventing appliances, Manchester, England (see p. 24), is of interest:

Observations were made for an entire day on 179 chimneys. The general averages of these stacks gave the equivalent of black smoke 102 minutes in 10 hours. The averages for the individual stack varied from the equivalent of black smoke for 423 minutes in the worst to 4 minutes in the best. The relative amount of the smoke from different kinds of equipment may be taken as follows:

Average of 36 hand fires with air admission, 81 minutes in 10 hours; average of 10 hand fires with air admission, good firing, 40 minutes; average of 4 sprinkling stokers, about 103 minutes in 10 hours; average of 21 coking stokers, about 16 minutes in 10 hours; best coking stokers, about 4 minutes in 10 hours.

Coking stokers show best economy as well as prevention of smoke.

Sheffield Association suggest that the permissible limit of smoke emission should vary with the number of boilers as follows: For 1 boiler, 2 minutes per hour; for 2 boilers, 3 minutes per hour; for 3 or more boilers, 4 minutes per hour.

The following are reasons why furnaces sometimes smoke:

1. The furnaces and the grates are not properly designed to burn the coal available. There is almost no equipment on the market that will handle equally well all the fuels found in the United States.
2. There is a lack of sufficient draft.
3. The firemen are unskilled.

4. There is not enough combustion space.
5. Wood, paper, and other refuse are burned.
6. The load is changed quickly.
7. Excessive overloads are maintained.

THE PREVENTION OF SMOKE IN BOILER PLANTS.

FEASIBILITY.

Within the last few years there has been a remarkable development in the utilization of coal under the steam boiler. To-day many steam power plants in the United States are burning bituminous coal practically without smoke. This has been brought about by improving the design of the furnaces and by careful attention on the part of the fireman.

It is now possible to design and operate boiler plants burning a high-volatile coal which will be practically smokeless under usual operating conditions, giving off no black or dense gray smoke except when a fresh fire is being built. Banking the fire, shutting dampers, etc., causes smoke of a light or gray shade only. This has been demonstrated at the engineering experiment station of the University of Illinois, where a boiler has recently been installed, properly equipped with a furnace for burning Illinois coal. Under ordinary conditions this plant makes no smoke whatever. This equipment is not suitable for burning low-volatile coals such as are largely used in the East. In experimenting with this furnace an effort was made to produce smoke, but it was found impossible to make black smoke, the worst being about 50 per cent black.

A number of large commercial plants having properly designed furnaces are now operating daily without smoke in many of our larger cities. Reports on some of these plants inspected by engineers connected with the technologic branch will be published in a subsequent bulletin.

THE PRINCIPLES OF SMOKELESS COMBUSTION.

Coal can be burned smokelessly, the same as gas, gasoline, or kerosene oil, if the equipment is properly designed and adjusted. Each of these fuels will give off smoke if conditions are not favorable. All the authorities on the subject of combustion and smoke prevention agree upon the following conditions as requirements for a smokeless furnace:

1. The coal should be supplied to the furnace in small quantities at frequent intervals. The more nearly the feed approaches a continuous and uniform supply the better the results.

2. The air supply should be slightly in excess of the theoretical amount required and be admitted principally through the fuel bed, with an auxiliary supply admitted at the front or rear of the furnace to burn gases from the coal.

3. The temperature in the furnace should be sufficiently high to ignite the gases given off from the fuel bed.

4. There should be a fire-brick combustion chamber of sufficient dimensions and so designed as to cause the thorough mixture of the gases and air, permitting complete combustion before the mixture reaches the boiler surfaces.

Much has already been written on the theory and chemistry of combustion. "Steam-boiler economy," by William Kent, and "Steam boilers," by Peabody and Miller, are both good works on this subject. (See p. 23.)

It has been found in this country, as well as in Europe, that when smoke is given off, there is also a loss of carbon monoxide (CO) and other combustible gases. The loss due to the carbon which we see and call smoke is seldom more than 1 per cent, but the loss due to the escape of the combustible gases may amount to an additional 3 to 10 per cent.

The steam-engineering section of the technologic branch has found, as have other investigators, that, contrary to general opinion, with extremely high temperatures more smoke is produced and more unburned gases are lost up the stack. High temperature is of course due to a supply of air approaching the theoretical amount, and on account of the difficulty of obtaining a complete mixture of the gases and air some gas is allowed to escape unburned. (See Table 1.)

The combustible gas most frequently found in the flue gases is carbon monoxide (CO). This gas is nearly always present when the stack gives off black smoke, indicating imperfect combustion. Hydrogen and hydrocarbon gases may also be expected in connection with the CO, but on account of the difficulty of determining the small percentages of these gases they are seldom recorded, though the loss due to their escape is considerable. In confirmation of these statements, the accompanying tables are submitted. Table 1 gives a summary of the relation of smoke to unburned gases and combustion-chamber temperatures as determined from more than 200 boiler tests made at the St. Louis fuel-testing plant.

TABLE 1.—*Relation of smoke to CO and combustion-chamber temperatures.*

	Per cent of black smoke.						
	0.	0 to 10.	10 to 20.	20 to 30.	30 to 40.	40 to 50.	50 to 60.
Number of tests	37	18	56	51	36	17	4
Average per cent of smoke	0	7.1	15.5	24.7	34.7	43.1	52.9
Average per cent of CO in flue gases	0.05	0.11	0.11	0.14	0.21	0.33	0.35
Average per cent unaccounted for in heat balance	9.14	10.60	9.46	10.93	11.41	13.41	13.34
Number of tests[a]	26	16	48	45	32	17	4
Average combustion-chamber temperature (°F.)	2,180	2,215	2,357	2,415	2,450	2,465	2,617

[a] Temperatures in combustion chamber were not determined on all tests.

Table 2, from the Manchester report (see p. 24), gives analyses of chimney gases, including determinations of hydrogen (H) and methane (CH_4), which occur in small percentages.

TABLE 2.—*Analyses of chimney gases.*

Boiler.	Smoky.						Clear.					
	CO_2.	O_2.	CO.	CH_4.	H_2.	N_2.	CO_2.	O_2.	CO.	CH_4.	H_2.	N_2.
No. 1, hand fired	11.00 10.65	6.90 6.45	0.90 2.15			81.20 80.75						
No. 1, with smoke-prevention device							7.00 9.00	13.50 9.75	0 0			79.50 81.25
No. 2, hand fired	10.25	8.60	.50	0	0	80.65						
No. 3, hand fired	13.25	3.50	.05	0.25	0	82.95						
No. 4, fire under caustic pot, hand fired	10.95	1.30	3.00	.70	3.23	80.82						
No. 5, split bridge, hand fired	8.75	7.00	3.25	.40	1.00	79.60						
No. 6, with smoke-prevention device							7.25	12.00	0	0	0	80.75
No. 7, with smoke-prevention device							7.15	12.15	0	0	0	80.70
No. 8, with smoke-prevention device							8.15	11.10	0	0	0	80.75

Table 3, compiled from results obtained at the fuel-testing plant, shows that the losses due to the escape of CO and other combustible gases may be considerable and that they are of more importance than the gain from a corresponding increase in carbon dioxide (CO_2). It is evident that the prevention of smoke and the efficiency of the plant are very closely related.

Calculations showing the theoretical losses due to the presence of combustible gases in the flue gases have been made and the results published in "A study of four hundred steaming tests."[a]

TABLE 3.—*Relation of CO to efficiency.*

Number of tests.	15	11	29	25	21	28	42	32	34	49	7
Average per cent of CO_2 in flue gases	7.69	9.46	9.29	9.09	9.48	9.48	9.90	9.60	9.57	10.22	10.94
Average per cent of CO in flue gases	.63	.53	.27	.22	.17	.19	.13	.16	.12	.15	.10
Average efficiency (72*)[a]	52.96	56.73	59.56	62.08	63.43	64.58	65.55	66.41	67.48	69.10	71.73

[a] For discussion of efficiency 72* see A study of four hundred steaming tests: Bull. U. S. Geol. Survey No. 325, 1907.

PROPER FURNACE EQUIPMENT.

Numerous inventions for preventing smoke have been made, based, according to the inventors, on the recognized principles discussed in the foregoing section. Most of them have not been properly designed to meet the severe service to which a boiler furnace is subjected.

[a] Bull. U. S. Geol. Survey No. 325, 1907, pp. 100–101.

The proper design of the furnace and settings, including the breeching and stacks, is a subject of much dispute. All authorities, however, agree that sufficient air must be admitted to allow complete combustion. This means that ample draft must be provided. Stacks less than 125 feet high are usually unsatisfactory, but steam or electrically driven fans are now very commonly used to produce either forced or induced draft in connection with stacks shorter than would otherwise be required.

Provision should be made for the admission of air above the fuel bed. It is also now generally conceded that there should be a fire-brick chamber of sufficient length to allow time for the gases and air to mix and burn. Numerous observations made on power plants show that it takes an average of twelve seconds for the gases to pass from the furnace to the top of a stack 125 feet high. This allows but one second for combustion to take place before the gases leave the combustion chamber. These conditions have been so successfully met in some plants as to permit the use of low-grade coal without the production of objectionable smoke. These plants are few when compared to the total number in operation, but they indicate the possibilities of securing practically perfect combustion.

In general, furnaces designed for burning coal may be divided into two general classes, as follows:

I. Those into which coal is shoveled at intervals by hand:

- (*a*) Plain or rocking grates, with no fire-brick arch.
- (*b*) Same as *a*, with steam jet under a small combustion space.
- (*c*) Plain or rocking grates, with a fire-brick arch, large combustion space, and provision for admitting air over the fire either at the front or at the bridge wall.
- (*d*) Plain or rocking grates, with large or small combustion chamber and with or without fire-brick arch, equipped with steam jets and air-admission dampers which close automatically after each firing.
- (*e*) Combinations of any two or more of the above.
- (*f*) Down-draft furnaces, consisting of two grates, the upper one of water tubes to prevent its destruction by the heat, and the lower one like the common hand-fired grate. The fire is built on the upper grate, and coal is fed or shoveled on top of the fire. The furnace is so arranged that the gases and flame pass down through the upper grate and over the lower one, on which a fire of coke, supplied from the upper grate is maintained.

II. Those to which coal is fed continuously by an automatic device:

(*g*) Powdered-coal devices, in which particles of coal are thrown or blown into the furnace and burned before reaching the bottom of the combustion chamber, which must be of fire brick.

(*h*) Sprinkling stokers.—Devices for automatically feeding and distributing small sizes of coal as evenly as possible over the entire grate surface. Automatic shaking grates are usually installed with this apparatus.

(*i*) Coking stokers:

1. Overfeed stokers, in which the coal is fed continuously and coked under a fire-brick arch. Special provisions are made to admit air to mix with the volatile gases. These may be further subdivided into front-feed and side-feed stokers.
2. Traveling chain-grate stokers, in which the coal is fed at the front under a fire-brick arch and the entire surface of the gate moves toward the bridge wall at a rate which allows all the coal to be consumed.
3. Underfeed stokers, in which the coal is automatically fed at frequent intervals beneath the bed of hot fuel, air is forced through the burning coal by means of a fan, and as the volatile gases are given off from the fresh coal they mix with the air and pass up through the fire. Under favorable conditions combustion is completed within a short distance from the surface of the fuel bed.

DIFFICULTY IN SECURING PERFECT COMBUSTION.

With so great a variety of furnaces to choose from it seems at first thought that there should be no difficulty in abating smoke. It is, however, difficult to construct a furnace that will be smokeless under any and all conditions of operation. Some furnaces now in operation are practically so, conforming to every requirement outlined for smokeless combustion, but there is no type of grate or stoker on the market to-day which does not give off offensive black smoke in some of the plants in which it is installed. This may or may not be due to faults in the furnace. It may be due to lack of combustion space or to improper handling.

The efficiency of the furnace and the degree of success attained by any equipment in the prevention of smoke depend on the following factors: Skill of the fireman, proper design of the furnace and boiler setting, character of the coal, capacity of the boilers and furnaces, and load carried.

The skill of the fireman is the most important element in connection with the ordinary equipment. As a matter of fact, the personal element is the greatest hindrance to progress in the abatement of smoke. Both the owner and the fireman must be interested to obtain the best results. Intelligent supervision in the boiler room to secure proper air admission and care in firing will result in the saving of the losses due to smoke or unconsumed gases and to heating an excessive amount of air. At many plants such supervision has reduced the coal bills by 5 to 20 per cent, depending on the coal and the methods formerly in use.

It is a generally conceded fact that intelligent men trained in boiler-room practice could save 10 per cent of the fuel used in 50 per cent of the plants of the United States, and that in another 25 per cent of the plants such men could save 5 per cent of the fuel. It is the practice of nearly all large power plants to employ a boiler-room expert, and many of them have chemists who make frequent tests and investigations to determine the conditions favorable to the best economy. The saving of only a small percentage of the coal consumed will make a handsome return for the cost of the experimental work. There are now in a few of our larger cities competent engineers who are making a specialty of supervising boiler plants for a number of firms.

A few examples of carelessness and indifference on the part of firemen will in a measure explain why many persons are skeptical regarding the value of mechanical stokers and other smoke-preventing devices.

At a plant which had a smoke-preventing device, but which was smoking, the fireman said a connecting chain had been broken for several days and he "didn't have time to bother with it." It would not have required more than ten minutes to join the two ends with wire for a temporary repair. In another plant the fireman said: "The thing takes too much steam, and I shut it off." Many other cases of willful neglect have been observed.

Very few firemen can be induced to fire regularly and frequently, because it is easier to put in enough coal to last twenty or thirty minutes at one time and have little or nothing to do in the interval between firings. In one instance the engineer took occasion to measure the draft between the grates before and after firing on a down-draft furnace which had a good draft. The draft before firing was 0.35 inch of water, but after the fireman had thrown on 63 shovelfuls of coal the flow of air was so seriously retarded that the draft increased to 0.62 inch. Great volumes of smoke were given off, indicating this lack of air.

Professor Benjamin, in his paper on smoke and its abatement (see p. 23), speaking of steam and air jets, expressed himself as follows:

"It is a very effective method of smoke prevention, and is used very largely in Cleveland. I have not given it very much weight in my paper, because it depends so much upon the individuality of the engineer and fireman. I have found that men who use that means had to be watched so continually and reprimanded so much that I got out of patience with that sort of prevention."

Difficulties are also encountered with stokers. One of the greatest troubles is the tendency of the fireman to poke the fires unnecessarily instead of using or adjusting the attachments provided for feeding and handling the coal. In many plants where it is possible they will shovel green coal into the stokers, instead of feeding it through the hopper, and then take a bar and stir up the fresh coal with the coke and ashes, causing smoke and wasting the coal.

It is not an uncommon experience that on inspection the boiler tubes are found to be covered with scale on one side and soot on the other. One plant with nearly 4,000 horsepower had soot hanging from the surfaces of the tubes, and on inquiry it developed that these tubes had not been cleaned for a period of four months, no cleaning having been done since the new master mechanic had taken charge.

The following quotation is from the Manchester report, already cited (see p. 24):

Negligent management of the self-acting damper is responsible for much of the smoke from hand firing. * * * No doubt its use obviates to some extent the necessity for constant attention, but in many cases it has been disconnected after attention has been drawn to the smoke.

The foregoing examples emphasize the facts that the management of the boiler room is a problem for properly trained men and that as the coal burned is a considerable item of expense, averaging about 50 per cent of the cost of producing power, there is more opportunity to save in the boiler room than in the engine room with any given equipment. The average boiler room is a hot, dirty, and otherwise unattractive place. For these reasons but little attention has been paid to it by superintendents and operating engineers in moderate-sized plants. The boiler rooms are managed for the most part by men hired not so much for what they know as for their ability to do hard work, and they get comparatively small wages. There are, however, some mechanical appliances, such as the chain grate, which leave but little to the skill of the fireman. (See "Suppression of industrial smoke," by A. Bement, cited in bibliography, p. 23.)

Many furnaces may be classed as smokeless when attended by careful men, but unsatisfactory when fired by ordinary firemen. In some power plants it is difficult for even a trained man to secure reasonable economy and prevent smoke. This may be due to the fact that the plant is poorly designed. It does not follow that a plant having a high chimney will have a sufficient draft. The chimney may be too small, or there may be many elbows in the flues leading from the boiler to the stack, or there may be serious leakage of air through holes in the flue, boiler setting, and breeching. A poor draft is responsible for a great deal of trouble in the boiler room. Difficulty in burning coal in some one furnace in a plant has been reported where investigation showed that the damper had turned on its shaft and instead of being open, as the fireman supposed, was nearly closed. Such difficulties can be avoided only by systematic supervision.

In many plants the grate surface is not properly proportioned to the load carried. This can be remedied in hand-fired furnaces, but not without considerable expense in stoker plants. Some plants maintain fires under too many boilers for good economy; on the other hand, there are probably more in which the furnaces are overloaded.

The hand-firing of plain furnaces violates all the principles laid down for securing good combustion. The coal is usually supplied in large quantities at long intervals, and the result is that at the times of firing the temperature of the furnace is lowered, the resistance to the flow of air through the fuel bed is increased, and consequently great quantities of combustible gas are generated which can not be burned for lack of air and the necessary amount of heat.

Hand-fired furnaces with steam and air jets may save enough by better combustion to make up for the cost of the steam used in the jets. They are looked upon as makeshifts by experienced smoke inspectors and others competent to judge of them.

Hand-fired furnaces with ample combustion chambers and adjustable openings for air admission are suitable for some kinds of coal, if tended by experienced and careful firemen.

Down-draft furnaces have shown decided economy in many plants and have been fairly successful in the prevention of smoke. The principle is a good one, but few installations of these furnaces are properly fired. Whether they can be run smokelessly depends on the required capacity, the kind and size of coal, and the attention.

Mechanical apparatus for burning powdered coal in boiler furnaces has been tried in many plants and with but few exceptions has been found unsatisfactory on account of the cost and difficulty of maintaining the furnace. It has, however, proved a decided success in firing cement kilns.

Sprinkling stokers have as yet made little headway in this country. Records given in the Manchester (England) smoke-prevention report show that these stokers are not as successful in preventing smoke as those of the coking type.

Furnaces with mechanical stokers of the overfeed types, including chain grates, which feed the coal gradually and coke it under a fire-brick arch, are used more widely than any others except the plain hand-fired furnaces. When these stokers are properly installed in connection with ample combustion chambers, and carefully operated, they give good results and prevent smoke. Many of these furnaces are not properly installed and a still greater number are badly operated. The inclined-grate stokers will burn either high-volatile coals or coals high in fixed carbon. The chain-grate stokers are successful in burning high-volatile coals such as are found in Indiana and Illinois. They require less attention from the fireman than other types of stokers, and they can be operated smokelessly when properly installed. This stoker has not been adapted to burning low-volatile coals such as are largely used in the East.

Underfeed stokers that automatically feed the coal are usually successful with either high or low volatile fuels when properly installed and operated at a reasonable rate of combustion.

Many furnaces are burning coal unsuited to them, and under the load conditions it is impossible to prevent smoke. A change to another kind, or in some cases to another size of the same kind of coal, would prove satisfactory.

INDIRECT METHODS OF SMOKE ABATEMENT.

There is at present a general tendency to centralize power, heating, and gas plants. In the heating of buildings it is customary under existing conditions to generate steam in the building. Where this is done, it is in general considered more economical to install engines for generating current for light and power also. However, many buildings furnish their own heat, but purchase current. Large power or light plants can now be located at any convenient place, say at the coal mines, because of the ease and economy with which electric current can be transmitted; but heating plants, whether for residence or for business districts, must be within a comparatively short distance from the section to be heated on account of the cost of installation and the losses from radiation. There are now more than 150 central heating plants in the United States, furnishing steam or hot water to residences or business buildings or to both. The greater number of these plants are located in the coal-producing States. Some of them have been built especially for the purpose of heating; others are additions to electric-lighting or industrial plants and utilize the exhaust steam from the engines. These central plants can be operated without smoke under favorable conditions, and they relieve the smoke situation in a measure. The plan of purchasing both heat and light, not only for residences, but also for business houses, is popular because it relieves the consumer of the details of operating a plant, does away with the dust of coal and ashes, and makes available for storage purposes space which would otherwise be occupied by the plant.

It has been suggested that in certain types of furnaces in which perfect combustion can not be maintained, the resulting smoke may be washed from the chimney gases in the same way as dust and soot are now removed from the air that is used in ventilating large office buildings, schoolhouses, and hospitals.

The increasing use of storage batteries by street railways and other interests has aided in the prevention of smoke. These batteries furnish the extra power needed when traffic is heavy during rush hours on the street railways and make unnecessary any sudden heavy demands on the power plants. The load on the engines being more nearly uniform, there is less change in the rate of combustion in the furnaces and less smoke, for change of load and crowding of boilers constitute a most prolific source of smoke.

SUMMARY.

The increasing use of gas and coke for domestic, manufacturing, and power purposes and the centralization of power and heating plants tend to relieve cities of a large percentage of the smoke now given off by small and inefficient heating and power plants. Notwithstanding the fact that other ways of utilizing coal are growing in favor, it will evidently be necessary to burn coal in small boiler plants for some time to come. These coal-burning plants will continue to keep the problem of smoke abatement before the residents of large cities.

It is recommended that in order to improve the conditions in any city a record of all equipment and furnaces in the power plants be made, and that improvements, methods of operation, and the kinds of coal used be made a special study. It is only by such systematic methods that the local problem can be solved, as conditions in any one city are generally different from those in others, depending on the amount and kind of manufacturing and the character of the coal available.

The personal element is the most difficult obstacle to overcome in the fight against smoke. Study of the requirements and a desire to obtain good results on the part of the firemen will do more to clear the air in cities than any other one influence.

Being principally the result of an imperfect air supply, smoke can be prevented by providing for sufficient air and for its mixture with the gases in the furnace.

Well-designed furnaces may smoke to a greater or less degree, depending on the methods of the firemen, the kind or size of the coal, and the rate at which the coal is burned. They may be expected to give smokeless combustion when burning a suitable coal, except under the following unfavorable operating conditions:

1. When fires are built. The furnace not being heated to the required temperature, the gases cool below their ignition point and escape unburned.

2. When so much coal is burned on the grate that it is impossible to supply sufficient air without frequent poking. This condition usually results in so large a volume of gas from the coal that it can not be properly mixed with air and burned in the combustion chamber. On reaching the boiler surfaces it is cooled, combustion is arrested, and soot and smoke result.

3. When the rate of combustion is suddenly increased, as when more coal is added, and fires are poked to get up pressure in short time.

4. When the fires are checked by closing doors or dampers, thus cutting off the air supply. Banked fires are difficult to maintain and start up without smoke. Automatic dampers are frequently the cause of smoke when not properly adjusted or designed.

There is need of further study of coals, furnaces, and combustion, but enough is now known to enable an engineer to design and operate a steam plant without objectionable smoke.

BIBLIOGRAPHY.

SURVEY PUBLICATIONS ON COAL.

The following reports (except Bulletin No. 261) can be obtained by application to the Director of the United States Geological Survey, Washington, D. C.:

BULLETIN No. 261. Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1905. 172 pp. Can be obtained by sending 10 cents in cash to the Superintendent of Documents, Washington, D. C.

PROFESSIONAL PAPER No. 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1906. In three parts, 1492 pp., 13 pls.

BULLETIN No. 290. Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905. J. A. Holmes, in charge. 1906. 240 pp.

BULLETIN No. 323. Experimental work conducted in the chemical laboratory of the fuel-testing plant, St. Louis, January 1, 1905, to July 31, 1906, by N. W. Lord. 1907. 49 pp.

BULLETIN No. 325. A study of four hundred steaming tests, made at the fuel-testing plant, St. Louis, Mo., 1904, 1905, and 1906, by L. P. Breckenridge. 1907. 196 pp.

BOOKS ON COMBUSTION AND SMOKE PREVENTION.

BARR, WILLIAM M. Combustion of coal and the prevention of smoke. Norman W. Henley Publishing Company, New York.

BOOTH, WILLIAM H., and KERSHAW, JOHN B. C. Smoke prevention and fuel economy. Norman W. Henley Publishing Company, New York, 1905.

HAYS, JOSEPH WELLER. Combustion and smokeless furnaces. Hill Publishing Company, New York, 1906. 104 pp., illustrated.

KENT, WILLIAM. Steam boiler economy: A treatise on the theory and practice of fuel economy in the operation of steam boilers. "Coal can be burned without smoke provided (1) the gases are distilled from the coal slowly; (2) that the gases when distilled are brought into intimate contact with very hot air; (3) that they are burned in a hot fire-brick chamber; (4) that while burning they are not allowed to come in contact with comparatively cool surfaces, such as the shell or tubes of a steam boiler. This means that the gases shall have sufficient space and time in which to burn before they are allowed to come in contact with the boiler surfaces."

PEABODY, C. H., and MILLER, E. F. Steam boilers: A treatise on boilers and furnaces. Chapter on combustion.

POPPLEWELL, WILLIAM CHARLES. The prevention of smoke combined with the economical combustion of fuel. Scott Greenwood & Co., London, 1901.

NICHOLSON, WILLIAM. Smoke abatement: A manual for the use of manufacturers, inspectors, medical officers of health, engineers, and others. C. Griffin & Co. (Limited), London, 1905. 59 illustrations.

WILLIAMS, CHARLES WYE. Combustion of coal and the prevention of smoke, chemically and practically considered. London and Liverpool, 1841; new ed., London, 1854.

PROCEEDINGS OF ENGINEERING SOCIETIES.

BEMENT, A. Suppression of industrial smoke, with particular reference to steam boilers. A paper presented before the Western Society of Engineers, October 17, 1906. 60 pp., 26 illustrations. With discussions by W. L. Abbott, Chicago Edison Company; R. H. Kuss, assistant smoke inspector, Chicago; Frank Elliott, chief engineer Northwestern Elevated Railroad, Chicago; W. L. Goddard, International Harvester Company; A. J. Saxe, supervising engineer, Chicago; Carl Scholz, president Coal Valley Mining Company; H. Kreisinger, fuel-testing plant, United States Geological Survey; E. H. Taylor, Fuel Engineering Company, Chicago; John C. Schubert, smoke inspector, Chicago. Communicated by letter: Prof. William Kent, Syracuse, N. Y.; F. S. Peabody, Peabody Coal Company; E. B. Powell, New York Edison Company; J. W. Green, Cedar Rapids, Iowa; H. W. Woodward, assistant smoke inspector, Cleveland, Ohio; H. E. Horton, Chicago; R. S. Moss; Philip McCarty, smoke inspector, Denver; Clinton Rogers, Rochester, N. Y.

BENJAMIN, CHARLES H. Smoke and its abatement. Trans. Am. Soc. Mech. Eng., vol. 26, New York, 1905, p. 713. Discusses, in a general way, the methods employed for preventing smoke in stationary plants and on locomotives.

HARTMAN, JOHN M. Notes on burning bituminous coal. Proc. Eng. Club, Philadelphia, April, 1904.

MABERY, C. F., and BENJAMIN, CHARLES H. Economy in combustion and smoke prevention. Jour. Assoc. Eng. Socs., May, 1896. Doctor Mabery discusses the chemical aspect of the combustion of coal; Professor Benjamin discusses smoke prevention from the mechanical standpoint. Good smoke-preventing device should have variable feed, variable spacing of grate bars, grate bars of the automatic shaking type, some form of air control, sufficient grate area, easy accessibility for cleaning, good firing.

ROWAN, F. J. The smoke problem. Trans. Inst. Eng. and Shipb. Scotland, October, 1904. Discusses the production of smoke; the estimation of smoke; the prevention of smoke; some considerations affecting municipal control.

SHAW, W. N. The treatment of smoke. Jour. San. Inst., October, 1902. Discusses the removal of smoke as a parallel to the removal of sewage.

FRANKLIN INSTITUTE. The smoke nuisance and its regulation, with special reference to the condition prevailing in Philadelphia. Jour. Franklin Inst., June, 1897. Discussion showing that smoke prevention is possible. R. H. Thurston says preventives are legislation, skilful operation of furnaces, and special construction of furnaces. " I am inclined to expect highest efficiency, ultimately, through the use of the mechanical stoker."

PUBLICATIONS BY STATES, CITIES, AND CITIZENS' COMMITTEES.

BRECKENRIDGE, L. P. The prevention of smoke. Engineering Experiment Station, Urbana, Ill.

BUFFALO. The abatement of the smoke nuisance. Committee of manufacturers of the chamber of commerce. Contents: To whom smoke prevention is beneficial; the present and the proposed ordinance; ordinances of the cities of New York, Pittsburg, Cleveland, Detroit, Syracuse, Rochester, Minneapolis, Cincinnati, and Indianapolis.

CLEVELAND. Report of the municipal committee on the smoke nuisance, March, 1907. Contents: Effect of coal smoke; attempt to enforce ordinance of 1882; discussion of question " Is there a mechanical device which will prevent the emission of smoke?" legal basis requiring its installation; responsibility of the owner; review of the present ordinance of the city; recommendations.

——— Smoke prevention and economy. Department of smoke abatement, February, 1905. Contents: Determining factors of smoke abatement; description of smoke-prevention devices; smoke prevention and fuel economy synonymous; answers to query " Can smoke be prevented?" from tests and letters.

MANCHESTER (England). Report of committee for testing smoke-preventing appliances, 1895. Contents: Origin of the movement; scope of the work; details regarding tests; deductions from smoke-observations; tables of results of tests. 42 pp., 3 illustrations, and 10 important tables.

MILWAUKEE. Second annual report of Charles Poethke, smoke inspector, 1905. Contents: Smoke-preventing devices installed; an indication of fuel economy; cooperation of manufacturers; gratifying results; imperfections of ordinance.

ST. LOUIS. Report of the smoke abatement department, C. H. Jones, chief inspector, October, 1906. Contents: Smoke-consuming devices (classified) in use; difficulties of the department; effect of insufficient boiler capacity.

——— The smoke nuisance. Report of the smoke-abatement committee of the civic league, November, 1907. Contents: Injurious effects of smoke; damage to plant life; smoke and fuel economy; does smoke come from East St. Louis? the problem of the committee; the first ordinances invalid; the present ordinance valid; kinds of fuel used in St. Louis; principles of proper combustion; smoke devices in use; prolific causes of smoke; comparison of devices in use; smoking locomotives the most reckless offenders; brick kilns as smoke makers; does enforcement of ordinance mean persecution; three important factors for the solution of the smoke problem; draft of the new ordinance.

SYRACUSE. Report upon smoke abatement. Chamber of commerce committee, 1907. Contents: Damage done by smoke; results in other cities; principle of combustion; causes of smoke; devices for preventing smoke; railroad smoke; economic results from smoke abatement; conclusions.

PAPERS IN TECHNICAL JOURNALS.

BEILBY, GEORGE THOMAS. Smoke abatement. Engineering, June 26, 1903. Advocates the substitution of gas fuel for coal.

BENJAMIN, CHARLES H. Smoke and its abatement in large cities. Tech. Quart., September, 1902.

——— The prevention of smoke from bituminous coal. Engineer (U. S.), April 1, 1903.

BOOTH, W. H. Smoke prevention. Am. Machinist, September 29, 1898. Discusses principles of combustion and the requirement of a furnace so that it may not produce smoke.

——— Smoky furnaces and how to avoid them. Elect. Review, London, 1st part, July 26, 1901.

——— The smokeless combustion of bituminous fuels. Elect. Review, London, September 26, 1902. Discusses principles of combustion.

BRECKENRIDGE, L. P. Burning Illinois coal without smoke. Eng. News, June 11, 1903. The essential features of a smokeless plant are sufficient boiler capacity, a good draft, uniform size of coal, some good type of automatic stoker, intelligent direction in the boiler room.

CARY, ALBERT A. The suppression of smoke in steam plants using bituminous coal. Iron Age, October 2, 1902. "The whole secret of burning coal smokelessly is to obtain complete combustion in the furnace or combustion chambers before any appreciable amount of the combustible gases meet the chilling water surfaces of the boiler. No one furnace setting can be built to burn all kinds of fuel with equal efficiency."

——— The prevention of smoke. Eng. Record, vol. 53, April 21, 1906, pp. 514–516. Condensed from an address before the New York section of the Society of Chemical Industry. Smoke prevention depends on intelligence in the boiler room, proper design of the grate to burn the particular kind of coal used to the best advantage, proper design of the furnace and combustion chamber.

DONKIN, BRYAN. On smoke and its diminution. Engineer, London, May 26, 1899. Discusses methods in use for diminishing smoke.

HEMPEL, W. On smokeless combustion and boiler firing. Abstract from "Stahl und Eisen." Colliery Guardian, July 24, 1896. Discusses influence of temperature and pressure on gaseous products of combustion.

KERSHAW, JOHN B. C. Industrial smoke and its prevention. Cassier's Magazine, vol. 29, December, 1905, pp. 109–114. Reviews a number of earlier works on smoke abatement and concludes that the method of preventing smoke is good stoking and scientific control.

——— Smoke abatement: A report on the London smoke-abatement conference, December 13–15, 1905. Cassier's Mag., vol. 29, February, 1906, pp. 335–341.

KING, R. P. The abatement of the smoke nuisance. Municipal Engineering, vol. 29, November, 1905, pp. 366–369. Gives municipal aspect of the smoke problem. "Of the successful devices there are four classes—steam jets, furnaces, mechanical stokers, smokeless coal."

LONDON. Conference on smoke abatement; abstract of proceedings. Engineer, London, November–December, 1905.

MAYNER, WILLIAM. Smokeless combustion and economy of fuel. Sci. Am. Suppl., vol. 60, August 26, 1905, pp. 24788–24789. Discusses the waste obtained by burning coal in ordinary furnace. Describes the furnace invented by Charles Wegener, of Charlottenburg.

PARKER, T. T. Smoke abolition. Am. Machinist, October 16, 1902. Two ways of changing horizontal tubular boilers so that they may be made smokeless.

POPPLEWELL, W. C. The smoke problem and its possibilities. Feilden's Mag., December, 1902. Article describes several different stokers.

RAWORTH, JOHN S. The prevention of smoke. Electrician, London, September 26, 1902. Describes test made with Wilson smokeless process by Electric Traction Company at Kidderminster.

SIMMERBACH, O. The suppression of smoke by the use of coke. (From Zeitschrift der Dampfkessel-Ueberwachungs-Vereine.) Progressive Age, February 15, 1897. Discusses the advantages presented by coke for use under boilers as compared with coal.

WILKINSON, THOMAS L. The smoke problem of Denver. Min. Reporter, December 10, 1903. Discusses the general principles of combustion and several devices for smoke prevention.

WRIGHT, J. The possibilities of electrical smoke deposition. Elect. Review, London, November 23, 1900. Discusses the possibilities of electrical smoke deposition, cites several laboratory experiments to show that it is possible, and suggests a plan by which it might be attempted in practice.

An improvement in smoke-consuming furnaces. Sci. Am., March 31, 1900. Describes a smoke-preventing attachment for hand-fired furnaces.

Apparatus for consuming smoke. Sci. Am. Suppl., February 25, 1899. Brief review of the report of the commission appointed in Paris for testing smoke-consuming apparatus.

Smoke. Progressive Age, September 15, 1898. Editorial, discussing the probability of avoiding the smoke nuisance by substituting gas for coal.

Smoke abatement. Engineering, August 7, 1896. Editorial review of smoke problem, particularly of the report of the "committee for testing smoke-preventing appliances."

Smoke prevention and smokeless furnaces. Eng. News, January 2, 1896. Discusses briefly conditions of combustion, waste due to smoke, and hygienic questions.

The smoke nuisance. Builder, August 12, 1899. General discussion of the smoke nuisance with particular reference to the waste caused by smoke from domestic fires and the damage done to property, etc., by smoke.

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Bulletin No. 334.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists can be had on application.

Most of the above publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except classes 2, 7, and 8), on application.
2. A certain number are delivered to Senators and Representatives in Congress for distribution.
3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at practically cost.
4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they can be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Foresty; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports; Q, Fuels; R, Structural materials. This paper is the eighth in Series Q, the complete list of which follows (PP=Professional Paper; B=Bulletin):

SERIES Q, FUELS.

B 261. Preliminary report of the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1905. 172 pp.

PP 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1906. 3 parts. 1,492 pp., 13 pls.

B 290. Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905, by J. A. Holmes. 1906. 240 pp.

B 323. Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo., January 1, 1905, to July 31, 1906, by N. W. Lord. 1907. 49 pp.

B 325. A study of four hundred steaming tests made at the fuel-testing plant, St. Louis, Mo., in 1904, 1905, and 1906, by L. P. Breckenridge. 1907. 196 pp.

B 332. Report of the United States fuel-testing plant at St. Louis, Mo., January 1, 1906, to July 1, 1907, Joseph A. Holmes in charge. 1908. —— pp.

B 333. Coal-mine accidents: their causes and prevention: a preliminary statistical report, by Clarence Hall and W. O. Snelling, with an introduction by J. A. Holmes. 1907. 21 pp.

B 334. The burning of coal without smoke in boiler plants, a preliminary report, by D. T. Randall. 1908. 26 pp.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

JANUARY, 1908.