SMOKE ABATEMENT IN THE CITY OF KNOXVILLE

by

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INTRODUCTION

The subject of smoke abatement has been widely discussed and has been an item which many of the more progressive cities of our land, as well as abroad, have undertaken as a means of economic and health betterment.

The smoke problem in cities arises mainly from the fuels that during their combustion give off part of their volatile matter, mixed carbon, ash, and sulphur. Although coke and anthracite coal burn without appreciable smoke, due to their low volatile content, ash is carried up the stack in proportion to the draft. Semi-bituminous coals to a degree, bituminous coals, which are characterized by their high volatile content, and liquid fuels are bad smoke producers if not properly burned. Smoke emission from stacks consist of combustible material (carbon, hydrogen, and tar) and relatively small amounts of ash. This combustible matter is the product of distillation which is driven off when fresh coal is fired and should all be burned, but due to one or more of the following reasons complete combustion does not take place, thus causing these products to be carried away in various states of decomposition:

1. Lack of air.
2. Improper distribution of air.
3. Large charges of green coal.
4. Small furnace volume (improper design).
5. Too low a temperature.
6. High velocity of gases through combustion chamber.

PURPOSE

The purpose of writing this thesis is to familiarize the reader with the methods by which smoke emission can be reduced and eliminated and to give the ways in which to handle the most essential elements that make for the success of any smoke abatement campaign. In carrying out this purpose the main body of the discussion is centered on the smoke abatement work in Knoxville as this city is a typical one which needs strict regulation in regard to smoke emission. Knoxville does not present any new problem in smoke abatement or have any distinct essential characteristic all its own, and as the writer has been connected with its Bureau of Smoke Regulation as a part-time worker for the past school year, and has a knowledge of the methods and results gained, makes it all the more desirable as a specific reference to smoke abatement in general.

Through the writing of this brief discussion of smoke abatement it is hoped that it will serve as a stimulus to others to carry this subject forward and to help make the cities of our land more efficient in the use of fuel and to make them cleaner and more healthful places in which to live.

GENERAL SURVEY OF THE FIELD

All of our American cities have long recognized the need of a clean and pure water supply, sewerage system, garbage disposal, etc. as distinctive health safeguard, but air pollution from smoke in these same cities still continues to be a great problem. Large volumns of dense smoke can be seen pouring out of the stacks and chimneys, but few of the people pay any attention to them as they are used to seeing smoke; so in order to get the masses of people to realize the importance of making a city free of this nuisance they must be shown a saving in dollars and cents and in improvement to health.

The economic considerations may be summarized as follows:

1. Loss due to incomplete combustion of fuel.
2. Loss due to damaged merchandise.
3. Cost of cleaning and renewing wall paper, cleaning the buildings, windows, skylights, etc.
4. Cost of laundry and dry cleaning of curtains, draperies, etc., in addition to wearing apparel.
5. Cost of replacing sheet metal work due to corrosion.
6. Cost of artificial lighting.
7. Cost of extra painting.
8. Cost of extra precautions.
9. Cost of extra doctor bills due to increased troubles of the eye, ear, nose, throat, etc.
10. Reduced earning capacity due to effect of smoke on workers.

The most important health considerations may be listed as follows:

1. Smoke shuts out sunlight and as the ultraviolet rays of the sun are so necessary to good health this consideration is of utmost importance.
2. The solid particles of smoke irritate the sensitive membranes of the eyes, nose, throat, lungs, gastro-intestinal tract; acts as carrier for germs.

As a result of the 1927 soot-fall survey of the University of Tennessee Chemistry department a rough estimate of the annual cost of smoke to the city of Knoxville was between one million, seven hundred and fifty thousand dollars, and two million dollars, which amounts to something like fifteen dollars per person per year.

As the activities of the Smoke Bureau of Knoxville is to be the main discussion, a brief summary of some of the important facts of the city, its topography and atmospheric conditions, together with the almost universal use of high volatile bituminous coal for fuel will give the reader something of an idea as to the smoke situation.

Knoxville is located in Eastern Tennessee on the Tennessee River, in a large valley that acts as a protector from heavy storms and equalizes its temperature. It is in the foot hills of the Great Smoky Mountains that rise to an altitude of about seven thousand feet above sea level, the city itself being 933 feet above the level of the sea. The United States census estimates of July, 1928, was 105,366 persons inside of its twenty-six square miles of area. The city has

doubled its population every decade but one in the past one hundred years. The city was one of the first settled in the state, dating back to the last portion of the eighteenth century, and is like most all old cities in hilly country in the respect that its growth has been along the numerous ridges and valleys resulting in narrow, winding, and consequently congested streets inthe business section. The fact that the larger office buildings and hotels are surrounded by lower buildings whose chimneys and stacks are well below the level of the upper stories, adds greatly to the prevailing smoke situation in that the smoke and soot are very bad in the streets and lower buildings, as well as the higher department store floors, offices, and hotel rooms.

Knoxville has approximately three hundred and fifty industrial plants within the city limits, a large percentage of which are small and serve local needs, but many are larger ones of nationally known firms mainly in the field of textile goods, iron and steel products, mechanical equipment, marble, wood products, etc. Serving these manufacturers and other needs of the city are two railroads that cut through the center of the city and follow the valleys and rivers with their main and branch lines. (See appendix for a map of the city).

Knoxville suffers with an exceedingly low wind velocity, which together with a large number of river fogs that are more predominate in the winter heating months, causes the smoke to settle and to hang over the city instead of being carried away. The yearly average wind velocity for the city since 1871, is only six miles per hour.

THE THEORY OF COMBUSTION

As smoke is caused from incomplete combustion it is, therefore, important that the theory of combustion be taken up before the other phases of smoke abatement are discussed.

The chemist would regard combustion as the phenomenon resulting from any chemical combination that involves heat, but the engineer thinks of it as the chemical union of the combustible part of a fuel and the oxygen of the air at such a rate as to cause a rapid increase in temperature. Such action is always carried on in accordance with fixed laws as to weight and volume, a definite quantity of heat being liberated when a unit of weight is burned. If coal is the substance burned the unit weight is a pound, and the heat liberated is expressed in B.T.U. (British Thermal Units) per pound.

Coal may be regarded, when separated into its ultimate chemical constituents, as a compound composed principally of varying proportions of carbon, hydrogen, oxygen, sulphur, and refractory earths, carbon and hydrogen being the only desirable elements from the stand point of combustion.

Table 1 will give the reader an idea of the varying proportions of each constituent and the limits of variation of each for the coal that is burned in Knoxville.

TABLE 1'

Proximate Analysis	Low (in %)	High (in %)
Moisture	1.8	3.92
Volatile Matter	27.23	37.18
Fixed Carbon	51.53	56.55
Ash	2.71	14.09
Ultimate Analysis		
Sulphur	0.70	2.64
Hydrogen	4.81	5.54
Carbon	69.67	79.61
Nitrogen	1.29	1.96
Oxygen	7.32	9.86
Heating Value in B.T.U. per Pound		
Moisture, Ash free	14,951	15,255
As Received	12,508	14,220

' Gebhardt, "Steam Power Plant Engineering," p.39.

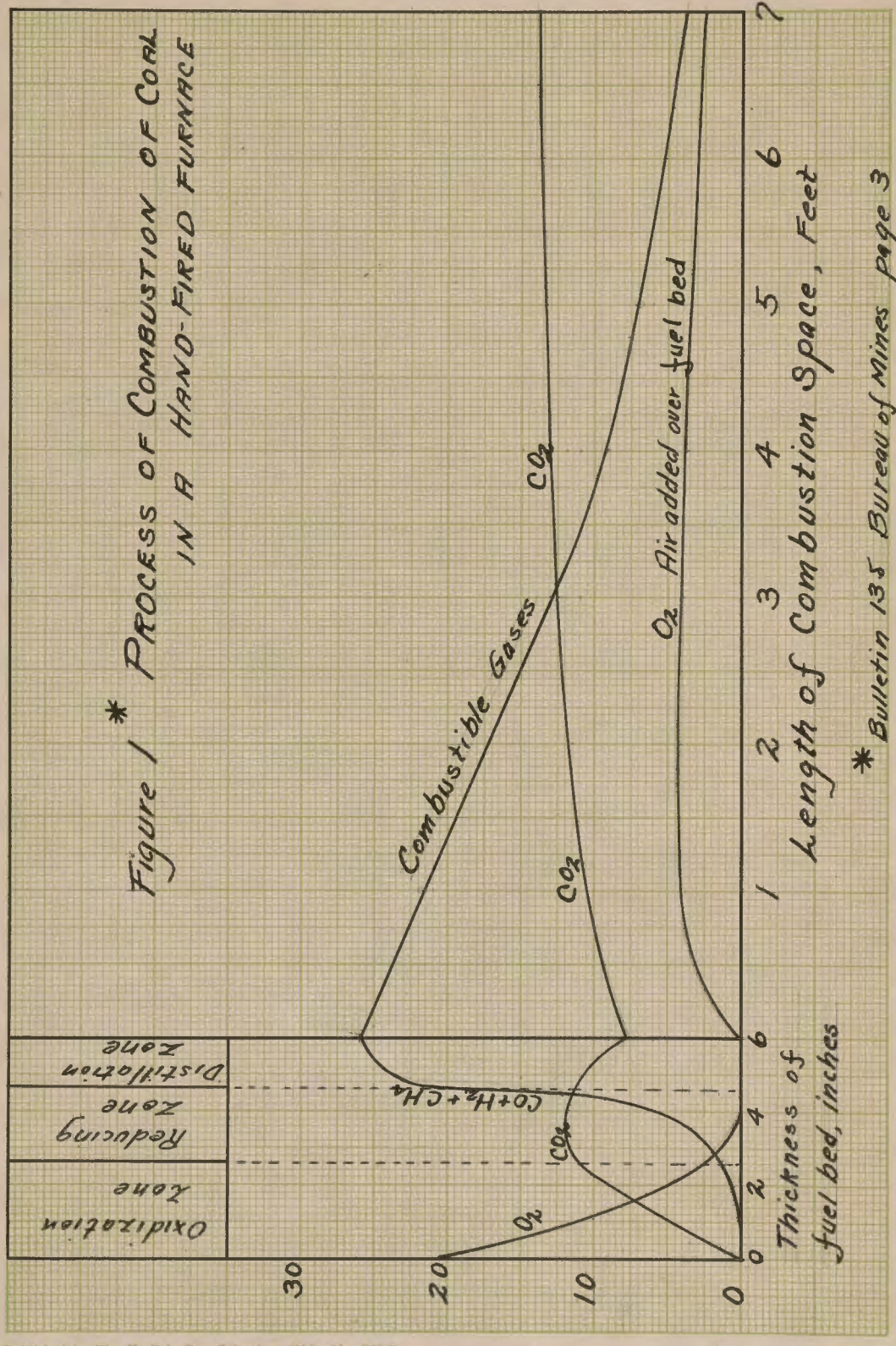
In the industrial furnaces the combustion of coal takes place in two stages: first, combustion in the fuel bed, which includes the distillation of the volatile and partial combustion of the fixed carbon, and, second, combustion of the gases and other combustibles rising from the fuel bed in the combustion space. When fresh coal is fired into the furnace the first step in the process of combustion is the distillation of the volatile matter which consists essentially of the elementary fuels, gaseous hydrocarbons, tar, carbon

monoxide, (CO), and hydrogen (H). These elementary fuels give water vapor (H_2O) and carbon dioxide (CO_2) as their final product, while the fixed carbon (C) or coke is left on the grates to be partly burned to CO_2. The distillation of the volatile matter begins at about 660°F. and is quite rapid at 1300°F., the hydrocarbon appearing first, followed by hydrogen and carbon monoxide at the higher temperature. As a summarizing statement of the foregoing discussion it may be said that on the fuel bed distillation occurs followed by partial combustion of the coke, and over the fuel bed the combustion of the volatile matter as well as the combustion of the CO resulting from the partial combustion of coke.

Taking up the combustion of the volatile matter (the smoke forming gases) in a little more detail we may say that on leaving the fuel bed the volatile matter is a complex hydrocarbon compound, and without sufficient oxygen for complete combustion, this compound is quickly decomposed by the high furnace temperature into soot, hydrogen, and carbon monoxide. All hydrocarbons are unstable at furnace temperatures. Unless enough air is mixed with them at the time they are distilled they are quickly decomposed into the above mentioned gases. As all the gaseous products resulting from complete combustion are colorless and invisible at stack temperature it is, therefore, essential that we have full control of all the factors that bring about complete combustion if we are to have a 'smokeless' stack.

The different steps through which coal passes during its combustion have pointed out, but some of the steps may not be fully understood and as a graphical representation of facts is always more easily understood, reference to figure one will show the reader just what is happening and at what stage each of the reactions and transformations are occurring. This graph is drawn from a hand fired pressure boiler with a specially designed furnace for taking the various samples. The curves are of the percentages of the different gases at various points in the fuel bed and combustion space. The thickness of the fuel bed is six inches.

In the analysis of these curves it can be noticed that all of the oxygen is used up at about three and one half inches from the grate and at this same point the CO_2 reaches its maximum value of twelve percent. Beyond this point the percentage of CO_2 drops off and the percentage of CO and other combustible matter increases rapidly, thus showing that the CO_2 is reduced to CO by the contact with the hot carbon in the absence of oxygen. At the surface of the fuel bed the gases contain about twenty-six percent of the combustible, no oxygen, and eight percent CO_2. When the air is added over the fuel bed the combustible gases are burned and at the end of a seven foot furnace these gases are reduced to four percent, and, at the same time, the CO_2 has increased to 14 percent. Figure 2 shows the process of combustion and chemical reactions in a hand fired, low pressure heating boiler.



*Bulletin 135 Bureau of Mines page 3

Published by The H. Cole Co., Columbus, Ohio. No. 250 G.

FIGURE 1

CHEMICAL REACTIONS OF COMBUSTION[1].

CARBON (TO CO) $2C + O_2 = 2CO$.

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

CARBON MONOXIDE $2CO + O_2 = 2CO_2$.

HEAT OF COMBUSTION

CARBON TO CO_2 = 14,540 B.T.U. PER LB.

" " CO = 4,380 " " "

CO " CO_2 = 10,160 " " "

IGNITION TEMPERATURES

SULPHUR 470° F

FIXED CARBON (BITUM.) 766° "

" " (ANTH.) 925° "

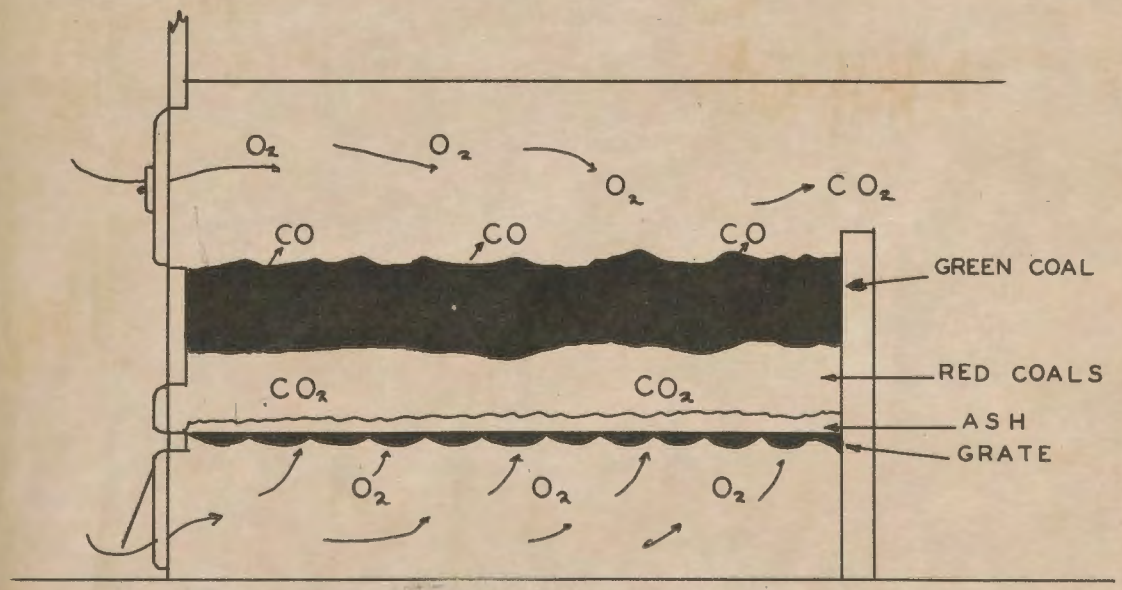


Figure 2.

[1] United States Radiator Corporation.

The three main processes in the fuel bed are:

1. The distillation of the volatile matter,
2. The oxidation of the carbon to carbon dioxide,
3. The reduction of the carbon dioxide to carbon monoxide which is, in turn, burned to carbon dioxide in the presence of sufficient temperature provided it is mixed with the proper amount of air.

The zones in which the above processes take place are indicated at the top of the graph in figure 1. The boundaries of these zones are not as distinct as they are shown but merge gradually into one another.

As coal is a chemical compound it is readily seen that during its combustion there would be several important chemical reactions. The elements either combine directly with the oxygen of the air, change their character by reacting withwater vapor, or by decomposing thermally into the other elementary fuels before final or complete combustion. Examples of each class of reactions are as follows:

(1) $2\ H_2 + O_2 + 3.76\ N_2 = 2\ H_2O + 3.76\ N_2$

$3.76\ N_2$ which appears on both sides of the equation comes from the fact that air contains twnety-one percent oxygen and seventy-nine percent nitrogen by volume (approximately), therefore 79/21 = 3.76, or for every pound of oxygen 3.76 pounds of nitrogen, which does not support combustion, are passed through the furnace.

(2) $C + H_2O = CO + H_2$

(3) $C_2H_2 + \text{heat} = 2C + 2H_2$

Table 2 gives the important chemical reactions and Table 3 the elements and compounds encountered in combustion.

TABLE 2'

Combustible Substance	Reaction	Heat Value B.T.U. per lb. (Average)
Carbon to CO	$2C + O_2 = 2CO$	4,440
Carbon to CO_2	$2C + 2O_2 = 2CO_2$	14,354
Carbon Monoxide	$2CO + O_2 = 2CO_2$	4,354
Hydrogen	$2H + O = 2H_2O$	5,751
Sulphur to SO_2	$S + O_2 = SO_2$	4,000
Sulphur to SO_3	$2S + 3O_2 = 2SO_3$	5,940
Methane	$CH_4 + 2O_2 = CO_2 + 2H_2O$	22,760
Acetylene	$2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O$	21,300
Ethylene	$C_2H_4 + 3O_2 = 2CO_2 + 2H_2O$	21,010
Ethane	$2C_2H_6 + 7O_2 = 4CO_2 + 6H_2O$	21,375
Hydrogen Sulphide	$2H_2S + 3O_2 = 2H_2O + 2SO_2$	

' A. D. Pratt, "Principles of Combustion in the Steam Boiler Furnace" p. 12 and
Gebhardt, "Steam Power Plant Engineering" p. 69.

TABLE 3'

THE ELEMENTS AND COMPOUNDS ENCOUNTERED IN COMBUSTION

Substance	Molecular Symbol	Molecular Weight	Form	Ignition Temp.F.	Lb. of Air per lb. Sub. Burned
Fixed Carbon					
1. Bituminous	C"		Solid	726	19
2. Semi-Bituminous	C"		"	870	" AP.
3. Anthracite	C"		"	925	"
Hydrogen	H_2	2	Gas	1130	34.81
Oxygen	O_2	32	"		
Nitrogen	N_2	28	"		
Sulphur	S_2	64	Solid	470	
Carbon Monoxide	CO	28	Gas	1210	2.48
Carbon Dioxide	CO_2	44	"		
Methane	CH_4	16	"	1202	17.32
Acetylene	C_2H_2	26	"	900	13.35
Ethylene	C_2H_4	28	"	1022	14.85
Ethane	C_2H_6	30	"	1000	16.16
Sulphur Dioxide	SO_2	64	"		
Hydrogen Sulphide	H_2S	34	"		
Water Vapor	H_2O	18	Vapor		
Air		29	Gas		

" Atomic Symbol.

'Pratt, P. 10; Gebhardt,P.69.

GENERAL PRINCIPLES OF SMOKE ABATEMENT

The first thing that is needed in order to cope with the smoke situation after the people have demonstrated their desire for smoke regulation by their support is a smoke abatement ordinance. This ordinance would be clear and complete, defining all terms of smoke emission, types of recommendations to be made, methods of dealing with the offenders, personal requirements, together with all the classes of stacks and chimneys covered. It is important that the smoke bureau be under the supervision of a competent technical engineer who is qualified by training and experience in the theory and practice of the construction and operation of steam boilers and furnaces as well as in the theory and practice of smoke abatement and smoke prevention. It is also equally important for the proper success and cooperation in the work that this individual be of such a personality that he can command the respect and confidence of the technical and business men with whom he is to deal. By the word "personality" it is also meant the ability to persuade the owners, managers, and engineers of the various plants by proper presentation of the conditions and facts that the smoking stack in question is a nuisance and a detriment to the neighborhood, and that he is not only willing, but able to show and advise how to overcome the condition at the least possible expense, and through such methods gain the support and cooperation of these organizations and plants for the smoke abatement work.

The main object of any smoke abatement campaign is to make the public "smoke abatement conscious" to the extent that they will demand and be willing to pay for a better and a more clean and efficient fuel burning equipment, and to accomplish this end the people must be kept thoroughly aroused in order to have them in the right frame of mind for cooperation. They must be "sold" on the idea that smoke pulluted atmosphere is not only disagreeable, detrimental to health, and expensive due to property damaged and loss from excessive laundry, cleaning and doctor bills, but a tremendous waste of fuel that is preventable. The people must be shown that smoke can be reduced, expecially the skeptics who say "it can't be done." The issue must be kept before the people at all times, not only through the newspapers, but by any other means such as lectures, talks, instruction courses, literature, etc., the extent depending upon the amount of funds available. In all publicity work stress must be laid upon the value of the spirit of cooperation and to have the people to fully realize that only by their united support and constant effort can the smoke evil be removed and smoke abatement be looked upon as full success. When the public is backing the movement whole-heartedly the necessary appropriations for carrying on the work will be forth coming without any difficulty.

As cooperation and team work have been stressed let us now consider how the various classes of people, business organizations, individuals, etc. can directly help in the work. It is of vital importance that the engineers of the city become

interested and give a portion of their time to the work, co-operate with the boiler, furnace and equipment manufacturers, fuel dealers and producers,and all work together for the common end of efficient, convenient, and "Smokeless" fuel burning equipment. The plant and factory owners together with other industrial organizations must become interested in the working out their problem in relation to smoke abatement so that the investment which may be required will be a profitable one in fuel conservation. The owners of hotels, apartments, and heating plants, together with the real-estate men who operate them must become interested in keeping their equipment in order and to train their janitors and firemen in the art of firing the boilers according to the best methods to reduce smoke to a minimum, and thereby reduce the fuel required at the same time. Domestic furnace operators must take an active and lively interest from the standpoint of fuel economy, cleanliness, better and more efficient heating systems, and civic pride, but in most instances the domestic furnace operators will sit back and wait for the industrial plants and railroads to clean up before they will make any attempt at own reduction and elimination. Aside from the people who work and cooperate in the movement in a whole-hearted manner there will always be some to say "it can't be done" and others who would rather propose some ideal solution which may become effective in ten to twenty years instead of co-operating in a movement that will bring immediate results, and another group who say that they are fully aware of the need for such work and cooperation, but when it comes time for them to make the necessary changes and exercise the proper care to

eliminate the smoke from their stacks they are not willing and usually site to some other stack that they think is a much worse offender then theirs. In taking such a stand these people fail to realize that every stack is a potential smoke nuisance and any step that can be taken to reduce the emission from any of these stacks is a step forward and will have the proper influence upon the other people toward their reduction and elimination of smoke.

The smoke abatement problem is essentially an engineering program with practical investigations and solutions of complete and "smokeless" combustion of fuel, not only in the large heating plants, but in all of the industrial plants, laundries, railroads, hotels, warehouses business houses, office buildings, apartments, etc. In some cities the ordinance covers the domestic furnaces, but in event it does not, as is the case in Knoxville, all steps that can be taken in the way of obtaining the support and causing the domestic fuel user to cooperate should be carried out to the fullest possible extent. As a matter of fact the engineering phase is the least troublesome, as there are no smoky fuels in the eyes of the engineer, but it is merely a matter of proper mixture of the oxygen of the air with the smoke forming gases at a reasonably high temperature. There is on the market today fuel burning equipment that meet the above requirements in practically all of the various branches of steam generation and power fields, but steps must be taken to induce the people, by ordinance requirements or other wise, to install these new and up to date "smoke-

less" equipment in the new industries and establishments and in the replacement of old equipment. It is the task of the smoke bureau to see that the above mentioned practice is carried out and after such equipment is installed to see that it is operated in such a manner that will insure the minimum smoke emission. Aside from this new equipment installation one of the main tasks of the bureau is the working out and offering of practical recommentations for the reduction and elimination of smoke fromthe fuel burning equipment that was in service before the ordinance went into effect. A check must be kept on this old equipment to see that the recommendations made by the bureau, or any other plan for that matter, that will enable the plant to operate within the ordinance, are carried out and such device or equipment operated in such a way as to insure minimum smoke emission.

As for the matter of surveys it is of value to get data as a means of comparison with past years and with other cities. The United States Weather Bureau can furnish valuable information as to the wind velocities, direction of wind, fogs, humidity and other phenomena. It is important that a record be kept on the various stacks, the Ringlemann's chart being a convenient and easy method and is used by most cities. The soot-fall, which is expressed in tons per square mile per year with the percentage of combustible in the soot is also a valuable record to have and can be used as somewhat of an index to the progress made in the work, but the best way to reduce smoke is to go after the smoking stacks.

A smoke abatement program, if properly organized and conducted, should help the industries of the city and in a general way help to make the city grow and prosper, and in this capacity, it can be a large asset to the city. As such a campaign leads to better health conditions, better satisfied citizens, and a financial gain, together with the big advertising medium which it affords makes the smoke bureau one of the most helpful departments of a city's organization.

There may be several important factors omitted in the foregoing discussion, but in order to cause as little overlapping and repetition as possible it is deemed wise to take up any other such points in the next section of this paper.

SMOKE ABATEMENT IN KNOXVILLE

The starting of the smoke abatement in Knoxville dates back a considerable number of years, the first step being taken in this direction was a smoke ordinance passed in 1911, as a result of the agitation brought about by a group of far-sighted citizens. This ordinance provided for the abatement of emission of dense black or dense gray smoke from certain stacks and chimneys within the limits of Knoxville; declaring the same to be a nuisance and provided for a Smoke Inspector and prescribing a penalty for the violation of the ordinance. A fine was imposed upon the owner of the stack that permitted the emission of the "dense smoke" from his stack. The local Building Inspector was given the smoke inspection work and armed only with the ordinance itself to combat the nuisance. Needless to say this step was a failure in spite of the efforts and the general desire on the part of the citizens who cooperated in the movement and bought many so called "smoke consumers" that were sold by zealous salesman. Practically no efforts were made to enforce this ordinance and it remained on the statutes until it was repealed in March 1928, when the present ordinance was passed.

Knoxville continued to grow by leaps and bounds bringing about many changes, among which was the City-Manager-Council form of government in 1923. With this new form of government came changes of importance and worth while nature. The sanitary system was expanded, new water works built, City Planing Com-

mission appointed, public health and public welfare greatly expanded, a Recreation Bureau established, and the streets became better, wider and more clean, but at thesame time the increased comsumption of coal for power and heating purposes added greatly to the smoke nuisance and this situation was one of general discontent and much need was felt for bringing about a change in the condition to keep abreast of a general and wide spread improvement in other lines.

It would require considerable space to give the details of the various steps that were taken which resulted in the passage of the Smoke Abatement Ordinance in March 1928, and such a discussion would not add materially to this paper. It can, however, be said that in a general way the work in Knoxville has been characteristic of that in other places and similar methods as those discribed in the foregoing section were followed. A great deal of credit must be given to the persons and organizations that made possible the establishment of the Smoke Bureau.

The Standard American Society of Mechanical Engineers Ordinance with a few minor changes to meet with the local need was the one that this city adopted. This ordinance was very complete; handling all the various points in a very clear and exacting way, prescribing the violation, methods to be used in the smoke elimination, methods of dealing with the violations together with the requirements of the bureau head and many other essential points. (See page 77 for a copy of the City of Knoxville's Smoke Ordinance.)

In order to get the smoke abatement work started in Knoxville in the right way, the city employed for a three months period, Mr. John Hunter as Consulting Engineer, a person who had experience in directing the work of such a bureau, to come and start the work and to train an engineer to carry on the work. Mr. Hunter did not come to Knoxville until June 1928, so for a short period prior to his coming a preliminary survey was made under the engineer that was chosen to be the bureau head, Mr. F. L. Wilkinson Jr. This survey was taken in order to get some information as to the number, kind, size, etc. of the boilers and steam generation equipment in use in the city. When Mr. Hunter came the work was started in earnest. The intensive campaign which followed was marked with sound and practical recommendations on well known engineering methods that would result in immediate reduction of smoke. Mr. Hunter is a very capable man for the inauguration of this kind of work, as was shown by the splendid results he was able to obtain in such a short period of time. He soon won the citizens of Knoxville for the smoke abatement cause and thereby gained their confidence and support from the outset, and the bureau following the council and methods since his departure has been a large factor in keeping this issue a popular one.

As it is always of first importance to get the industrial plants and railroads well on the way to smoke elimination before the smaller heating plants and domestic fuel users will make any effort toward their betterment, and in view of this fact the three month period was devoted almost entirely to the

industrial plants and railroads. There were recommendations made covering over three hundred power boilers during this campaign and approximately eighty-five per cent of these boilers were changed in accordance with the recommendations by the middle of September.

In general there were two types of recommendations made on the high pressure boilers during this intensive campaign. First, where the nature of the plant in the way of financial ability of the owner, size and kind of equipment in use, return on investment, etc. justified an expenditure for a proper and "smokeless" fuel burning equipment, an underfeed stoker was recommended, and second, in the case of the smaller plants burning comparatively small amounts of coal, the use of simple and inexpensive steam-air-jets were resorted to. These simple devises would not result in any decided saving in fuel, as was the case of the mechanical stoker, the only real gainbeing the elimination of smoke for which the extra cost of operation is just about compensated for by a more complete combustion.

From the standpoint of "smokeless" and efficient combustion the underfeed stoker meets the requirments of the coals of this region better than any thing else. A stoker of this type can burn a lower grade of coal, increase the boiler capacity, maintain a more constant steam pressure with a variable load, lower operation costs, reduced labor turnover, and at the same time, if properly designed and operated, reduce the smoke emission to the lowest possible figure using a high volatile bituminous coal, thus making it the most desir-

able "smokeless" coal burning equipment to be had for this vinity. There are other types of mechanical stokers, as the overfeed type, but it is the personal opinion ot the writer that more care in operation is required and that a smaller range of overloads can be carried and still maintain a "smokeless" combustion.

As was brought out in one of the foregoing paragraphs, in all places where the engineers of the bureau thought that conditions of the plant justified installation of stokers, their installation was urged and all of theadvantages of such equipment was pointed out not merely as a permanent check on smoke but in view of the efficient and economic reasons as listed above. The work of the bureau together with other factors resulted in twenty-four mechanical stokers being installed since the starting of the smoke abatement campaign, and in each case the owners and operators were well pleased with their performance. Needless to say these persons all made strong boosters for the smoke abatement work.

The principle on which the underfeed stokers operate is that fresh coal is feed under the fuel bed and as it works upward the temperature gradually increases which causes the distillation of the heavy hydro-carbon gases to occurr at a low temperature, and as these gases rise up through the fuel bed from under the retort. The remaining combustible gases, which constitute roughly twenty-five per cent of the total gases distilled, are quickly burned with the secondary air that is admitted through suitable ports in the front wall and bridge wall. It is essential that the furnace volume and combustion space be of sufficient size as to give the necessary space and

time for the burning of the combustible gases and that the proper amount of air be admitted at such points as to insure complete and thorough mixing with these gases. It is also important that air can be arranged to be admitted under the dump-plates so as to insure complete combustion of all of the fuel. The zoning of the air under the retort is also a desirable feature and results in a more even and cleaner burning fuel bed. (See Appendix for cuts of mechanical stokers and discussion of these, together with a cost saving chart for stokers.)

One notable example of increased capacity as a result of an underfeed stoker installation was in a plant where two 150 and one 100 horse power boilers were required to carry the load. Stokers were installed under each of the larger boilers with the result that these two boilers were able to carry the load with a reasonable amount of ease. It goes without saying that the smoke emission was reduced to a minimum where before it was a serious nuisance. The boilers in this plant were old and frequent repairing is necessary thus causing the hand fired boiler to be used during such repairing periods thereby causing a larger smoke emission then otherwise would occur. One other stoker and boiler change with results gained will be taken and analyzed in the following section.

The next best method for regulating the smoke from power boilers is the use of steam-air-jets and steam-air-blocks. In round numbers there is about sixty per cent of the necessary air for complete combustion going through the grate bars of a hand fired boiler so the function of these pieces of apparatus is to supply the necessary secondary air in the combustion stage

and to mix it with the distilled hydrocarbon gases that are driven off when a fresh charge of coal is fired in order that they may burn, provided the furnace temperature is sufficiently high. The lowest temperatures at which these gases will burn with any degree of thoroughness is between 1800 and 2,000 degrees Fahrenheit. A discussion of this combustion was taken up in a foregoing section of this paper.

The principle upon which the steam-air devices operate is that air is forced through suitable openings in the setting into the combustion space above the fuel bed by directing a small flow of steam under pressure through a small hole in the end of a pipe that extends a short way into the above mentioned openings. (See figures 20 and 21 in the appendix for diagrams of installation of these steam-air devices.) These prints were made for general cases and the blanks are to be filled out to make it fit a specific situation. Figures 22 and 23 in the appendix show how the steam-air-jet is used in the fire box and vertical boilers. When dealing with small vertical boilers of five to ten horse power it is usually necessary to use a "smokeless" fuel in order to insure proper smoke elimination as the steam required for obtaining the over fired air is a much greater percentage of the total steam generated as compared to larger boilers, that the pressure of the supply may drop thus materially effecting its operation. When properly used these simple steam air devices can reduce the smoke emission very appreciably, however, in cases where the load is very heavy or a bad grade of coal is used, together with a low setting, they

have not given as satisfactory results as those to be discussed in the following section, but these cases are few as compared to the others. Cracking the fire door a little for a short period after firing helps very decidedly insuch cases. The fireman often complain of the noise and the time required to use these devices especially where he has other duties and does not have proper time to take the necessary care of the fire, but through constant supervision and cooperation with the owner and operators better use of these devices are usually obtained.

The settings and furnace designs that are in common use in Knoxville today are very inadequate when it comes to burning the soft coal of this region. The settings are very low as they were designed for the low volatile coal of the anthracite group. A large percentage of these boilers are not equipped with a reversing arch which is a very desirable feature from the standpoint of combustion. This arch baffles the gases away from the cooling shell of the boiler for a greater length of time thereby increasing the period in which the gases are in the hot zone. (See page 74 for a diagram and setting dimensions of a correct hand fired horizontal return tubular boiler.) Page 77 in apendix of this paper, in booklet 388 on pages 7 and 9 gives much valuable information as to the requirements of the smoke bureau for power boilers in respect to settings, etc.

If care is taken in selecting a clean and graded coal, for example a nut size for hand fired power boilers, it is felt by the engineers of the smoke bureau that a saving in power cost will result as less fuel will be lost by sifting through

the grate bars, less clinkering, the fire will burn more freely with a greater heat, and at the same time it takes less attention on the part of the fireman. The use of a good clean and uniform coal in a high set boiler with the proper care in firing will result in a very appreciable reduction in the smoke emission as well as economy of opperation. Some of the most improtant points in the way of exercizing proper care in firing may be listed as follows: firing one side at a time; cracking the fire door intil the gases are driven off; cleaning the fires by first removing the ash and live coals down to the grate bars, then covering the bare grate bars with green coal, and then raking the live coals from the other side over on top of this coal and then repeating for the other side; firing light and often, keeping a thin but level and clean fuel bed at all times; and in building the fire use the "upside-down-method," which is putting the fresh coal on the clean grate bars and igniting it by placing the kindling on top. For a discussion of results that have been gained by the use of these steam-air devices see following section of this paper.

The remaining high pressure boilers that are in use in Knoxville are those of the railroad engine. The locomotives present a serious problem when it comes to using bituminous coal as a fuel, as the furnace volume is necessarilly small and large amounts of coal must be burned on a small grate area. Proper furnace design using a baffle arch, proper care in firing, and the use of air jets are the principle ways in which the railroad smoke can be reduced. The outside construction and

design of passenger locomotives causes the Interstate Commerce Commission to refuse the use of steam-air-jets. The jet installation on locomotives is similar to that of other types of high pressure boilers except for the fact that it consists of four to eight jets on each side of the fire box. The flow on air is directed some twelve to fifteen inches above the fuel bed. Due to the water leg that is present on the boilers of this type it takes a longer time and requires considerable more expense in that a water tight fitting must be made on each end of the large pipes which provide an inlet for the secondary air. A large percentage of the switching locomotives have these air-jets installed, but it is felt that better results will be gained in the near future when more supervision can be given to this class of work.

In dealing with the passenger locomotives there are two general methods used. First, when the engines are started on their run from Knoxville the method is to have the fire well worked thus giving a good clean fire and a good head of steam when the engine leaves the round house, so when it comes to the station to take its train the firing of light and well placed charges will be all that is necessary to keep the fire in shape. In this way the working of the fire in the downtown yard is eliminated and places all of the more dense smoke in the round house district which is located a considerable distance from the heart of the city. This system cuts down the emission of dense smoke in the congested business section very appreaciably. The second method applies to the locomotives which do not change their run in Knoxville. The system is to have the fire well worked and in a good condition with a full head of steam before

entering the city limits only light and well placed charges must be added. Leaving the fire door cracked helps very materially when firing is necessary. One feature that is very helpful in the way of railway smoke elimination is that both of the railroads are provided with a cut-off which enables them to run most of their through freights on the outskirts of the city and only the local and interchange cars need to be handled in the more congested sections of the city.

A decided improvement has been made through the splendid cooperation on the part of the railroads, but at the same time they are still a source of much annoyance and they have a much greater opportunity to show a visual improvement than any other class. The method that is used to reach the railroads is to take a smoke record of a few of the locomotives each week and report them to the superintendent of the respective roads and let them handle the situation in their own organizations. Such a method has been gaining results and it is hoped that it will be one that will bring about a better and closer cooperation of the railroads with the smoke bureau and result in a more noticable change. For a discussion of some of the results gained on locomotives see figures 15 to 18.

When it comes to the low pressure heating boiler the steam air-jets-can not be used due to the lack of sufficient steam pressure, so "smokeless" opperation must be gained by one or more of the following ways: mechanical stoker; correctly designed boilers with suitable arrangements of grates, baffles or air entry ports; careful firing; use of the proper coal or the use of a "smokeless" fuel. It is apparent that a "smoke-

less" fuel will more nearly solve the problem than any other method. The reason for not saying complete "smokeless" combustion is due to the fact that oil comes under the head of "smokeless" fuels and if it is not properly burned smoke will result, but in case of coke or anthracite coal no smoke results. The next best method is the use of an underfed mechanical stoker, the characteristics of which were described under the high pressure work, they being the same for both classes. Five of such stokers have been installed in the low pressure field since the starting of the smoke campaign, these being included in the previous figure of twenty-four stokers for the last year period. The design of the boilers is the best method now in use, there being essentially three types of design. First, down draft type which is based upon the principle of the gases being mixed with the air drawn in through the charging door and then passing through the fuel bed on the upper grate and then being mixed with the secondary air admitted through the lower door and passing over the hot coals on this lower grate. The second type is based upon the principle of admitting secondary air over the fuel bed to mix with the smoke forming gases when they are in a zone of combustion. Much of the success of these boilers in regard to smoke emission, as well as efficiency depends a great deal upon the grade of coal used, the care which the fireman takes in firing and in the general care of the fire which includes such points as firing periods, cleaning of fires, removal of ashes, starting the fire, drafts, etc. A third class of "smokeless" boilers comes from the design which has an igni-

tion arch near the rear of the boiler. (See p.68 to 72 for cuts of these boilers)

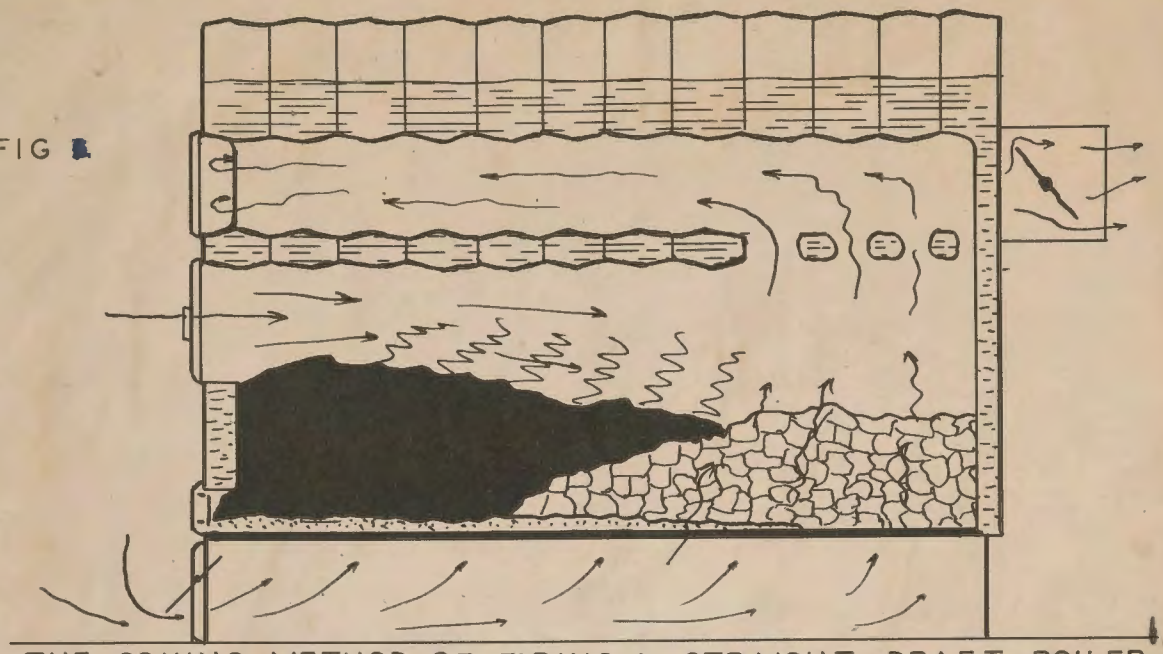
A good clean grade of coal such as the egg size is a coal that is recommended by the engineers of the smoke bureau for the general heating purposes in which the above types of boilers are used. In making this recommendation several things are taken into consideration, they being based upon the fact that egg coal in general is a good clean, and graded coal and is therefore, better for burning, has a higher heat value per pound as compared to a coal which contains dirt and slack. This coal has a less clinkering tendency and burns more freely with a level and even fuel bed, thus preventing dark spots and holes in the fire which cause the air to be improperly mixed for combustion. Such items as the above reduce the attention and working of the fire between charging periods to a surprisingly low figure as compared to a coal which contains a larger per cent of fines and dirt.

The down draft type of heating boiler or power boiler for that matter, needs a good draft and much of its operation performance depends upon this point as well as the most essential factors, which are the using of a correct kind of coal together with the exercising of proper care of the fire. An even and clean fuel bed must be kept at all times together with the proper air regulation. The fresh coal is scattered evenly over the live coals on top of the grates, a little deeper at the back side and gradually decreasing in thickness to the front where it is somewhat shallow. In using a bar it is of great importance to run this bar under the fuel bed and loose it, but do not turn

it upside down as the green coal would then be on the bottom thus giving the gases formed a chance to escape without passing through the fuel bed where they would be burned to a much larger degree. Turning the fuel bed upside down also results in a much worse clinkering tendency.

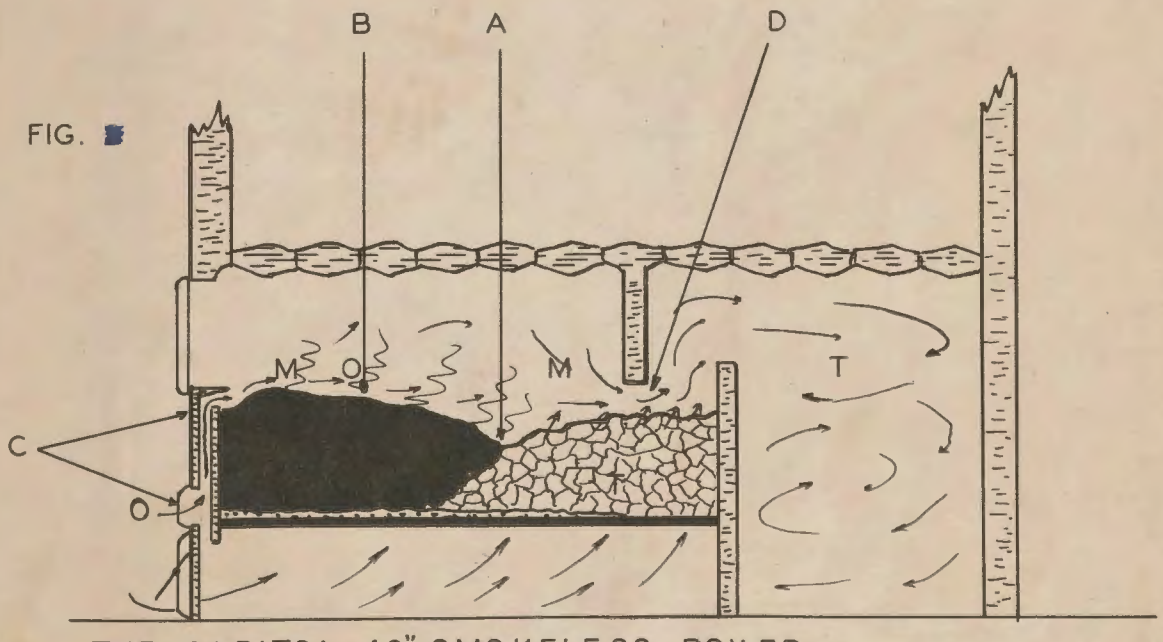
The care to be exercised in the second and third types which are on the straight draft principle that depends upon the air admission by suitable ports usually located on the side or through the fire door for smokeless combustion, is entirely different from the down draft boiler, but this care is just as essential, if not more so for proper operation performance. This method is to be used on all straight draft heating boilers whether they have the air entry ports, baffle walls, or not. The method prescribed is as follows: instarting the fire use the "up-side-down" method, and in firing, push all of the live coals to the rear forming an even ridge cross-wise of the furnace, and then putting the green coal on the front grates that are bare or practically so. When this coal starts to burn its travel will be forward while that of the gases will be to the rear; a condition which results in the gases being burned as they pass over the hot coals that were pushed back, provided these gases are mixed with the suitable amount of air admitted through the air ports or charging door. Such a process is called the coking method of firing. (See Figure 3.) The length of the firing period is also important as the fire must be kept hot and not allwed to cool or die down if proper results are to be gained. The ash pit must be kept clean if the necessary primary air is to be had as well as to protect the

FIG [redacted]



THE COKING METHOD OF FIRING A STRAIGHT DRAFT BOILER.

FIG. [redacted]



THE CAPITOL 40" SMOKELESS BOILER.

Figure 3.

'United States Radiator Corporation.

grate bars. Reducing the grate area by putting in a fire brick wall results in a decided smoke reduction as it enables a heavier fire to be carried on a smaller grate area and prevents dead spaces where air can by-pass.

With one exception the last few paragraphs have dealt mainly with the means by which "smokeless" combustion and smoke elimination can be attained, but very little has been said as to the way in which the bureau has reached the various plants and coal users. The policy of the bureau was to visit all of the various plants and after a study of their situation, by observationand Ringelmann's chart reading or assisted somewhat in many cases by a picture of the stack, a recommendation was made. This chart reading was made for a record as well as to show the operator or owner just what the stack was doing in the way of smoke emission. When any new inspection is made it is the policy to take down the type and kind of boiler and equipment, including setting, fuel being used, duties of fireman, owners name and address, including the plant address, and any other items that would be necessary for future reference. All such information is filed in the office of the smoke bureau. The time for making the recommended changes was set at thirty days with possible extention os time is the bureau engineer deemed the reason for delay justified. The bureau has been very liberal and generous in time extention as it was hoped to obtain a better spirit of cooperation in this way rather than being harsh and unjust in their demands. The majority of the recommendations were made to the proper persons both in the field and by letter, so as to have a record of the recommenda-

tion in the files for reference. Prints, copy of ordinance, phamplets, and cards of instruction, etc, accompanied the recommendation to assist in making th changes and carrying out the provisions of same. In places where no change of construction was required, but instead, a change in the method of firing or care of fire, no limit was set, but the recommendation was expected to be carried out immediately and in the case of a fuel change it was expected to be made when the present supply was exhausted.

At the end of the period given for the boiler change a check of the plant was made for the purpose of determining if the recommended change had been made, and if so it was the policy to test this device or arrangement or to determine the method of handling it to gain the best results and to instruct the operator in the proper method. If the change had not been made or a suitable explanation given for the delay together with a definite statement as to when the change could be expected to be completed, a reading was taken on the stack in question and this used as a basis for a notice of violation. There were to be three such notices before court action, but none of the plants had to be dealt with by such forceful means. Several, however, had to be sent the first notice of violation, but very few required more than one. Up to the the date of this writing, 1929, there has been only one case brought to court. This case was one of violation of section four of the ordinance which requires a permit from the Bureau of Smoke Regulation for the construction installation, or repair of any boiler, (m) of section six being the exact head under which

this case was listed.

In making the inspections and recommendations it has been the policy of the bureau to drop a few hints as to fuel conservation and other suggestions as to the solving of boiler equipment problems, but in making suggestions the engineers of the bureau have not invaded the field of the consulting engineer and they consistently refused to act in that capacity, except for the city itself. The activities of the Smoke Bureau have led to the employment of consulting engineers to make plans for new power plant installations in three of the largest industrial plants of the city. The schanges will eliminate considerable smoke as these plants are very bad offenders.

In the heating season many small buildings in the congested areas with their low stacks have been a serious problem, but a plan of establishing six "block heating systems" as a remedy for the smoke nuisance is now under way. Under this system the smaller buildings of a block will be heated by the larger ones of the block and if such a plan is put into operation thirty-four of the smaller and offending chimneys will be eliminated. The present indications are that these plans will be adopted, bur as yet this system has not met with the entire approval of all buildings concerned. The domestic fuel user was reached through an educational program, which consited of radio talks, placards on stree cars, phamplets and instructions, and numerous press articles. Upon request the engineers of the bureau were available for instruction in a home thus enabling the domestic furnace users and operators

to have instruction as to the best way in handling their boiler in regard to smoke emission as well as other points of boiler care and operation. Coke was used to some extent in many of the homes as well as business houses, its sale being over three hundred per cent greater this year than last, however, this increase is due somewhat to the activities of the coke dealers. The retail coal dealers have now organized to put on a campaign of instructing their customers in a proper use of coal as a domestic fuel, their slogan being "The proper coal in the right place."

The whole program for the past year has been based upon education in order to gain the support and cooperation of the people and make them "smoke abatement conscious." Much credit must begiven to the newspapers in Knoxville for the many articles and editorials published in their columns thus keeping the public informed and actively interested in the work. With this principle of education in mind a very small budget and personnel was required for the first year as it was thought a great deal more could be accomplished by this small budget at first and then increasing it when the value of smoke abatement had been more firmly established. The results of this first year have been gratifying and it is believed that there will be little opposition to increasing of the budget for the coming year, so with this in mind the plan of the bureau, with the endorsement of the Advisory Board, is to divide the city into districts and have a larger personnel thus enabling much better supervision to be given to the various industrial plants, heating plants, railroads, etc.

DISCUSSION OF OBSERVATIONS

All of the following charts readings are to be understood to refer to the Ringlemann's chart which is given in booklet 399 on page 77 of this thesis. All of the violations are listed in which the smoke emission was number three or greater as indicated by the red shaded portions. (See city ordinance for allowances in excess of number two.) All observations on these charts were taken at fifteen second intervals and at such a distance from the stacks as to give a correct reading.

Figure 4, In this plant the the boilers were so heavily overloaded that a new set of boilers was required. Readings A and B were taken on the stoker fired and hand fired boilers respectively, one of the hand fired boilers being down thereby causing the stoker fired one to be carrying the main portion of the load. In order for this stoker to carry the load a bar was used to push the coal to the sides as the mechanical action of the stoker would not carry the large amounts of coal away fromthe center as rapid as was necessary in order that the required steam be generated. When this bar was used the green coal would be exposed causing a very dense smoke. This plant installed 2-250 horse power Heine water-tube boilers equipped with Detroit V-type mechanical overfeed stoker using natural draft. See page 65 for a cut of this type stoker. This kind of stoker is not the type that is prescribed by the bureau for burning soft coal "smokeless", but due to the fact

that these stokers were purchases with the boilers at a very material saving over any other equivalent equipment, due to slight usage, and were of such capacity that an over load would not be carried for many years to come, they were permitted to be installed. In order to make the necessary room for the new equipment, the two smaller boilers were taken out thus causing a still higher overload on the remaining boiler and added greatly to the already existing smoke nuisance. With the completion of the new plant this boiler is used as a stand unit.

Readings C and D were taken on the new boilers which shows excellent conditions as far as smoke emission is concerned. Most of the time there is just a small whif of smoke coming from the stack, a condition which indicates efficient combustion. A bad smoking stack is always a sign of poor efficiency, but a clear stack does not always indicate high efficiency, as a large excess of air may be present.

A flue gas analysis shows the following readings:

CO_2 = 7.0%

O_2 = 11.4% Flue gas temperture 600 degrees F.

CO = 0.2%

These readings were taken before the operation of the plant was stabilized and it is believed that a better combustion is now being obtained, however, the above readings show a fairly efficient operation.

The chart readings on these new boilers does not necessarily mean that they operate all the time in such a manner, but they are a true indication of the enormous reduction

smoke that was brought about by the change. An installation of this type is one that will give permanent check on the smoke so long as it is operated with the necessary care, and at the same time operate more efficiently in the way of steam generation.

Figure 5. This group of readings were taken on a moderate sized plant which operate hand fired boilers as indicated on the chart. Reading A was taken with a three boiler load at a period when the fireman was unaware of the observation. The two firing periods shows a very bad violation due to the air-jets not being used. The reading B was taken under test conditions when the fireman was operating the jets and fuel charges as instructed by the observer. The various lengths of time which the air-jets were on with the violation of each firing period is recorded on the chart. This record shows conclusively the possible reduction of smoke, however, it is felt that the three air-jets will not reduce the smoke as effectively when a heavier load is carried without the cracking of the fire door for a short time after each firing period. The fires needed cleaning very badly when the test was run, so with a cleaner fire the results would have been somewhat better, but it is well to see what can be expected under adverse conditions.

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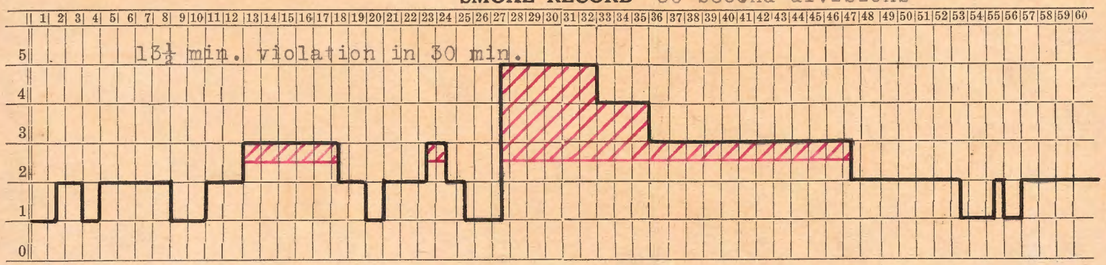
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 6/8 1928
Inspector Wilkinson

Name Moderate Size Industrial Plant Address
Number of stacks on plant, brick concrete steel 3 tile
This report covers No. 1 stack. Fuel Nut & Slack
Wind Light Weather Clear
Point of Observation Observation Began 9:56 A.M.
Smoke Prevention Device Jones Underfeed Stoker Cleaning or Starting Fires
Remarks (1) 240-H.P. B & W Boiler Heavy overload. One boiler down.

SMOKE RECORD 30 second divisions



A

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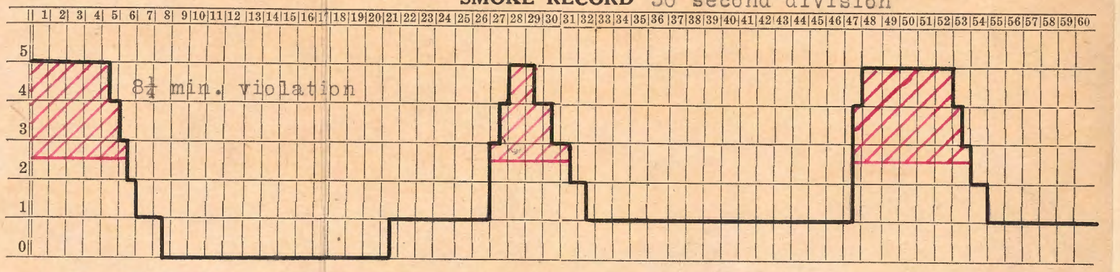
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 6/8 1928
Inspector Wilkinson

Name Address
Number of stacks on plant, brick concrete steel 3 tile
This report covers No. 3 stack. Fuel Nut & Slack
Wind Light Weather Clear
Point of Observation Observation Began 10:26 A. M.
Smoke Prevention Device None Cleaning or Starting Fires
Remarks (1) 100 H.P. HR.T. Hand fired boiler. Heavy load; low setting; remaining boiler of plant of same type and setting down for repairs.

SMOKE RECORD 30 second division



B

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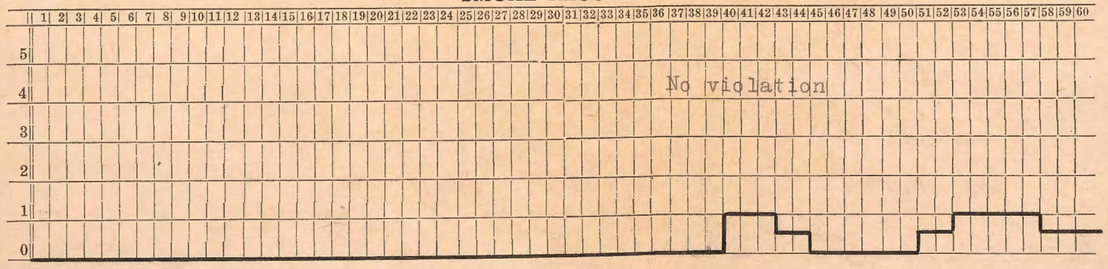
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 4/18 1929
Inspector Chapman

Name Address
Number of stacks on plant, brick concrete steel 2 tile
This report covers 1 Large Stack. stack. Fuel Nut & Slack
Wind Light Weather Clear
Point of Observation Observation Began 2:30 P.M.
Smoke Prevention Device Stoker Cleaning or Starting Fires
Remarks 2 - 250 H.P. Heine Boilers, Detroit V-Type; overfeed stokers, natural draft.

SMOKE RECORD 30 second division



C

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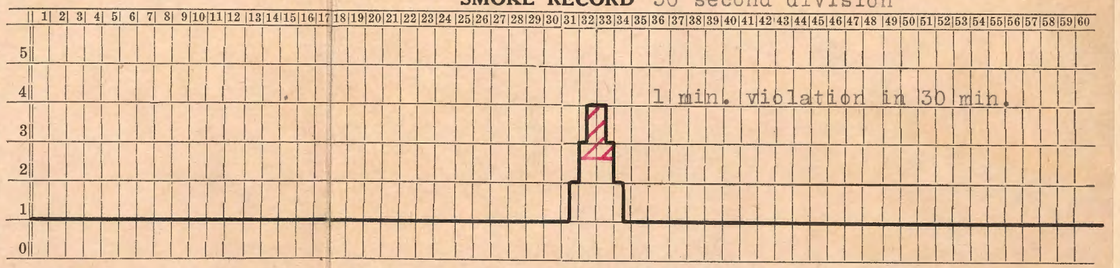
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 4/24 1929
Inspector Chapman

Name Address
Number of stacks on plant, brick concrete steel tile
This report covers stack. Fuel Nut & Slack
Wind Light Weather Clear
Point of Observation Observation Began 2:35 P.M.
Smoke Prevention Device Cleaning or Starting Fires
Remarks Same as "C"

SMOKE RECORD 30 second division



D

Figure 4

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 3/29 192 9

Inspector Chapman

Name Moderate Size Ice Plant Address

Number of stacks on plant, brick concrete steel tile

This report covers 3 Boilers all on one stack. stack. Fuel Nut & Slack

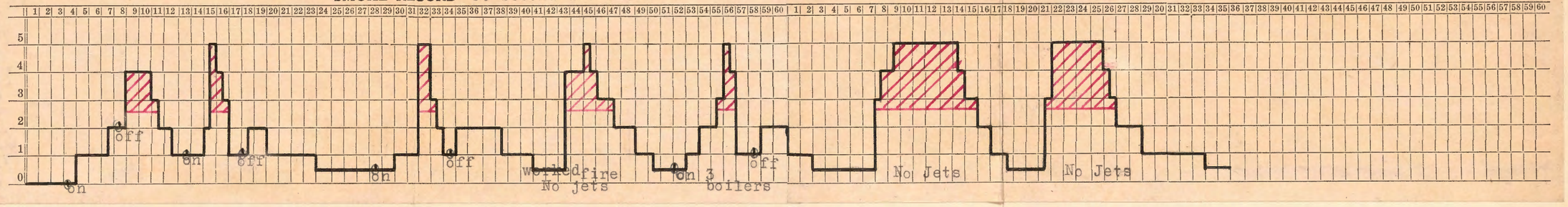
Wind Light Weather Cloudy

Point of Observation Observation Began 3:20 P.M.

Smoke Prevention Device 3 Steam-Air-Jets to each Boiler. Cleaning or Starting Fires

Remarks Test. 6 shovels to a boiler; two operating at 100# pressure, other just starting fire. No jets on the dead boiler. Pressure 100#.

SMOKE RECORD 30 second divisions



B

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 192

Inspector

ame Address

umber of stacks on plant, brick concrete steel tile

his report covers stack. Fuel

/ind Weather

oint of Observation Observation Began

moke Prevention Device Cleaning or Starting Fires

emarks 4 - 110 H.P. H.R.T. 30 " setting; hand fired

SMOKE RECORD

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 4/4 192 8

Inspector Chapman

Name Same size as "B" Address

Number of stacks on plant, brick 1 concrete steel tile

This report covers 3 Boilers stack. Fuel Slack

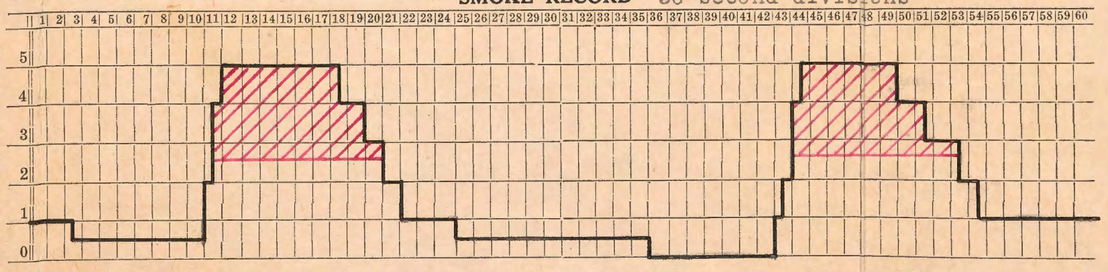
Wind Moderate Weather Clear

Point of Observation Observation Began 1:56 P.M.

Smoke Prevention Device Steam-Air-Jets Cleaning or Starting Fires

Remarks Fireman not aware readings being taken; not using jets.

SMOKE RECORD 30 second divisions



A

Figure 5

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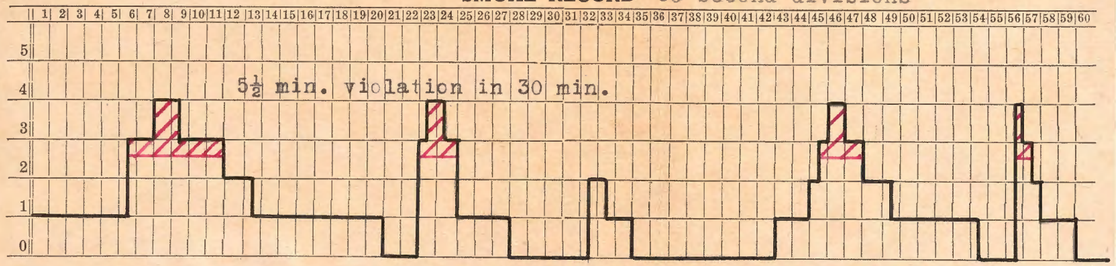
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 6/12 1928
Inspector Wilkinson

Name Moderate Size Laundry Address
Number of stacks on plant, brick concrete steel 1 tile
This report covers stack. Fuel Run of Mine
Wind Light Weather Clear
Point of Observation Observation Began 10:03 A.M.
Smoke Prevention Device None. Cleaning or Starting Fires
Remarks 1 150 H.P. H.R.T. 72" setting Huber Hand Stoker
Pressure 85 to 110#.

SMOKE RECORD 30 second divisions



A

394

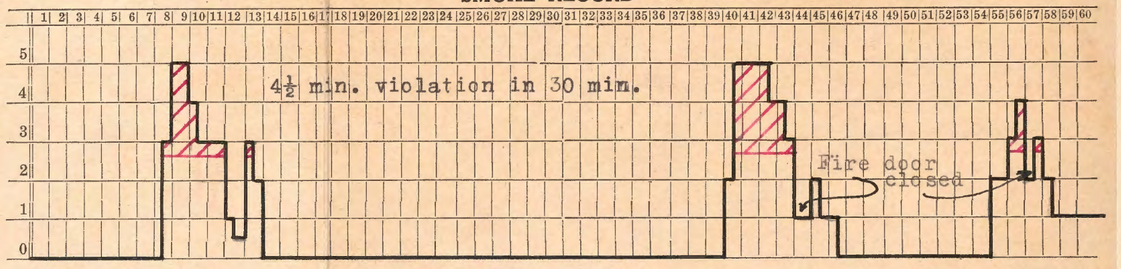
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 4/18 1929
Inspector Chapman

Name Same as "A" Address
Number of stacks on plant, brick concrete steel 1 tile
This report covers stack. Fuel Nut & Slack
Wind Light Weather Clear
Point of Observation Observation Began 1:30 P.M.
Smoke Prevention Device None Cleaning or Starting Fires
Remarks Using care in firing. Fireman unaware that readings were being taken.

SMOKE RECORD 30 second divisions



B

Figure 6

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 6/11 1928
Inspector Wilkinson

Name Small Laundry Address
Number of stacks on plant, brick concrete steel 1 tile
This report covers stack. Fuel Screenings
Wind Light Weather Cloudy
Point of Observation Observation Began 2:41 P.M.
Smoke Prevention Device None Cleaning or Starting Fires
Remarks 1 — 80 H.P. H.R.T. 24" Setting
Hand fired. Pressure 80 to 95#.

SMOKE RECORD 30 second divisions

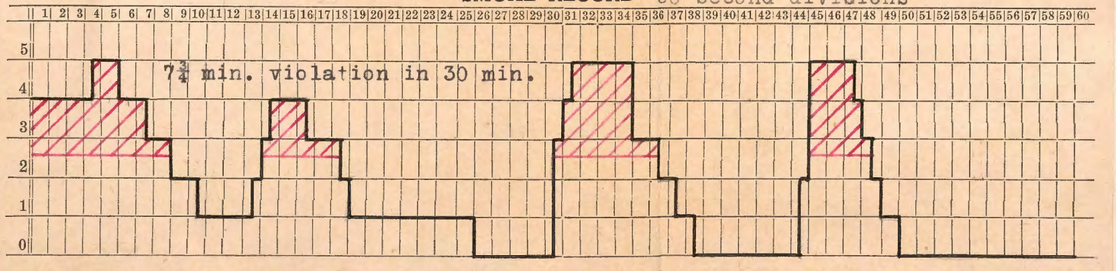

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Figure 7

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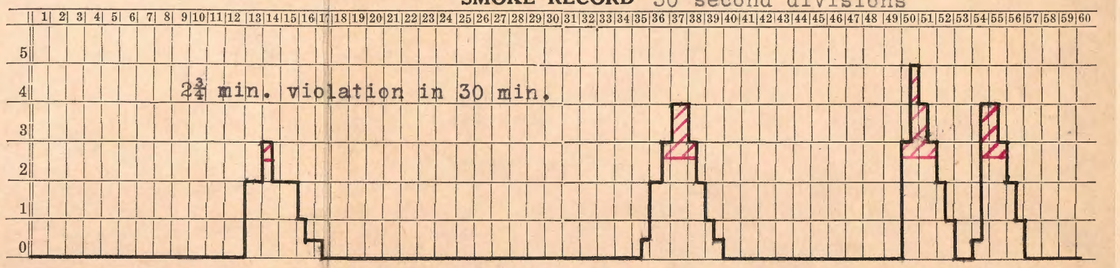
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 5/15 1929
Inspector Chapman

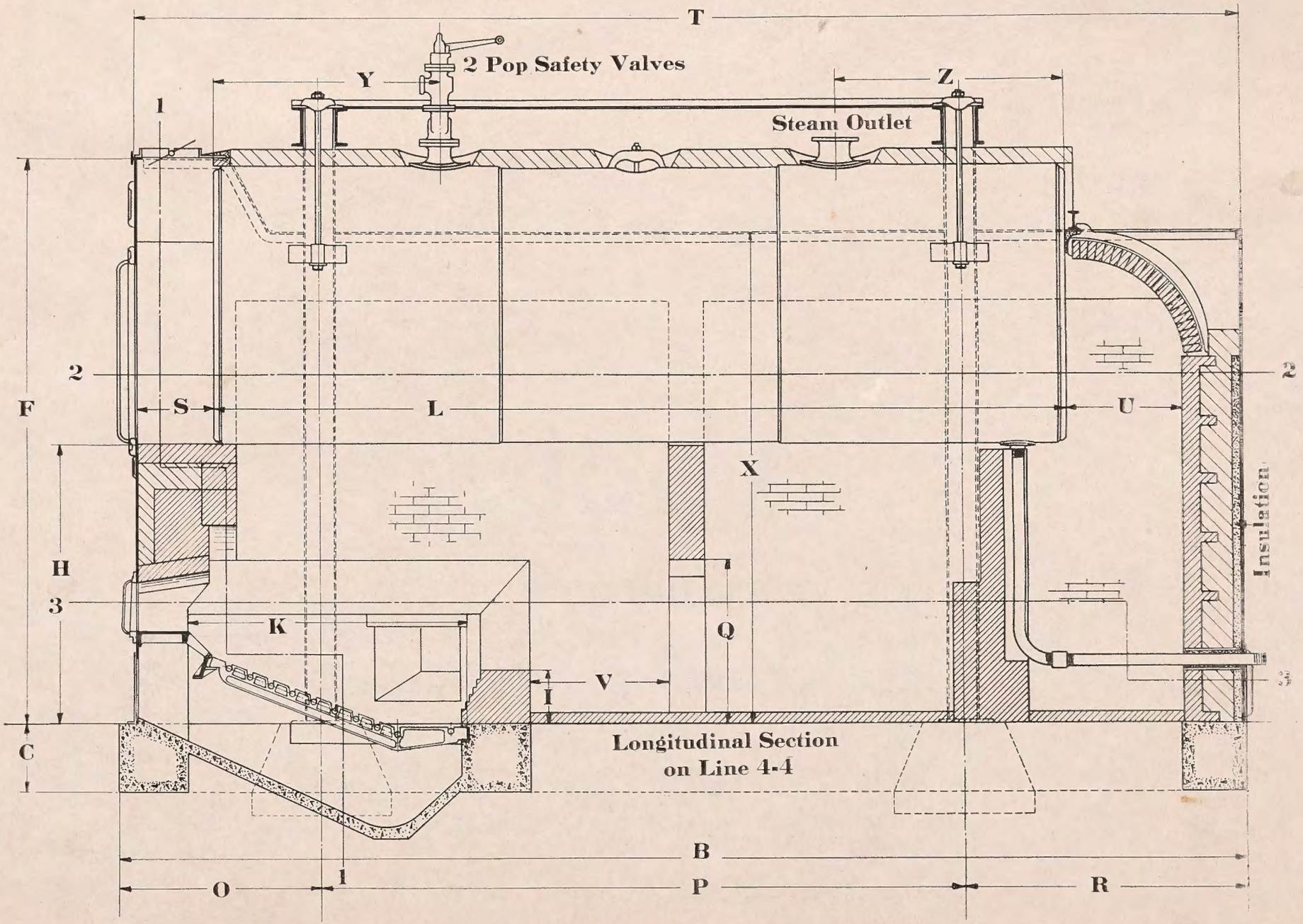
Name Address
Number of stacks on plant, brick concrete steel 1 tile
This report covers stack. Fuel Screenings
Wind Very light Weather Rain
Point of Observation Observation Began 2:03 P.M.
Smoke Prevention Device None Cleaning or Starting Fires
Remarks Same Boiler with 60 " setting. Hand fired.

SMOKE RECORD 30 second divisions



B

Figures 6 and 7



Type of Hand Stoker, Boiler, and Setting in use in Plant where readings of Figure 6 were taken, but the Stoker or Boiler is not of the above make.

Figure 6. These readings were taken on a moderate sized laundry which operates a boiler as indicated on the chart. Reading A shows the record of the first inspection of this boiler which indicates that it was operated above the ordinary without instruction as to care of fire for deeping down the smoke. The reading B shows how the plant now operated under normal conditions as this observation was taken at a period when the fireman did not know readings were being made The load conditions were about the same in both cases. Air-jets were tried on this boiler but due to the low bridge wall constructions the gases were allowed to escape unburned over this wall due to the fact that they were not properly mixed and held in the hot zone over the fuel bed for a sufficient length of time. (See print on back side of observation sheet for diagram of this setting.) The method which is now used is to fire light and often, keeping as clean a fire as possible, and cracking the fire door for a period of two to three minutes after each charging period. Surprisingly good results can be gained in this way and under a test when the fireman knows the readings are being taken a much better record than B can be obtained, and using straight grate (See page 73) still better results can be gained.

Figure 7. The observations of this set were taken on a small horse power hand fired boiler under two different setting conditions as designated on the record cards. The plant in question is a small laundry. Reading A was taken with a twenty-four inch setting during which time the boiler was overloaded, and as a new brick work was needed the boiler was raised to give a sixty inch setting with the result that the

capacity was raised enough so as to carry the load with more ease. Air-blocks were installed in this new setting, but they did not give such a marked degree of satisfaction. Reading B was taken with the high setting with the air-blocks off and at a time when the fireman was unaware of the readings being taken. Under observed test of the fireman the smoke emission can be cut down still more by careful handling of the fires. Little difference was shown with the air-blocks being used. This condition is believed to be caused by the air-blocks not giving the proper mixing effect as do the air-jets and stratification and laning results. In theory these air-blocks are ideal as the hole arrangement is designed to give the maximum air near the bridge wall where it is most needed, but due to the slaging over and these blocks being constantly subjected to the high furnace temperatures and the stratification that is believed to take place they have not proved as satisfactory as the jets. The above reading gives somewhat of an indication of a normal operating conditions as a series of readings over a period of six months have given similar results. The comparison of smoke charts together with the increased boiler capacity and fuel saving shows very forceably the advantages of the high set boiler over a low set one.

Figure 8. Reading A was taken on a first inspection trip which resulted in a recommendation of the air-jet installation and reading B shows how the fireman is operating the jets under average working conditions. As a criticism of the fireman's methods as to jet operations it can be seen that they were not left on sufficiently long to insure proper smoke elimination. The reading C shows what results can be gained if the jets were used properly, these readings being taken under test conditions. A flue gas analysis taken under conditions as listed below indicate the advantage in combustion by the use of the jets.

	Jets not on:	Jets on:
CO_2 =	8.0%	14.0%
O_2 =	10.0%	2.0%
CO =	1.0%	1.4%

The reading again shows conclusively the performance of the jets as a smoke preventing device and together with the comparative flue gas readings as given above indicate much better combustion. With the higher CO the last set shows a gain of two hundred and ten B.T.U. per pound of carbon burned as shown by the figure 19, to say nothing of the smaller oxygen content.

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 6/9 1928

Inspector Wilkinson

Name Moderate Size Laundry Address

Number of stacks on plant, brick ... concrete ... steel 1 tile ...

This report covers ... stack. Fuel Nut & Slack

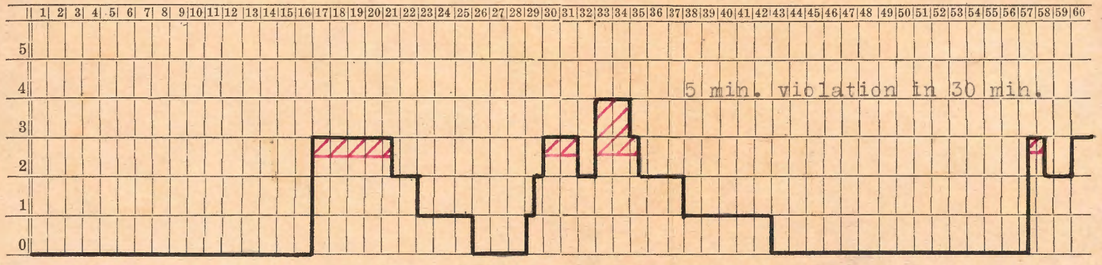
Wind Little - Light Weather Clear

Point of Observation ... Observation Began 9:43 A.M.

Smoke Prevention Device None Cleaning or Starting Fires ...

Remarks 1-150 H.R.T. 42" Setting. Hand Fired
Pressure 90-105#

SMOKE RECORD 30 Second Divisions



A

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 12/5 1928

Inspector Chapman

Name ... Address ...

Number of stacks on plant, brick ... concrete ... steel 1 tile ...

This report covers ... stack. Fuel Nut & Slack

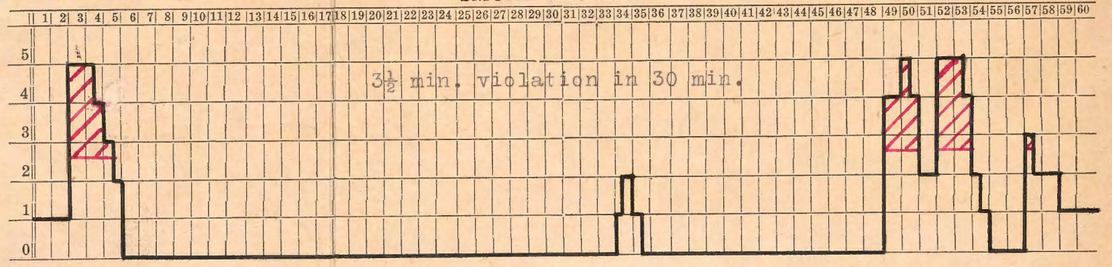
Wind Moderate Weather Cloudy, rainy

Point of Observation ... Observation Began 2:48 P.M.

Smoke Prevention Device 4 Air-Steam-Jets Cleaning or Starting Fires ...

Remarks Fireman did not know readings were being taken.
Using jets but cutting off too soon.

SMOKE RECORD 30 second division



B

394

Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 12/27/ 1928

Inspector Chapman

Name ... Address ...

Number of stacks on plant, brick ... concrete ... steel 1 tile ...

This report covers ... stack. Fuel Nut & Slack

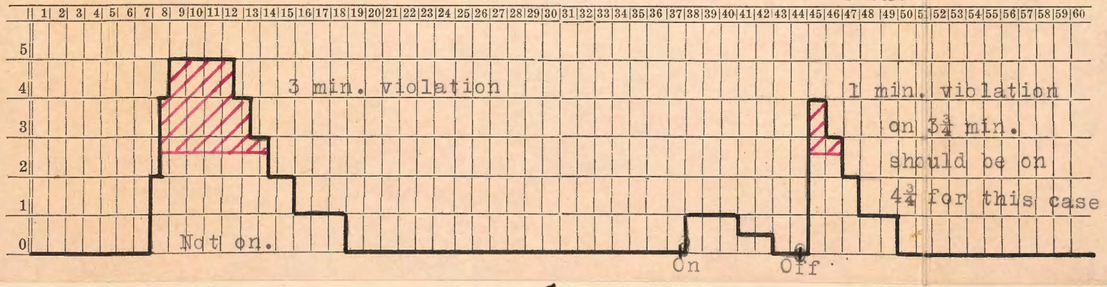
Wind Moderate Weather Cloudy, rainy

Point of Observation ... Observation Began 10:15 A.M.

Smoke Prevention Device 4 Steam-Air-Jets Cleaning or Starting Fires ...

Remarks Test 6 shovels to a firing

SMOKE RECORD 30 second divisions



C

Figure 8

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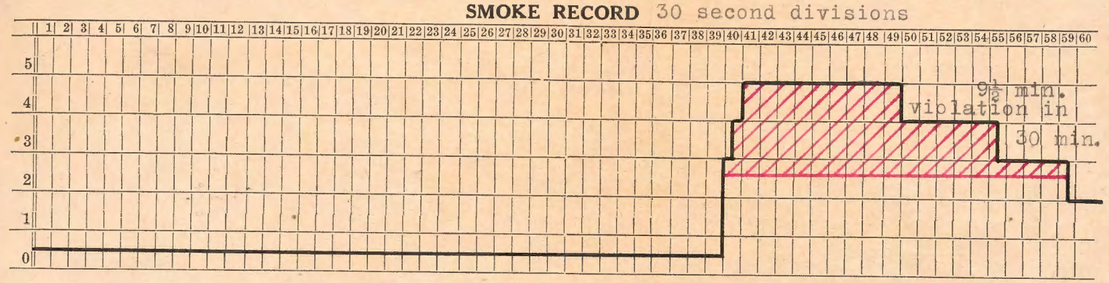
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 6/12 1928.
Inspector Wilkinson

Name A moderate size Cleaning Plant Address
Number of stacks on plant, brick concrete steel 1 tile
This report covers stack. Fuel Run of Mine
Wind Light Weather Clear
Point of Observation Observation Began 10:35 A.M.
Smoke Prevention Device None Cleaning or Starting Fires
Remarks (1) 80 H.P. H.R.T. Boiler 30 " Setting. Hand Fired.
Intermittant firing; fireman has other duties in plant.

SMOKE RECORD 30 second divisions



A

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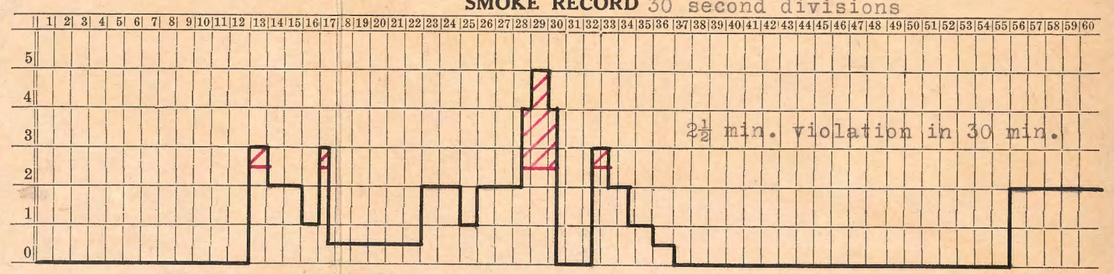
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 3/18 1929
Inspector Chapman

Name Address
Number of stacks on plant, brick concrete steel 1 tile
This report covers stack. Fuel Nut & Slack
Wind Light Weather Clear
Point of Observation Observation Began 1:30 P.M.
Smoke Prevention Device 4 Steam-Air-Jets Cleaning or Starting Fires
Remarks Fireman unaware of reading being taken.
Pressure 85 to 100#.

SMOKE RECORD 30 second divisions



B

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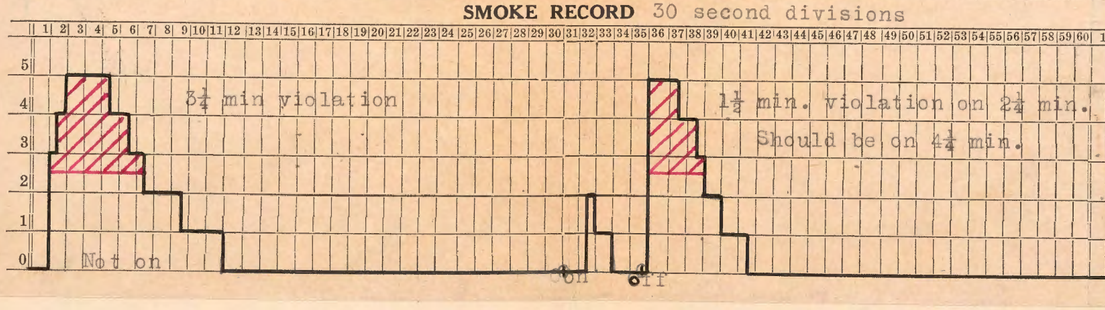
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 3/20 1929
Inspector Chapman

Name Address
Number of stacks on plant, brick concrete steel 1 tile
This report covers stack. Fuel Nut & Slack
Wind Very light Weather Clear
Point of Observation Observation Began 2:51 P.M.
Smoke Prevention Device 4 Steam-Air-Jets Cleaning or Starting Fires
Remarks Test. 4 shovels to a firing.

SMOKE RECORD 30 second divisions



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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 192....
Inspector

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SMOKE RECORD

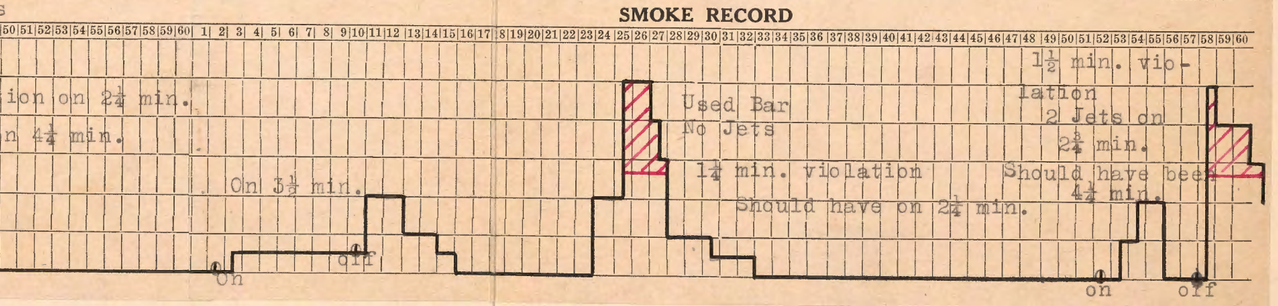

Figure 9

Figure 9. Reading is typical of many plants in the city where the fireman has other duties which takes him away from the boiler room for a long period of time resulting in the steam getting low and then a heavy charge of coal being put on a poor kept fuel bed and worked heavily in order to build up the steam pressure quickly. Such a condition results in a very bad smoke condition as well as poor fuel economy. The situation at this plant has improved considerably as is shown by the reading B which was taken under normal operating conditions when the fireman was unaware of the observation. Reading C shows what the jets will do under conditions as indicated and to what extent a "smokeless" stack can be had if the fireman will take ordinary care of the fire and use the jets at all times when a fresh charge of coal is fired and when the fuel bed is disturbed.

Figure 10. The plant on which these observations were taken was one that used wood shavings and coal as fuel. Reading A was taken at a period when only wood was used with the air coming into the furnace with the shavings through a large pipe in front of the setting. Very little smoke resulted. With the low thirty inch setting, using part coal when a heavy load was carried and wood refuse was not so plentiful, a very dense smoke resulted. The reading of the flue gas analysis taken when about thirty-five percent coal was used is as follows:

CO_2 = 5.2% O_2 = 14.2% CO = 1.6%

The large amount of oxygen resulted from the over fire air through the wood duct and through the holes in the setting. As the brick work was in a very bad condition a new setting was made in which a seven foot distance was given from floor to boiler shell and a reverse arch was put in. The large pipes were put in the setting for air-jets, but to date they have not been connected. A much better smoke condition resulted from this change. With the use of coal in about the same proportions as when the above flue gas readings were taken, smoke would come in small puffs of three to eight seconds duration for short periods after firing, the short smoky and clear intervals being caused by the irregularity in which the wood refuse was fired. Reading B shows graphically the result. Before the change of setting was made the load during the

winter months was hard to carry, but after this change, which was made in the middle of the winter, a decided difference was also noted in capacity and fuel saving.

Figure 11. These readings were taken on a plant which operated one down draft and one horizontal return tubular boiler. Air blocks were first tried in the H.R.T. boiler, but the desired results were not obtained, so three air-jets were put in to operate with the air blocks, and if this combination was properly operated the smoke emission would be very slight. A test was run for flue gas firing six shovels of coal at each test. The smoke emission was found to be very dense for three to four minutes after firing and when the air arrangements were used the smoke never got above number 1. The flue gas readings are as follows:

	Jets not on:	Jets on:
CO_2 =	7.0%	8.0%
O_2 =	12.0%	13.0%
CO_2 =	2.0%	0.0%

Draft = 0.29 inches of water. Flue gas temperature four hundred degrees Fahrenheit.

From Figure 19. Neglecting the extra percent oxygen which is compensated for by the percentage gain in CO_2, there was three hundred and fifty B.T.U. per pound of carbon burned by using the jets. Reading A was taken on both the boilers of the plant which shows one firing period that was exceptionally good. Reading B was taken on the H.R.T. boiler only. The air-jets and air-block arrangement was used at both times. The first firing period was not nearly so good as it should have been due to the fact that the fuel bed was covered with a

heavy charge when the fire had died down leaving a portion in a cool state thus causing a drop in temperature to a point where all of the gas mixture would not burn. The second firing period shows much the same conditions, but this time the fuel bed was cooled down much below the other time. Such intermittent firing is caused by the fireman having other duties around the plant which necessitates his being away from the boiler room for some length of time. A closer attention to the fire is the only remedy for a situation of this nature.

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 6/13 1928

Inspector Wilkinson

Name Small Industrial Plant Address

Number of stacks on plant, brick concrete steel 1 tile

This report covers stack. Fuel Wood shavings over fire.

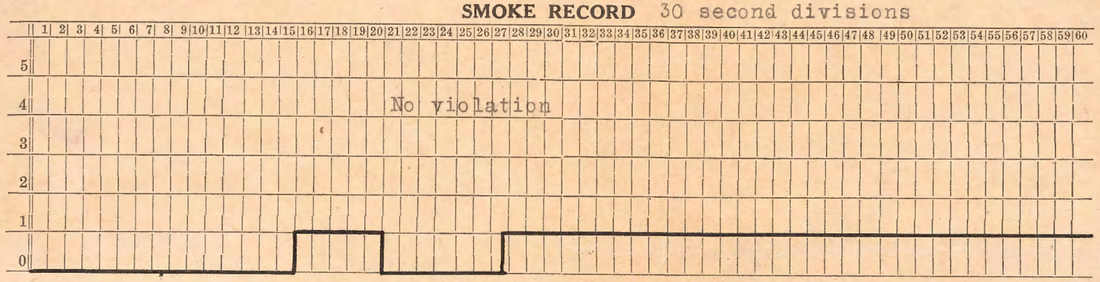
Wind Light Weather Clear

Point of Observation Plant Observation Began 3:06 P.M.

Smoke Prevention Device None Cleaning or Starting Fires

Remarks 1 - 150 H.P. H.R.T. 30" Setting; hand fired for coal only.
Pressure 85# to 100#

SMOKE RECORD 30 second divisions



A

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 4/15 1929

Inspector Chapman

Name Same as "A" Address

Number of stacks on plant, brick concrete steel 1 tile

This report covers stack. Fuel Wood shavings and coal.

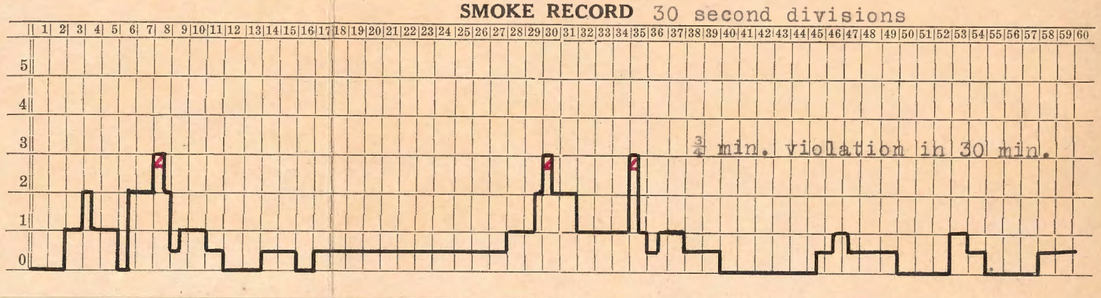
Wind Very light Weather Cloudy

Point of Observation Plant Observation Began 3:56 P.M.

Smoke Prevention Device None Cleaning or Starting Fires

Remarks 1 - 150 H.P. H.R.T. 7'0" Setting Same Boiler as "A".

SMOKE RECORD 30 second divisions



B

Figure 10

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 5/14 1929

Inspector Wilkinson

Name Address

Number of stacks on plant, brick concrete steel 2 tile

This report covers Steel Stack of H.R.T. Boiler stack. Fuel Nut & Slack

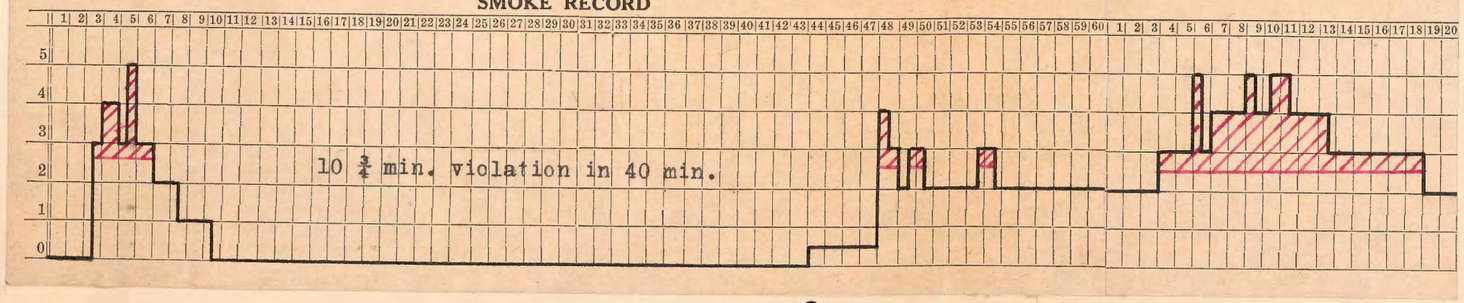
Wind Light Weather Clear

Point of Observation Plant Observation Began 9:37 P.M.

Smoke Prevention Device 2 Air Jets & 2 Blocks Cleaning or Starting Fires

Remarks Jets used but fire had died down to where temperature not sufficient.
Same plant as "B". Pressure 85#.

SMOKE RECORD



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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 4/12 1929

Inspector Wilkerson

Name Same Plant as "A" Address

Number of stacks on plant, brick concrete steel tile

This report covers stack. Fuel Nut & Slack

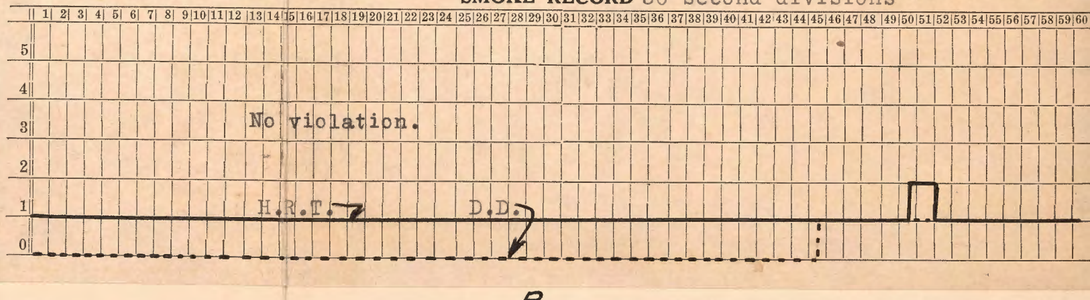
Wind Light Weather Clear

Point of Observation Plant Observation Began 10:18 A.M.

Smoke Prevention Device Same as "A" Cleaning or Starting Fires

Remarks 1 - 80 H.P. H.R.T. and 1 Down Draft Boiler
Hand fired.

SMOKE RECORD 30 second divisions



B

Figure 11

Figures 10 and 11

Figure 12. This reading was taken on a boiler equipped with air-blocks. During the first two firing periods as indicated on the reading A, the air-blocks were not used, however, the third firing period under known observation with the air-blocks turned on failed to show a decided difference, due partly to the fact that openings in the blocks were badly slagged over. This is another case in which the air-blocks did not show their effectiveness as much as the air-jets. Air-jets were not installed in this boiler so a direct comparison could not be made, but under similar conditions better results have been gained. Reading B was taken before the blocks were installed.

The firing in this plant is done by several as the regular fireman has other duties to call him away from the boiler room, consequently, proper care cannot be taken of the fire and a bad smoking condition prevails as a result of such intermittent firing.

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 4/8 1929

Inspector Chapman

Name Moderate Size Dairy Co. Address

Number of stacks on plant, brick concrete steel 1 tile

This report covers stack. Fuel Nut & Slack

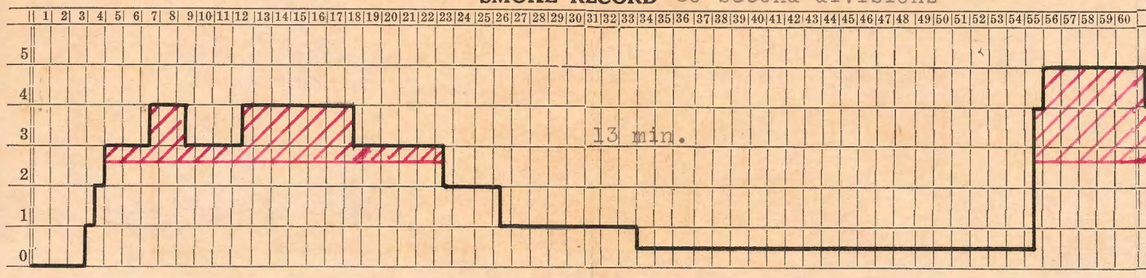
Wind Moderate Weather Clear

Point of Observation Observation Began 1:22 P.M.

Smoke Prevention Device Air-Blocks Cleaning or Starting Fires

Remarks Fireman did not know readings were being taken; blocks not on.
No special fireman; any of three men fire, all of whom have other duties in plant.

SMOKE RECORD 30 second divisions



A

4

Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 192

Inspector

ame Address

umber of stacks on plant, brick concrete steel tile

his report covers stack. Fuel

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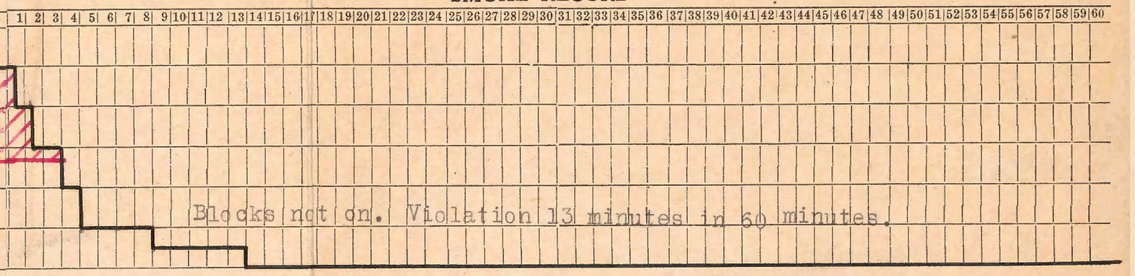
SMOKE RECORD



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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 6/1 1928

Inspector Wilkinson

Name Address

Number of stacks on plant, brick concrete steel 1 tile

This report covers stack. Fuel Nut & Slack

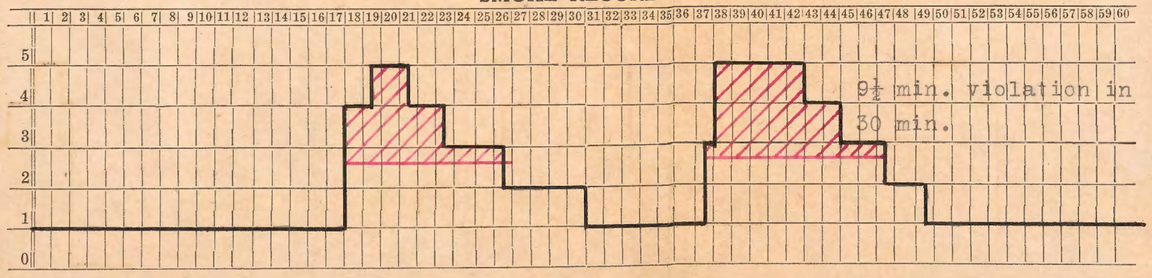
Wind Light Weather Cloudy and rainy

Point of Observation Observation Began 2:23 P.M.

Smoke Prevention Device None Cleaning or Starting Fires

Remarks 1 - 125 H.P. H.R.T. Boiler 40" setting.

SMOKE RECORD 30 second divisions



B

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 192

Inspector

Name Address

Number of stacks on plant, brick concrete steel tile

This report covers stack. Fuel

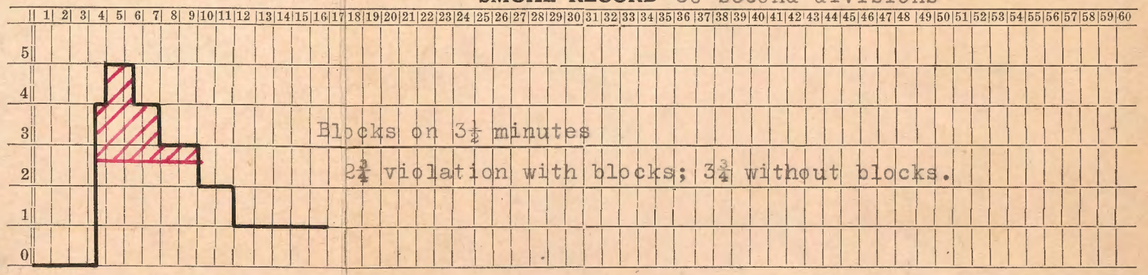
Wind Weather

Point of Observation Observation Began

Smoke Prevention Device Cleaning or Starting Fires

Remarks

SMOKE RECORD 30 second divisions



A

Figure 12

Figure 13. These readings were taken on a low pressure heating boiler. (See page 68 for cut of boiler.) Readings A were made when only the back arch was in, A, being taken when the straight firing method was used. By this method it is meant that the fresh coal is scattered on top of the live coals. The second reading was taken using the coking method (See figure And page 34 for a discussion of this method) which shows a decided reduction in smoke emission over the straight firing method. The boiler was changed so as to have two arches as was shown in the cut, but the front arch in this case is dropped four and one half inches below the center line of the back arch. Reading B was taken after this change was made and using the coking method to fire at first to get the live coals in the rear. The reading did not start until the second charge of coal had been scattered over the burning fuel bed. Excellent results were given and only a dense smoke resulted when the fire was worked heavily.

Figure 14. The observation as shown by this chart reading was taken on a small fire box boiler with an air-jet installation. (See figure 23) The reason for any dense smoke in this case is because the jet should not be burned after the charge is placed in the fire box due to the blowing of the flames out in the fireman's face. The fire door must be cracked so as to get the necessary air for proper mixture.

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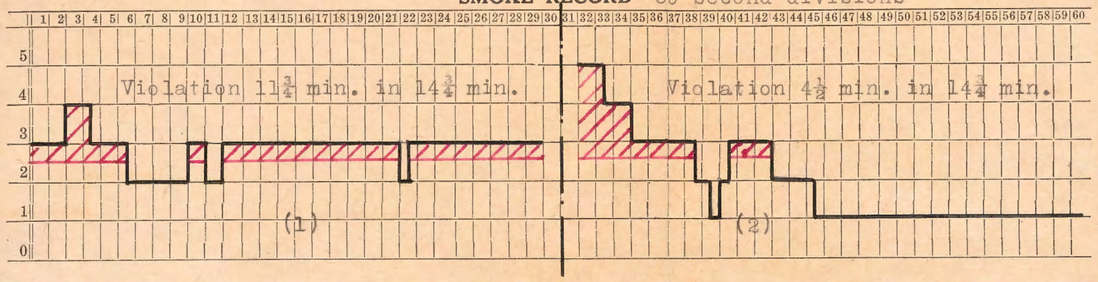
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 1/ 192 9
Inspector Wilkinson

Name Low Pressure Heating Boiler Address
Number of stacks on plant, brick concrete steel tile
This report covers stack. Fuel Nut & Slack
Wind Very light Weather Clear
Point of Observation Observation Began 11:55 A.M. 2:20 P.M.
Smoke Prevention Device Cleaning or Starting Fires
Remarks No. 1 Straight firing. No. 2 Coking Method Test

SMOKE RECORD 30 second divisions



A

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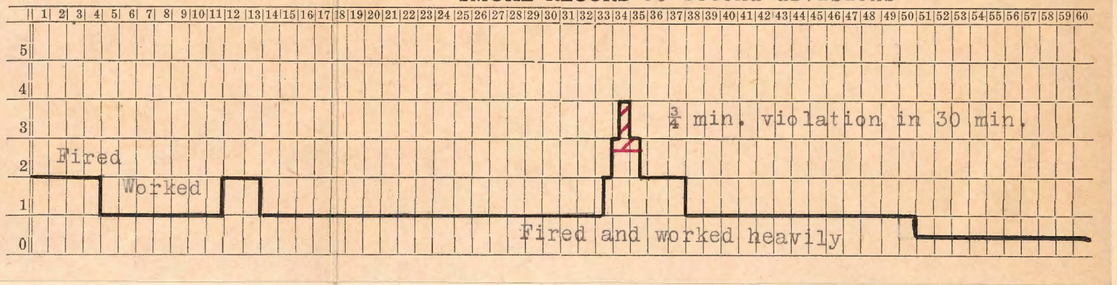
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 2/18 192 9
Inspector Chapman

Name Address
Number of stacks on plant, brick 1 concrete steel tile
This report covers stack. Fuel Nut & Slack
Wind Very light Weather Clear
Point of Observation Observation Began 3:08 P.M.
Smoke Prevention Device Cleaning or Starting Fires
Remarks Same boiler as "A" with an arch change. Test.

SMOKE RECORD 30 second divisions



B

Figure 13

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Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 5/1 192 9
Inspector Chapman

Name Small Fire Box Boiler Address
Number of stacks on plant, brick concrete steel 1 tile
This report covers stack. Fuel Nut & Slack
Wind Very light Weather Clear
Point of Observation Observation Began 3:08 P.M.
Smoke Prevention Device One Air-Jet Cleaning or Starting Fires
Remarks Test
One shovel of coal at each firing. 75# Pressure maximum.

SMOKE RECORD 30 second divisions

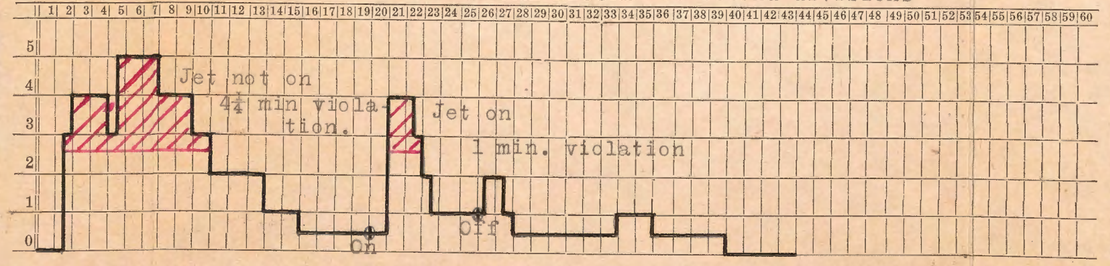

Figure 14

Figures 13 and 14

Figure. 15. The readings A and B are taken on passenger engines that did not change their run in Knoxville. A_1 shows that engine had just been fired as it came in to the depot, and before leaving another fresh charge of coal was made without leaving the fire door open. A_2 was taken on the same type locomotive under similar conditions, showing two firing periods in which the fire door was left part way open. The same amount of fuel was fired in both cases with practically the same care in placing. Reading B, shows an observation of two passenger engines of similar type and under similar conditions as A. These readings show clearly the results that can be gained by careful firing.

Figure 16. These readings were all taken on the same switching locomotives, the location being the same in each case. A_1 was taken when a heavy charge was fired and nets not used and A_2 the jets were used with the recorded results as graphically shown. Reading B was taken when heavy switching was being done, and when the engine was standing. In neither case were the jets used thus indicating clearly the smoke condition when the engine is in operation and standing. The cracking of the fire door in this last case will help considerably but for over all operation the jets are the only means by which the smoke emission can be kept down within reasonable limits using soft coal as a fuel.

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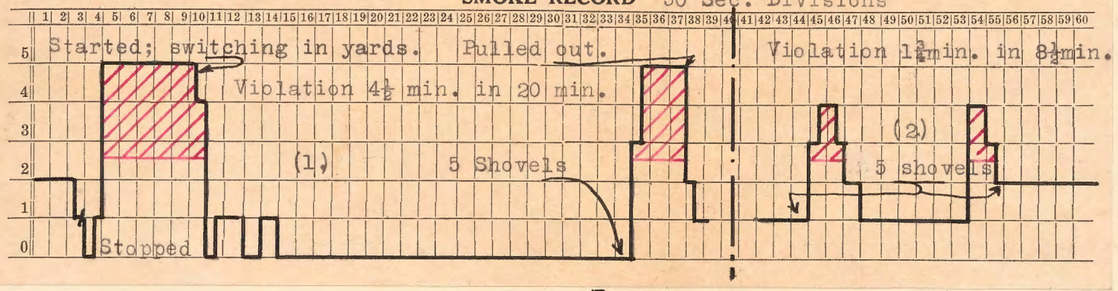
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 1/24, 3/26 1929
Inspector Chapman

Railroad ____ Engine No. ____ Location ____
Service—Passenger, freight, switching, light Passenger Pops 3 times each Blower
Smoke Prevention Device ____ Fuel Run of Mine
Running ✓ Standing ✓ Cleaning or Starting Fires ____
Wind Very light. Weather Cloudy; rainy. Cloudy.
Point of Observation ____ Observation Began 1:41 P.M. - 1:09 P.M.
Remarks (1) Fire door closed after firing. (2) Fire door left partly open after firing.

SMOKE RECORD 30 Sec. Divisions



A

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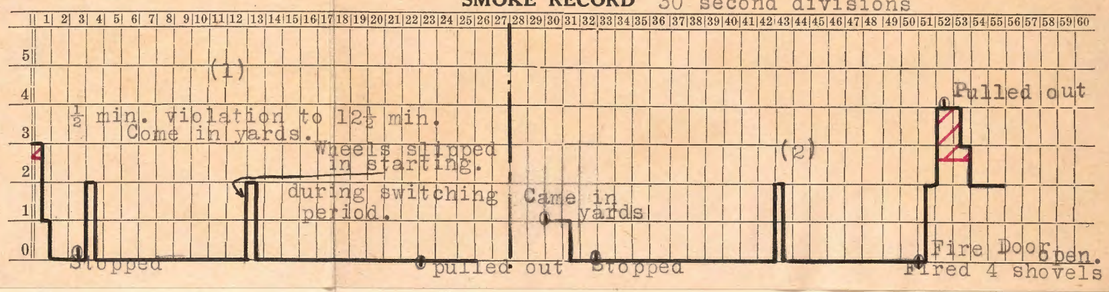
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 4/12/2 1929
Inspector Chapman

Railroad ____ Engine No. ____ Location ____
Service—Passenger, freight, switching, light Passenger Pops No. (1) 6 times Blower
Smoke Prevention Device ____ Fuel Run of Mine
Running ✓ Standing ✓ Cleaning or Starting Fires ____
Wind Very Light Weather Clear
Point of Observation ____ Observation Began 3:48 P.M.
Remarks Two engine pulling train. Readings taken all the time train was in sight.

SMOKE RECORD 30 second divisions



B

Figure 15

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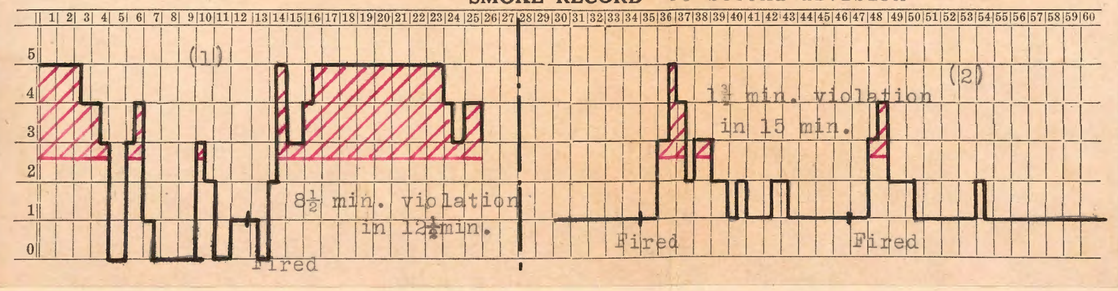
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 2/4 - 3/24 1929
Inspector Chapman

Railroad R.R. Switching Engine No. ____ Location ____
Service—Passenger, freight, switching, light Switching Pops ____ Blower
Smoke Prevention Device ____ Fuel Run of Mine
Running ✓ Standing ✓ Cleaning or Starting Fires ____
Wind Very light - Light Weather Cloudy - Clear
Point of Observation ____ Observation Began 1:15 P.M. - 5:11 P.M.
Remarks Both readings of same engine.

SMOKE RECORD 30 second division



A

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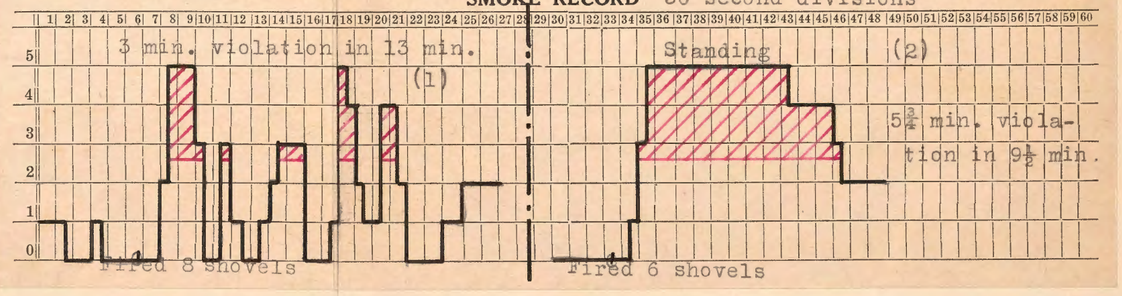
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 3/18-19 1929
Inspector Chapman

Railroad ____ Engine No. ____ Location ____
Service—Passenger, freight, switching, light Switching Pops ____ Blower
Smoke Prevention Device ____ Fuel Run of Mine
Running ✓ Standing ✓ Cleaning or Starting Fires ____
Wind Very light Weather Clear
Point of Observation ____ Observation Began 10:16 A.M. 3:47 P.M.
Remarks Both readings of same engine.

SMOKE RECORD 30 second divisions



B

Figure 16

Figures 15 and 16

Figure 17. The readings of this figure were taken on passenger locomotives. A_1 was taken on a locomotive standing in the yard awaiting to take its train. The fire was worked consistently during the first reading indicating the lack of attention before coming to the depot yards. During the last portion of the reading heavy charges were feed in short intervals resulting in a very dense smoke. During all these periods the fire door was closed. The safety valve raised on four occasions during this last period for considerable length of time indicating that a full head of steam had been gained and such heavy firing was unnecessary. Such working of the fires is a condition which the bureau is trying to remedy by proper attention before coming to the yards as explained in the last section. Reading A_2 is of the same type of engine as the above and under similar conditions as to firing. When the fire door is open a small distance the smoke condition was greatly reduced as indicated on the chart, thus showing how a little precaution like this will help the smoke reduction. Reading B was taken on the same engine and under similar conditions as A but during the last period the five small and well placed charges of coal show excellent results. The safety valve raised four times as was the case in the foregoing reading thus indicating the necessary steam was on hand.

Figure 18. These readings were taken on the same switching engine. Reading A shows the result of a heavy charge of coal as compared to reading D, which fired three light and well placed charges. Theswitching load was about the same in both cases. This is a notable example of smoke reduction using

the light and often method of firing.

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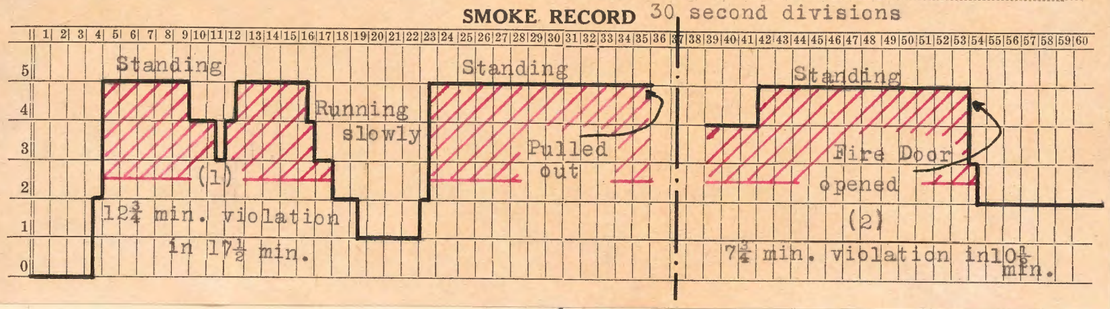
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 12/13 - 10/4 1928
Inspector Chapman

Railroad ____ Engine No. ____ Location ____
Service—Passenger, freight, switching, light Passenger Pops No (1) 4 times Blower
Smoke Prevention Device None Fuel Run of Mine
Running ____ Standing ✓ Cleaning or Starting Fires ____
Wind Very light Weather Cloudy - Clear
Point of Observation ____ Observation Began 1:32 P.M. - 1:27 P.M.
Remarks Worked fire and fired heavy during both readings; engines of same type. Same type as "A".

SMOKE RECORD 30 second divisions



A

Figure 17

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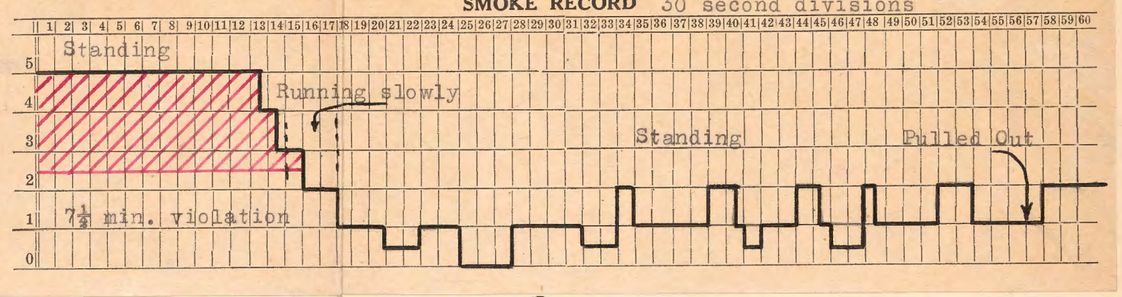
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 1/28 1929
Inspector Chapman

Railroad ____ Engine No. ____ Location ____
Service—Passenger, freight, switching, light Passenger Pops 4 Times Blower
Smoke Prevention Device None Fuel Run of Mine
Running ____ Standing ✓ Cleaning or Starting Fires ____
Wind Moderate Weather Clear
Point of Observation ____ Observation Began 1:28 P.M.
Remarks Worked fire at first of reading then fired light and often in last of reading.

SMOKE RECORD 30 second divisions



B

393

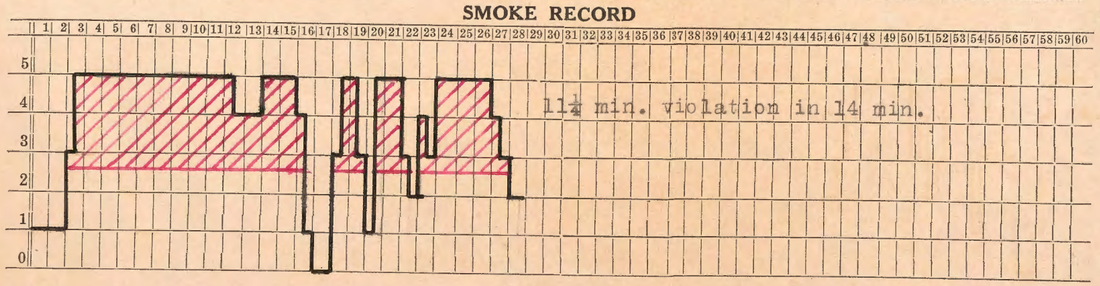
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 12/4 1928
Inspector Chapman

Railroad ____ Engine No. ____ Location ____
Service—Passenger, freight, switching, light switching Pops None Blower
Smoke Prevention Device None Fuel Run of Mine
Running ✓ Standing ✓ Cleaning or Starting Fires ____
Wind Very light Weather Clear
Point of Observation ____ Observation Began 4:15 P.M.
Remarks Extra Heavy charge at firing.

SMOKE RECORD



A

Figure 18

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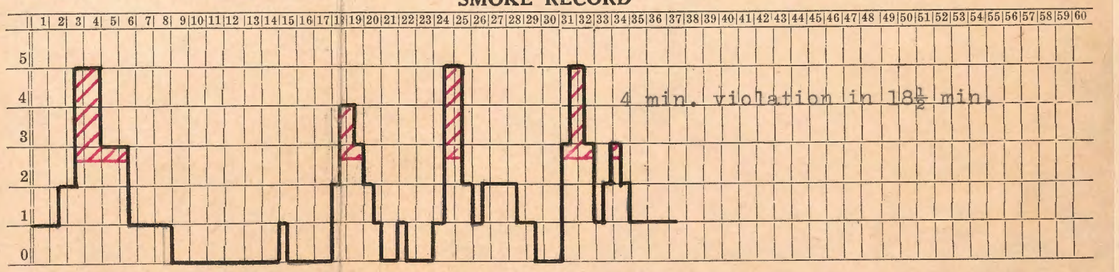
Smoke Inspector's Report

BUREAU OF SMOKE REGULATION
KNOXVILLE, TENNESSEE

Date 4/4 1928
Inspector Chapman

Railroad ____ Engine No. ____ Location ____
Service—Passenger, freight, switching, light Switching Pops Once Blower
Smoke Prevention Device None Fuel Run of Mine
Running ✓ Standing ✓ Cleaning or Starting Fires ____
Wind Light Weather Clear
Point of Observation ____ Observation Began 1:30 P.M.
Remarks Fired light and often.
Same engine as "C".

SMOKE RECORD



B

Figures 17 and 18

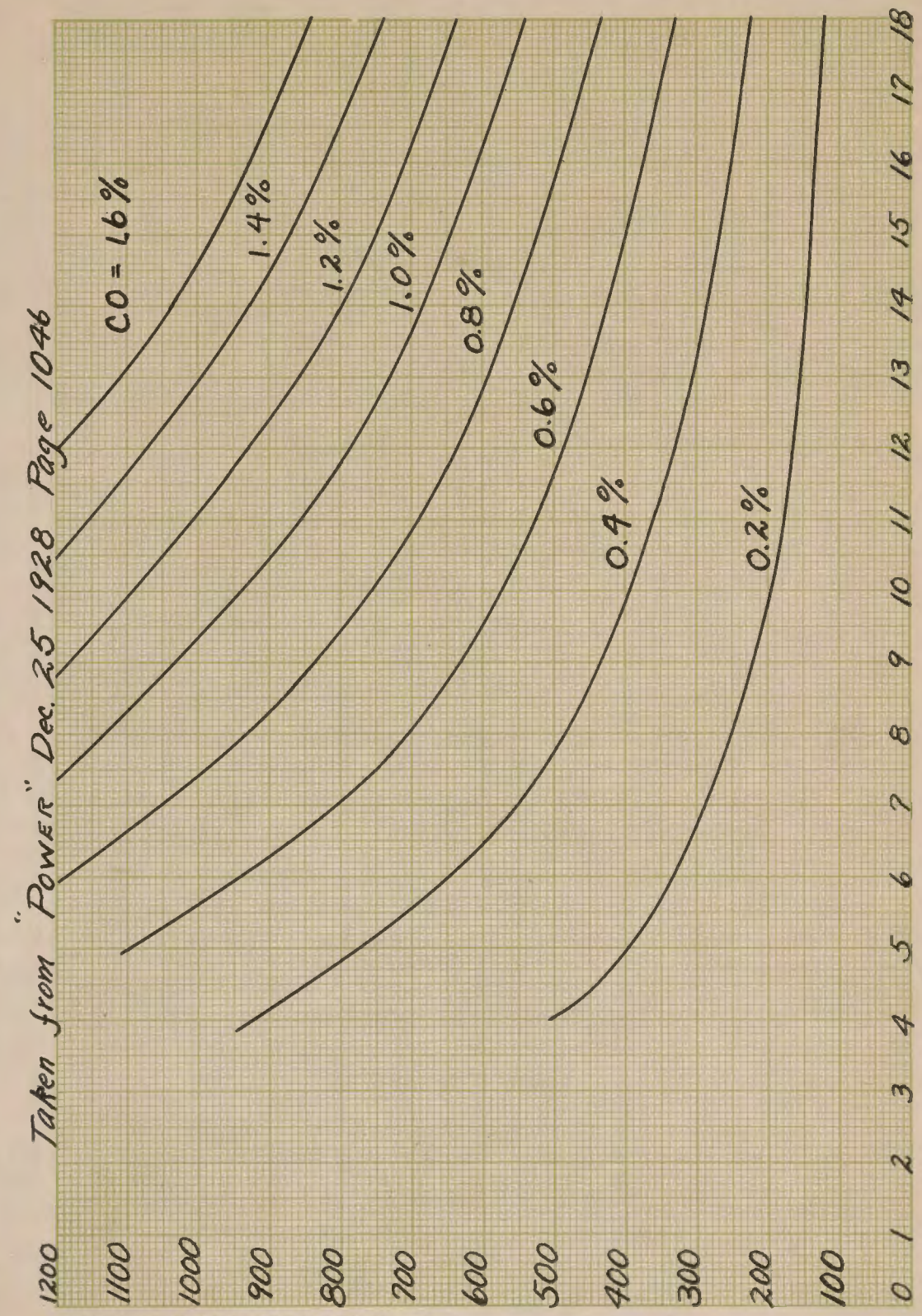

Taken from "Power" Dec. 25 1928 Page 1046
CO = 1.6%
1.4%
1.2%
1.0%
0.8%
0.6%
0.4%
0.2%
Loss in B.T.U. per lb of Carbon Burned
1200
1100
1000
900
800
700
600
500
400
300
200
100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Percent CO_2 in Dry Products of Combustion
Figure 19.

Figure 19.

CONCLUSIONS

As a conclusion it can be justly said that if the various instructions and methods prescribed in this paper, together with the other recommendations as made by the Bureau of Smoke Regulation, are carried out with care the smoke emission can be cut down very appreciably, and Knoxville be made a much cleaner city. This fact is clearly shown by the observations, comparative readings, and other facts discussed in this thesis, but until a "smokeless" fuel such as gas, oil, and coke can be had at a competitive price with coal for domestic use, the smaller heating plants, and the small high presser boilers; and the larger heating and power development plants be equiped with a correctly designed and operated plant using the right coal and exercising the proper care in handling the fires; together with the undivided support of the various classes of people, organizations and, the public in general will Knoxville, or any other place, be free from the smoke nuisance.

In spite of the apparent reduction of smoke Knoxville is still a smoky city and it is no doubt hard for the average citizen to realize the extent of the improvement, but with increased efforts, personnel, and the cooperation that has marked the success of the program in the first year's work it is hoped that a more visible improvement will soon be felt by the most careless observer.

KNOXVILLE
TENNESSEE

CITY PLANNING COMMISSION

BARTHOLOMEW & ASSOCIATES
CITY PLAN & LANDSCAPE ENGINEERS
SAINT LOUIS MISSOURI

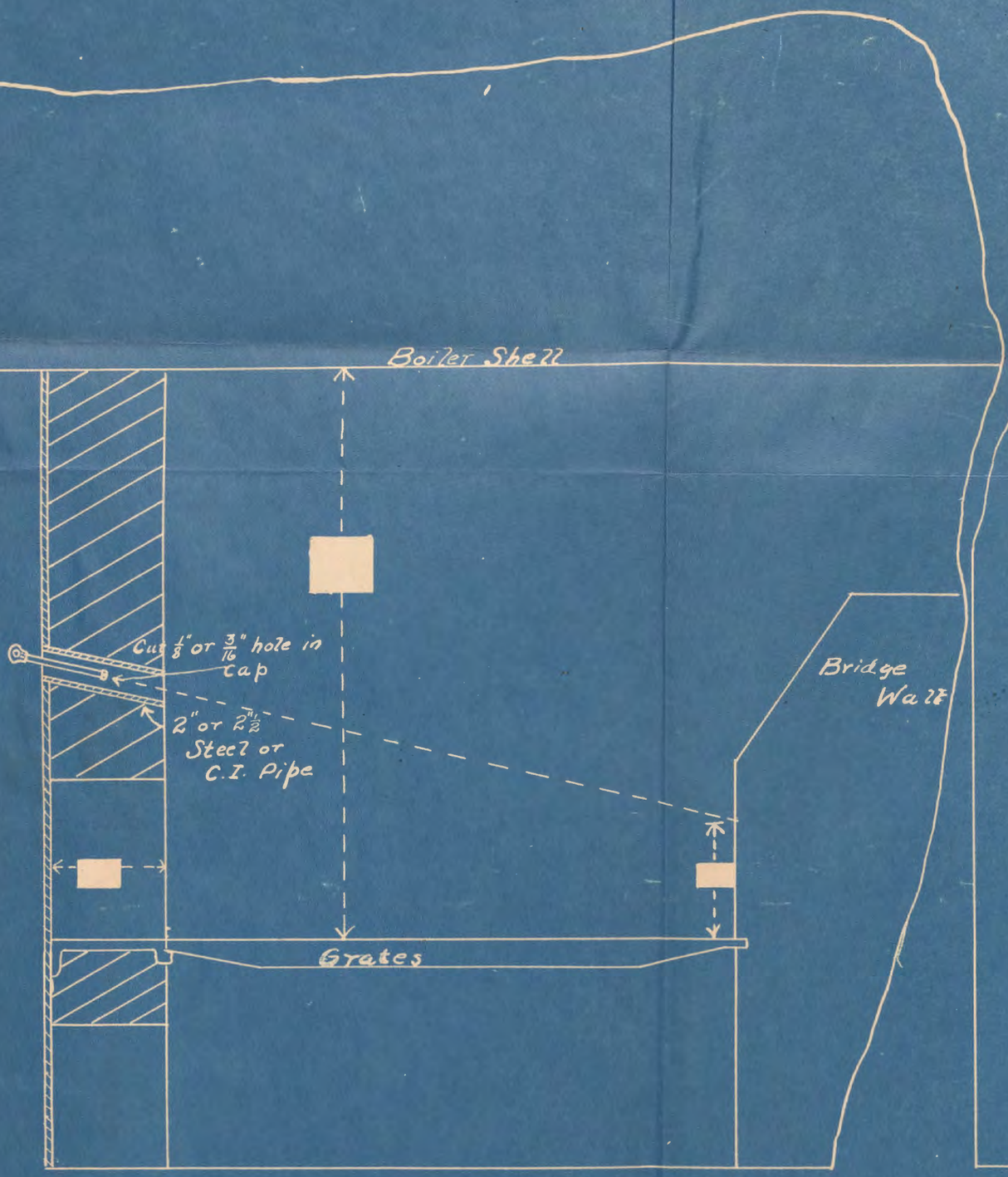
DISTRICT MAP

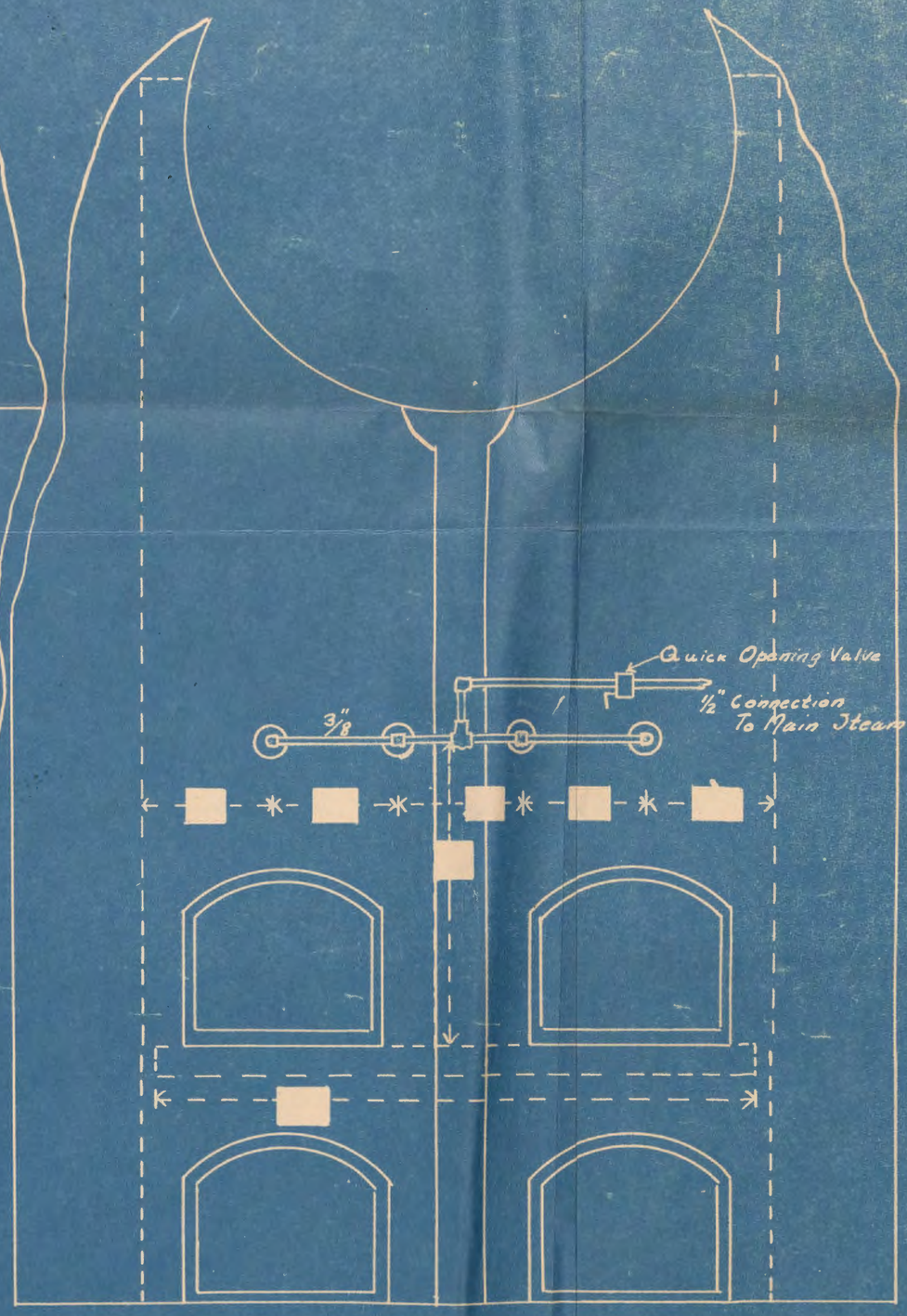
MAP OF CITY

LEGEND & SUMMARY - ZONING REGULATIONS

USE	SYMBOL	DISTRICT	HEIGHT STORIES	HEIGHT FEET	REAR YARD	SIDE YARD	FRONT YARD	LOT AREA PER FAMILY
RESIDENCE A-ONE FAMILY DWELLING SCHOOLS CHURCHES ETC B-1&2 FAMILY DWELLING SCHOOLS-CHURCHES ETC.		A	2½	35	25	2-5	25	5000
		B	2½	35	25	2-5	25	2500 *
MULTIPLE DWELLING USES PERMITTED IN RESIDENCE DISTRICT- APARTMENTS- HOTELS-INSTITUTIONS-CLUBS &ACCESSORY USES		C	3	45	25 INTERIOR 15 CORNER	2-5' PLUS 1' FOR EACH STORY ABOVE 2	25	600 *
		D	6	75	"	"	25	400 *
COMMERCIAL USES PERMITTED IN MULTIPLE DWELLING DISTRICT- ALL RETAIL STORES & PUBLIC GARAGES UPON CERTAIN CONDITIONS		E	2½	35	25	NONE EXCEPT ADJOINING RESIDENCE	*	2500
		F	3	45	25 INTERIOR 15 CORNER	"	*	600
		G	6	75	10	"	*	400
INDUSTRIAL USES PERMITTED IN COMMERCIAL DISTRICT- PUBLIC GARAGES & ANY MANUFACTURES NOT OBJECTIONABLE BY REASON OF SMOKE-DUST-ODOR OR NOISE~		H	*	150	NONE	NONE	NONE	400 *
		I	3	45	25 INTERIOR 15 CORNER	NONE EXCEPT ADJOINING RESIDENCE	*	600 *
		J	8	100	NONE EXCEPT ADJOINING RESIDENCE	"	NONE	400 *
UNRESTRICTED ANY USE EXCEPT NUISANCE		K	8	100	"	"	"	400

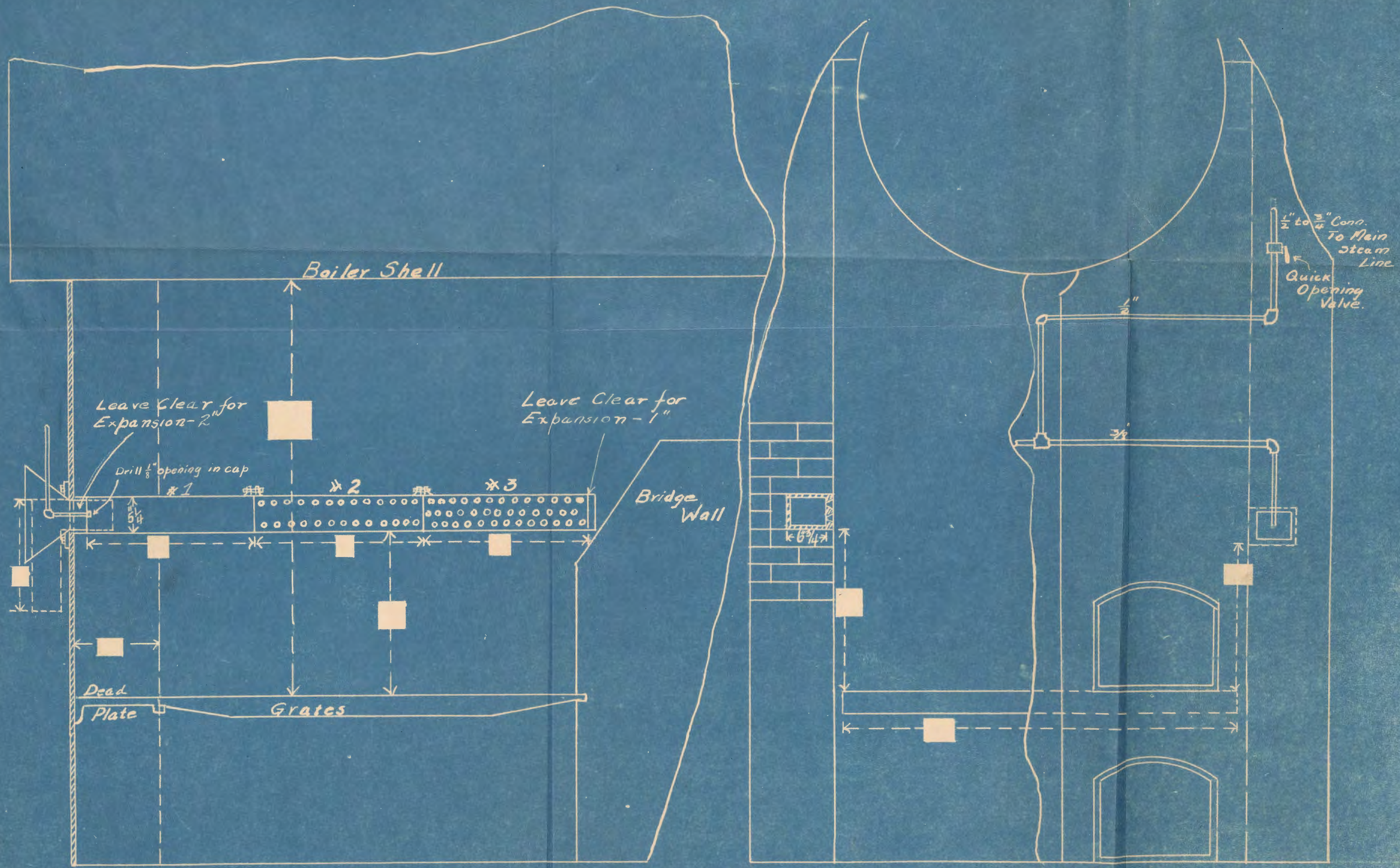
* REFER TO ORDINANCE





LAYOUT FOR INSTALLATION
AIR JETS
BUREAU OF SMOKE REGULATION
Knoxville, Tenn. June 20, 1928

FIGURE 20



DIRECTIONS:

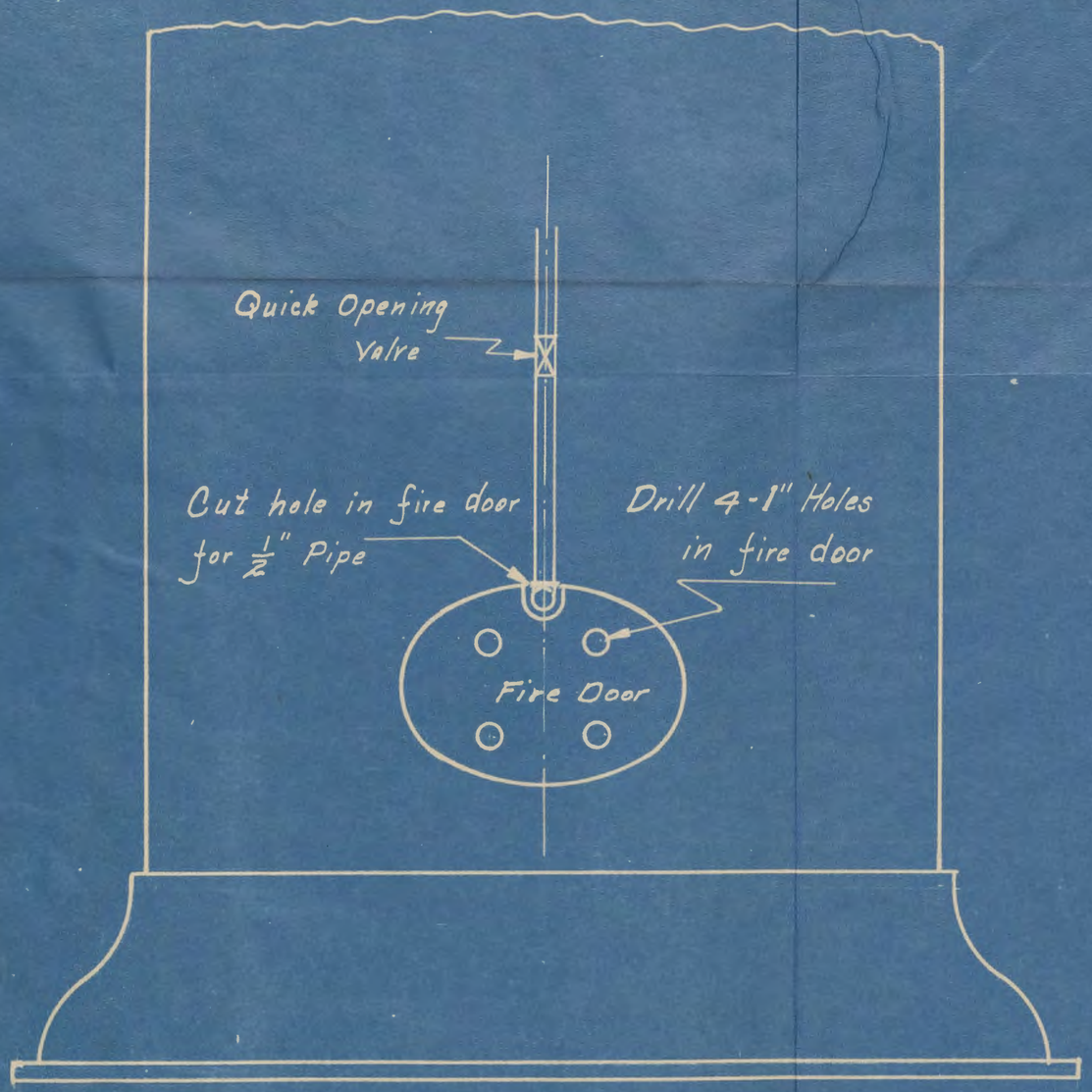
Remove Two Rows of Brick as Shown And Install Block #1 - Then Take Out Brick and Install #2 - Then #3 Leave Clearance for Expansion at Both Ends - After Blocks are in Position Make Openings in Front - Drill and Tap Holes For Cap Screws To Hold Horns in Place.

LAYOUT FOR INSTALLATION

HUNTER COMBUSTION AIR BLOCK

Knoxville, Tenn. June 19, 1928

FIGURE 21



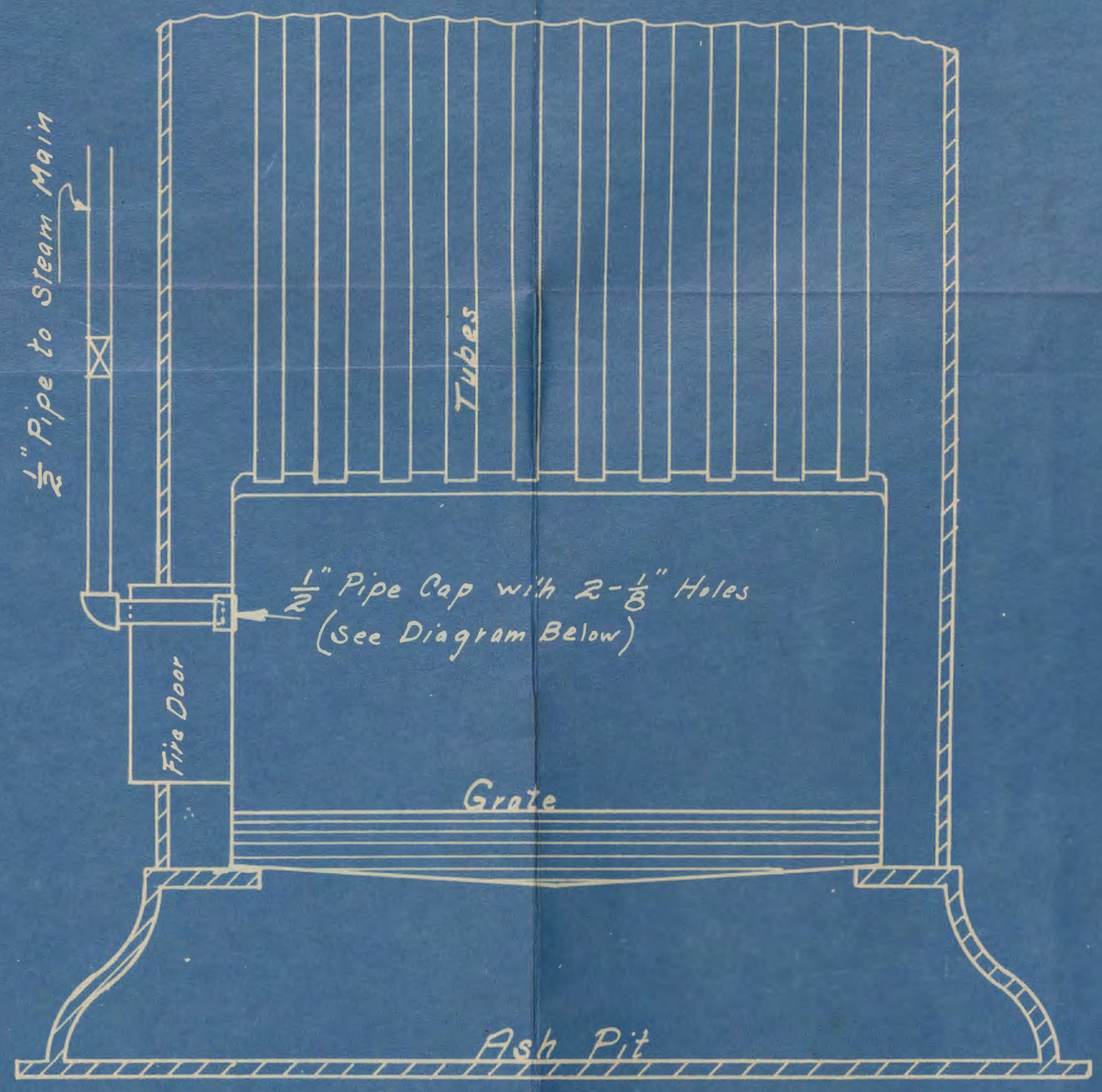
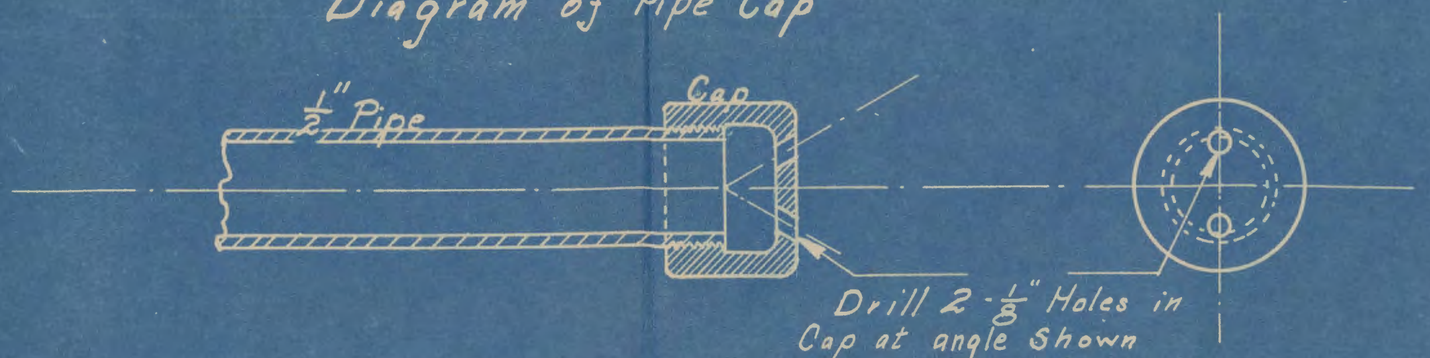
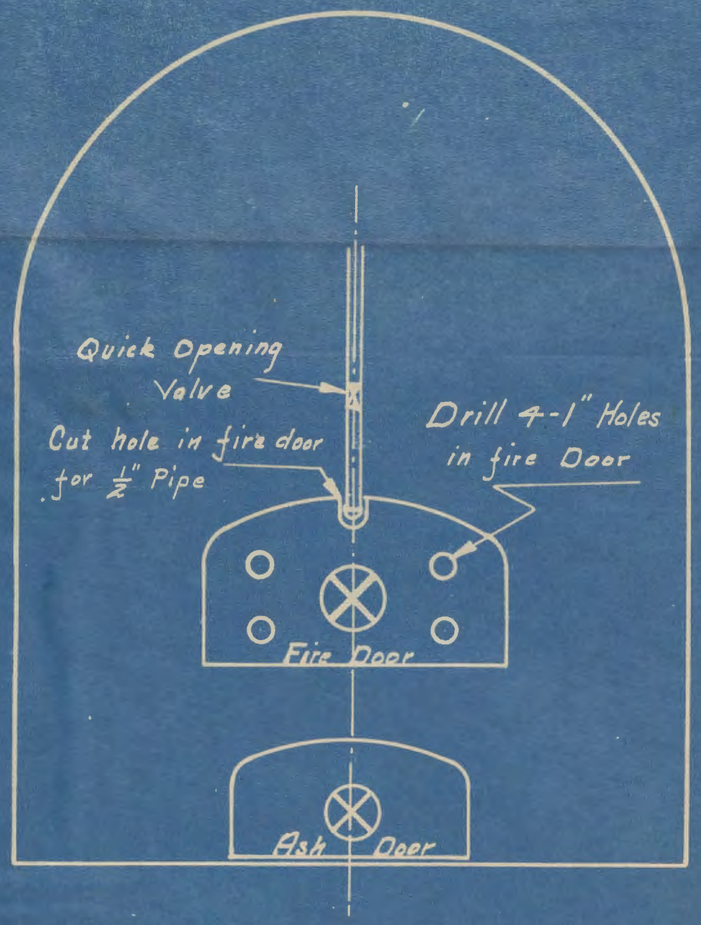


Diagram of Pipe Cap



LAY OUT FOR INSTALLATION
Air Jets
Vertical Boilers
Bureau of Smoke Regulation
Knoxville, Tenn. Nov. 26, 1928



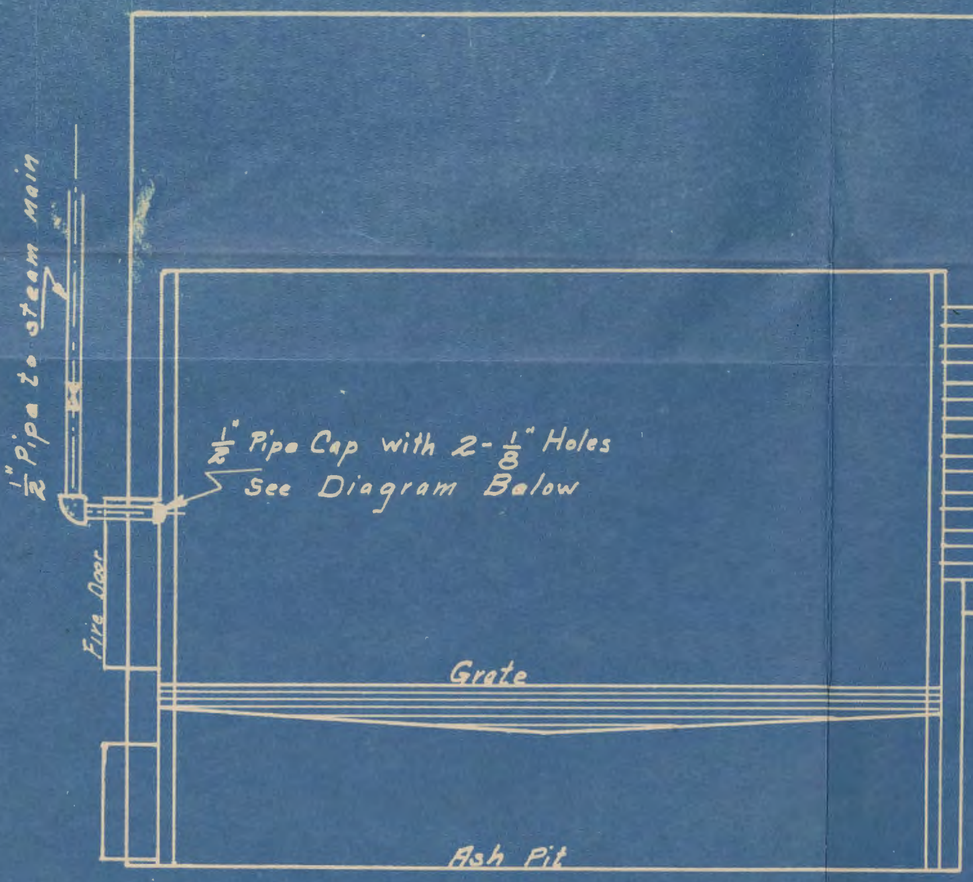
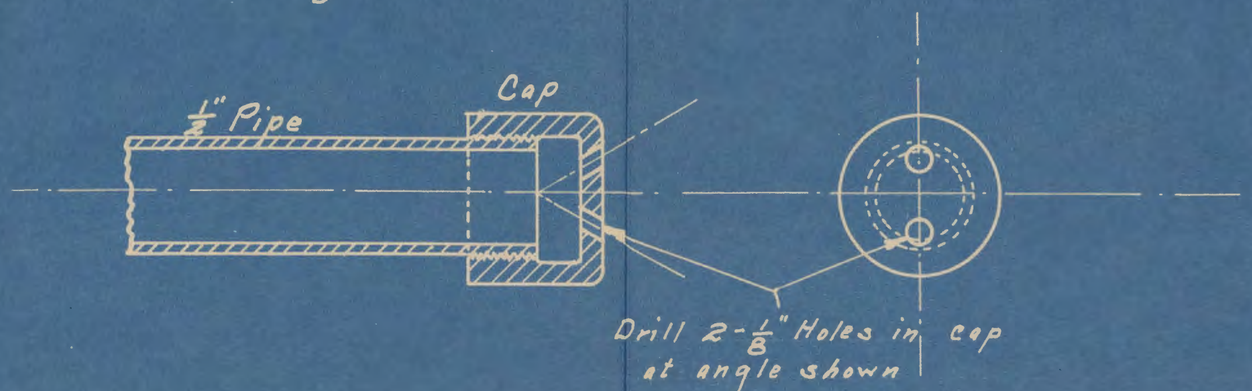


Diagram of Pipe Cap



LAY OUT FOR INSTALLATION

Air Jets

Fire Box Boilers

Bureau of Smoke Regulation

Knoxville, Tenn Nov. 26, 1928

APPENDIX

Zoning Ordinance No. 123 for the City of Knoxville, Tennessee

AN ORDINANCE to regulate and restrict the location and use of buildings, structures, and land for trade, industry, residence, or other purposes, the height, number of stories, and size of buildings and other structures, the size of yards and other open spaces, and the density of population, and for said purposes to divide the municipality into districts of such number, shape and area as may be deemed best suited to carry out these regulations; to prescribe penalties for the violation of its provisions and to provide for its enforcement.

WHEREAS, by the provisions of Chapter 412 of the Private Acts of the General Assembly of the State of Tennessee for the year 1923 and as amended by Chapters 93, 248 and 298, Acts 1925, authority is conferred upon the City of Knoxville to establish districts or zones within its corporate limits for the purpose of regulating the use of land and buildings, the height of buildings, the size of open spaces surrounding buildings and density of population, and

WHEREAS, the Council of the City of Knoxville deems it necessary in order to lessen congestion in the streets; to secure safety from fire, panic and other dangers; to provide adequate light and air; to prevent the overcrowding of land; to avoid undue concentration of population; to facilitate the adequate provisions of transportation, water, sewerage, schools, parks and other public requirements and otherwise to promote the public safety, health, convenience and the general welfare in accordance with a comprehensive plan; Now, Therefore, BE IT ORDAINED BY THE COUNCIL OF THE CITY OF KNOXVILLE, TENNESSEE.

SECTION 1. DEFINITIONS

For the purpose of this ordinance certain terms and words are herewith defined as follows:

Words used in the present tense include the future; words in the singular number include the plural and words in the plural number include the singular; the word "building" includes the word "structure", the word "shall" is mandatory, and not directory.

Accessory Building: A subordinate building or portion of main building, the use of which is incidental to that of the main building.

Alley: A way which affords only a secondary means of access to abutting property.

Apartment House: See Multiple Dwelling.

Basement: A story partly underground and having at least one-half of its height above the average level of the adjoining ground. A basement shall be counted as a story if subdivided and used for dwelling or business purposes.

Boarding House: A building other than a hotel, where lodging and meals for five or more persons are served for compensation.

Building, Height of: The vertical distance measured from the curb level to the highest point of the roof surface, if a flat roof; to the deck line of mansard roofs and to the mean height level between eaves and ridge for gable, hip and gambrel roofs. For buildings set back from the street line the height of the building may be measured from the average elevation of the finished grade along the front of the building.

Building: A structure having a roof supported by columns or walls and when separated by a division wall without openings, each portion of such building shall be deemed a separate building except as provided in Section 18.

Business: Includes the Commercial, Light Industrial and Heavy Industrial Uses and Districts as herein defined.

Cellar: A story having more than one-half of its height below the average level of the adjoining ground. A cellar shall not be counted as a story for purposes of height measurement.

Curb Level: The level of the established curb in front of the building measured at the center of such front. Where no curb has been established the city engineer shall establish such curb level or its equivalent for the purpose of this ordinance.

Dwelling, One-Family: A detached building designed for or occupied exclusively by one family.

Dwelling, Two-Family: A detached or semi-detached building designed for or occupied exclusively by two families.

Dwelling, Multiple: A building or portion thereof used or designed as a residence for three or more families or households living independently of each other.

Family: One or more persons occupying a premises and living as a single housekeeping unit, as distinguished from a group occupying a boarding house, a lodging house, or hotel, as herein defined.

Garage, Private: A garage with capacity for not more than four (4) self-propelled vehicles for storage only. Provided, however, a private garage may exceed a four (4) vehicle capacity if the lot whereon such garage is located contains not less than fifteen hundred (1500) square feet for each vehicle stored.

Garage Public: Any premises, except those described as a private or storage garage, used for the storage or care of self-propelled vehicles, or where any such vehicles are equipped for operation, repaired or kept for remuneration, hire or sale.

Garage, Storage: Any premises, except those defined as a private or public garage, used exclusively for the storage of self-propelled vehicles.

Hotel: A building occupied as the more or less temporary abiding place of individuals who are lodged with or without meals and in which there are more than twelve (12) sleeping rooms usually occupied singly and no provision made for cooking in any individual room or apartment.

Lodging House: A building, other than a hotel, where lodging for five (5) or more persons is provided for compensation.

Lot of Record: A lot which is a part of a subdivision, the map of which has been recorded in the office of the Register of Knox County.

Lot: Land occupied or to be occupied by a building and its accessory buildings together with such open spaces as are required under this ordinance, and having its principal frontage upon a street or officially approved place.

Corner Lot: A lot situated at the junction of two or more streets, and having a width not greater than seventy-five (75) feet.

Interior Lot: A lot other than a corner lot.

Through Lot: An interior lot having frontage on two parallel or approximately parallel streets.

Lot Lines: The lines bounding a lot as defined herein.

Non-Conforming Use: A building or land occupied by a use that does not conform with the regulations of the use district in which it is situated.

Place: An open unoccupied space other than a street or alley permanently reserved as the principal means of access to abutting property.

Stable, Private: A stable with capacity for not more than two horses provided, however, that the capacity of a private stable may be increased if the premises whereon such stable is located contains an area of not less than 2500 square feet for each horse accommodated.

Stable, Public: A stable with a capacity for more than two horses.

Story: That portion of a building included between the surface of any floor and the surface of the floor next above it, or if there be no floor above it, then the space between such floor and the ceiling next above it.

Story, Half: A story under a gable, hip or gambrel roof, the wall plates of which on at least two (2) opposite exterior walls are not more than two (2) feet above the floor of such story.

Street: A thorofare which affords principal means of access to abutting property.

Structure: Anything constructed or erected, the use of which requires more or less permanent location on the ground or attached to something having a permanent location on the ground.

Structural Alterations: Any change in the supporting members of a building, such as bearing walls, columns, beams or girders.

Yard: An open space on the same lot with a building unoccupied and unobstructed from the ground upward except as otherwise provided herein.

Front Yard: A yard extending across the front of the lot between the inner side yard lines and measured between;

(a) the front line of the lot and front line of the building, and

(b) the front line of the lot and the nearest line of any porch or paved terrace.

Rear Yard: A yard extending across the full width of the lot and measured between the rear line of the lot and the rear line of the building.

Side Yard: A yard between the building and the side line of the lot and extending from the street line to the rear yard.

SECTION 2. DISTRICTS

In order to regulate and restrict the location of trades and industries and the location of buildings erected or altered for specified uses, and to regulate and limit the height and bulk of buildings hereafter erected or altered, to regulate and determine the area of yards and other open spaces, and to regulate and limit the density of population, the city of Knoxville is hereby divided into districts of which there shall be eleven (11), known as:

"A" One-Family District.
"B" Two-Family District.
"C" Apartment District.
"D" Apartment District.
"E" Commercial District.
"F" Commercial District.
"G" Commercial District.
"H" Business District
"I" Light Industrial District.
"J" Light Industrial District.
"K" Heavy Industrial District.

The City of Knoxville is hereby divided into eleven (11) districts aforesaid and the boundaries of such districts are shown upon the map attached hereto and made a part of this ordinance, being designated as the "District Map" and said map and all the notations, references and other information shown thereon shall be as much a part of this ordinance as if the matters and information set forth by said map were all fully described herein.

Except as hereinafter provided:

(1) No building shall be erected, reconstructed or structurally altered nor shall any building or land be used for any purpose other than is permitted in the district in which such building or land is located.

(2) No building shall be erected, reconstructed or structurally altered to exceed the height or bulk limit herein established for the District in which such building is located.

(3) No lot area shall be so reduced or diminished that the yards or other open spaces shall be smaller than prescribed by this ordinance, nor shall the density of population be increased in any manner except in conformity with the area regulations herein established.

(4) Every building hereafter erected shall be located on a lot as herein defined and in no case shall there be more than one building on one lot except as hereinafter provided.

SECTION 3. USE REGULATIONS

"A" One-Family District

In the "A" One-Family District no building or land shall be used and no building shall be hereafter erected or structurally altered, unless otherwise provided in this ordinance, except for one or more of the following uses:

1. One-Family Dwellings.
2. Churches.
3. Schools, Elementary and High.
4. Museums, Libraries, Parks, Playgrounds or Community Centers owned and operated by the City of Knoxville.
5. Golf Courses.
6. Farming and Truck Gardening.
7. Nurseries and Greenhouses for the propagating and cultivating of plants only, provided, however, that before permit is issued, there are on file in the office of the Building Inspector, the written consents of the owners of the majority of the area of all real estate within three hundred (300) feet of any part of the premises.
8. Accessory Buildings, including one private garage or private stable when located not less than sixty (60) feet from the front lot line nor less than five (5) feet from any other street line, or a private garage constructed as a part of the main building.
9. Uses customarily incident to any of the above uses when situated in the same dwelling, including home occupation such as the office of a physician, surgeon, dentist, musician or artist. Provided no name plate exceeding one (1) square foot in area, nor bulletin boards, nor signs exceeding twelve (12) square feet in area appertaining to the lease, hire or sale of a building or premises, nor advertising sign of any other character shall be permitted in any One-Family District.

SECTION 4. USE REGULATIONS

"B" Two-Family District

In the "B" Two-Family District no building or land shall be used and no building shall be hereafter erected or structurally altered, unless otherwise provided in this ordinance, except for one or more of the following uses:

1. Any use permitted in the "A" One-Family District.
2. Two-Family Dwellings.
3. Nurseries and Greenhouses used only for the propagating and cultivating of plants.

SECTION 5. USE REGULATIONS

"C" and "D" Apartment Districts

In the "C" and "D" Apartment District no buildings or land shall be used and no building shall be hereafter erected or structurally altered, unless otherwise provided in this ordinance, except for one or more of the following uses:

1. Any use permitted in the "B" Two-Family District.
2. Multiple Dwellings.
3. Boarding and Lodging Houses.
4. Hotels, excepting those containing business for other than the sole convenience of the guests in the building.
5. Hospitals and Clinics.
6. Institutions of an educational or philanthropic nature.
7. Private Clubs, Fraternities, Sororities, Lodges, excepting those the chief activity of which is a service customarily carried on as a business.
8. Accessory Buildings and Uses customarily incident to any of the above uses when located on the same lot and not involving the conduct of a business including private and storage garages when located not less than sixty (60) feet from the front lot line nor less than five (5) feet from any other street line or a private or storage garage constructed as a part of the main building.

SECTION 6. USE REGULATIONS

"E", "F" and "G" Commercial Districts

In the "E", "F" and "G" Commercial Districts all buildings and land except as otherwise provided in this ordinance, may be used for any use permitted in the Apartment Districts or for any other use except the following:

1. Bakery (employing more than five (5) persons on the premises).
2. Blacksmith or horseshoeing shop.
3. Bottling works.
4. Building material storage yard.
5. Carting, express, hauling or storage yard.
6. Contractor's plant or storage yard.
7. Coal, coke or wood yard.
8. Cooperage works.
9. Dyeing or cleaning works (employing more than five (5) persons on the premises).
10. Ice plant or storage house of more than five (5) tons capacity.
11. Laundry (employing more than five (5) persons on the premises).
12. Livery stable or riding academy.
13. Lumber yard.
14. Machine shop.
15. Public Garage, except as provided in Section 19.
16. Milk distributing station other than a retail business conducted on the premises.
17. Stone monument works (employing more than five (5) persons).
18. Storage warehouse.
19. Wholesale houses.
20. All uses excluded from the industrial districts.
21. Any kind of manufacture or treatment other than manufacture or treatment of products clearly incidental to the conduct of a retail business conducted on the premises.

In the "G" Commercial District, public garages shall be permitted provided that repair and storage facilities for automobiles shall be purely incidental to an automobile sales room where the major business is the display and sale of new automobiles by an authorized agency and provided further that the area allowed for the repair and storage of cars shall not be nearer than thirty (30) feet from the front line of the building.

SECTION 7. USE REGULATIONS

"H" Business District and "I" and "J" Light Industrial Districts.

In the "H" Business District and the "I" and "J" Light Industrial Districts all buildings and land except as otherwise provided in this ordinance, may be used for any use permitted in the Commercial Districts or for any other use except the following:

1. Acetylene gas manufacture or storage.
2. Acid manufacture.
3. Alcohol manufacture.
4. Ammonia, bleaching powder, or chlorine manufacture.
5. Arsenal.
6. Asphalt manufacturing or refining.
7. Bag cleaning.
8. Blast furnace.
9. Boiler works.
10. Brick, tile or terra cotta manufacture.
11. Candle manufacture.
12. Celluloid manufacture.
13. Cement, lime, gypsum or plaster of paris manufacture.
14. Coke ovens.
15. Cotton gin.
16. Creosote treatment or manufacture.
17. Disinfectants manufacture.
18. Distillation of bones, coal or wood.
19. Dyestuff manufacture.
20. Explosives, manufacture or storage.
21. Exterminator and insect poison manufacture.
22. Emery cloth and sand paper manufacture.
23. Fat rendering.
24. Fertilizer manufacture.
25. Fireworks or explosive manufacture or storage.
26. Fish smoking and curing.
27. Forge plant.
28. Garbage, offal or dead animals, reduction or dumping.
29. Gas (illuminating or heating) manufacture.
30. Glue, size or gelatine manufacture.
31. Gunpowder, manufacture or storage.
32. Iron, steel, brass or copper foundry or fabrication plant.
33. Lamp black manufacture.
34. Match manufacture.
35. Oilcloth or linoleum manufacture.
36. Oiled or rubber goods manufacture.
37. Ore reduction.
38. Paint, oil, shellac, turpentine, or varnish manufacture.
39. Paper and pulp manufacture.
40. Petroleum products, refining or wholesale storage of petroleum.
41. Planing mills.
42. Potash works.
43. Pyroxlin manufacture.
44. Rock crusher.
45. Rolling mills.
46. Rubber or gutta-percha manufacture or treatment.
47. Salt works.
48. Sauerkraut manufacture.
49. Shoe polish manufacture.
50. Smelting of tin, copper, zinc or iron ores.
51. Soap manufacture, other than liquid soap.
52. Soda and compound manufacture.
53. Stock yards or slaughter of animals.
54. Stone mill or quarry.
55. Storage or baling of rags, iron or junk.
56. Stove polish manufacture.
57. Sulphuric, nitric or hydrochloric acid manufacture.
58. Tallow, grease or lard manufacture or refining from animal fat
59. Tanning, curing or storage of raw hides or skins.
60. Tar distillation or manufacture.
61. Tar roofing or waterproofing manufacture.
62. Tobacco (chewing) manufacture or treatment.
63. Vinegar manufacture.
64. Wool pulling or scouring.
65. Yeast plant.
66. And in general those uses which may be obnoxious or offensive by reason of emission of odor, dust, smoke, gas or noise.

SECTION 8. USE REGULATIONS

"K" Heavy Industrial District

In the "K" Heavy Industrial District buildings and land may be used for any purpose whatsoever not in conflict with any ordinance of the City of Knoxville regulating nuisances; provided, however, that no building or occupancy permit shall be issued for any of the following uses until and unless the location of such use shall have been approved by the Council.

1. Acid manufacture.
2. Cement, lime, gypsum or plaster of paris manufacture.
3. Distillation of bones.
4. Explosives, manufacture or storage.
5. Fat rendering.
6. Fertilizer manufacture.
7. Garbage, offal or dead animal reduction or dumping.
8. Gas manufacture.
9. Glue manufacture.
10. Petroleum refining.
11. Smelting of tin, copper, zinc, or iron ores.
12. Stock yards or slaughter of animals.

SECTION 9.

NON-CONFORMING USES

The lawful use of land existing at the time of the passage of this ordinance, although such use does not conform to the provisions hereof, may be continued, but if such non-conforming use is discontinued, any future use of said premises shall be in conformity with the provisions of this ordinance.

The lawful use of the building existing at the time of the passage of this ordinance may be continued, although such use does not conform with the provisions hereof, and such use may be extended throughout the building provided no structural alterations, except those required by law or ordinance, are made therein. If no structural alterations are made, a non-conforming use of a building may be changed to another non-conforming use of the same or more restricted classification.

The foregoing provisions shall also apply to non-conforming uses in districts hereafter changed.

Nothing in this ordinance shall be taken to prevent the restoration of a building destroyed to the extent of not more than 50% of its reasonable value, by fire, explosion or other casualty, or act of God, or the public enemy, nor the continued occupancy or use of such building or part thereof which existed at the time of such partial destructions.

SECTION 10.

HEIGHT AND AREA REGULATIONS

"A" One-Family and "B" Two-Family Districts.

In the "A" One-Family and "B" Two-Family Districts the height of buildings, the minimum dimensions of yards and the minimum lot area per family shall be as follows:

Height: No building hereafter erected or structurally altered shall exceed two and one-half (2½) stories or thirty-five (35) feet. See Section 18.

Rear Yard: There shall be a rear yard having a depth of not less than twenty (20) per cent of the depth of the lot, provided such rear yard need not exceed twenty-five (25) feet. See Section 18.

Side Yard: There shall be a side yard on each side of a building having a width of not less than ten (10) per cent of the width of the lot, provided such side yards need not exceed five (5) feet in width. See Section 18.

Front Yard: There shall be a front yard of not less than twenty-five (25) feet to the front line of the building and not less than fifteen (15) feet to the front line of a porch or paved terrace, provided, however, that:

(1) Where lots comprising forty (40) per cent or more of the frontage are developed with buildings having an average front yard with a variation of not more than six (6) feet, no building hereafter erected or structurally altered shall project beyond the average front yard line so established, provided, further, that this regulation shall not be so interpreted as to require a front yard of more than fifty (50) feet.

(2) On corner lots the side yard regulation shall apply to the street side of the lot except in the case of reversed frontage where the corner lot faces an intersecting street. In this case, there shall be a side yard on the street side of the corner lot of not less than fifty (50) per cent of the front yard required on the lots in the rear of such corner lot, and no accessory building on said corner lot, shall project beyond the front yard line on the lots in the rear; provided further that this regulation shall not be so interpreted as to reduce the buildable width of a corner lot facing an intersecting street and of record at the time of the passage of this ordinance to less than twenty-eight (28) feet, nor to prohibit the erection of an accessory building where this regulation cannot reasonably be complied with.

Lot Area Per Family: In the "A" One-Family District every building hereafter erected or structurally altered, shall provide a lot area of not less than five thousand (5,000) square feet per family.

In the "B" Two-Family District every building hereafter erected or structurally altered shall provide a lot area of not less than twenty-five hundred (2500) square feet per family.

Provided, however, that where a lot has less area than herein required and was of record at the time of the passage of this ordinance said lot may be occupied by not more than one family.

SECTION 11.

HEIGHT AND AREA REGULATIONS

"C" Apartment District

In the "C" Apartment District the height of buildings, the minimum dimensions of yards and the minimum lot area per family shall be as follows:

Height: No building hereafter erected or structurally altered shall exceed three (3) stories or forty-five (45) feet. See Section 18.

Rear Yard: There shall be a rear yard having a depth of not less than twenty (20) per cent of the depth of the lot, provided such rear yard need not exceed twenty-five (25) feet for interior lots nor fifteen (15) feet for corner lots.

Side Yard: For buildings not exceeding two and one-half (2½) stories in height the side yard requirement shall be the same as required in the One and Two-Family Districts.

For buildings more than two and one-half (2½) stories in height the side yard shall be increased one (1) foot in width for each additional story above the second story.

Front Yard: There shall be a front yard of not less than twenty-five (25) feet to the front line of the building and not less than fifteen (15) feet to the front line of a porch or paved terrace, provided, however, that:

(1) Where lots comprising forty (40) per cent or more of the frontage are developed with buildings having an average front yard with a variation of not more than six (6) feet, no building hereafter erected or structurally altered shall project beyond the average front yard line so established, provided further, that this regulation shall not be so interpreted as to require a front yard of more than fifty (50) feet.

(2) On corner lots the side yard regulation shall apply to the street side of the lot except in the case of reversed frontage where the corner lot faces an intersecting street. In this case, there shall be a side yard on the street side of the corner lot of not less than fifty (50) per cent of the front yard required on the lots in the rear of such corner lot, and no accessory building on said corner lot, shall project beyond the front yard line on the lots in the rear; provided further that this regulation shall not be so interpreted as to reduce the buildable width of a corner lot facing an intersecting street and of record at the time of the passage of this ordinance to less than twenty-eight (28) feet, nor to prohibit the erection of an accessory building where this regulation cannot reasonably be complied with.

Lot Area Per Family: Every building hereafter erected shall provide a lot area of not less than six hundred (600) square feet per family, provided, however, that this regulation shall not apply to apartment hotels where no cooking is done in any individual room, suite or apartment. See Section 18.

SECTION 12.

HEIGHT AND AREA REGULATIONS

"D" Apartment District

In the "D" Apartment District the height of buildings, the minimum dimensions of yards and the minimum lot area per family shall be as follows:

Height: No building hereafter erected or structurally altered shall exceed six (6) stories or seventy-five (75) feet. See Section 18.

Rear Yard: There shall be a rear yard having a depth of not less than twenty (20) per cent of the depth of the lot, provided such rear yard need not exceed twenty-five (25) feet for interior lots nor fifteen (15) feet for corner lots.

Side Yard: For buildings not exceeding two and one-half (2½) stories in height the side yard requirement shall be the same as required in the One and Two-Family Districts.

For buildings more than two and one-half (2½) stories in height the side yard shall be increased one (1) foot in width for each additional story above the second story.

Front Yard: There shall be a front yard of not less than twenty-five (25) feet to the front line of the building and not less than fifteen (15) feet to the front line of a porch or paved terrace, provided, however, that:

(1) Where lots comprising forty (40) per cent or more of the frontage are developed with buildings having an average front yard with a variation of not more than six (6) feet, no building hereafter erected or structurally altered shall project beyond the average front yard line so established, provided further, that this regulation shall not be so interpreted as to require a front yard of more than fifty (50) feet.

(2) On corner lots the side yard regulation shall apply to the street side of the lot except in the case of reversed frontage where the corner lot faces an intersecting street. In this case, there shall be a side yard on the street side of the corner lot of not less than fifty (50) per cent of the front yard required on the lots in the rear of such corner lot, and no accessory building on said corner lot, shall project beyond the front yard line on the lots in the rear; provided further that this regulation shall not be so interpreted as to reduce the buildable width of a corner lot facing an intersecting street and of record at the time of the passage of this ordinance to less than twenty-eight (28) feet, nor to prohibit the erection of an accessory building where this regulation cannot reasonably be complied with.

Lot Area Per Family: Every building hereafter erected shall provide a lot area of not less than four hundred (400) square feet per family, provided, however, that this regulation shall not apply to apartment hotels where no cooking is done in any individual room, suite or apartment. See Section 18.

SECTION 13.

HEIGHT AND AREA REGULATIONS

"E" Commercial District

In the "E" Commercial District the height of buildings, the minimum dimension of yards and the minimum lot area per family shall be as follows, provided, however, that buildings erected for dwelling purposes shall comply with the Front and Side Yard regulations of the "A" One-Family District.

Height: No building hereafter erected or structurally altered shall exceed two and one-half stories or thirty-five (35) feet. See Section 18.

Rear Yard: There shall be a rear yard having a depth of not less than twenty (20) per cent of the depth of the lot, provided such rear yard need not exceed twenty-five (25) feet. See Section 18.

Side Yard: Not required except on that side of a lot abutting upon the side of a lot zoned for Dwelling purposes in which case there shall be a side yard of not less than three (3) feet. In other cases a side yard, if provided for a commercial building shall be not less than three (3) feet.

Front Yard: Where all the frontage on one side of the street between two intersecting streets is located in the Commercial District no front yard shall be required. Where the frontage on one side of the street between two intersecting streets is located in the Commercial District and the Dwelling District the front yard requirement in the Dwelling District, including the side yard on a reversed corner lot only, shall apply to the Commercial District.

Lot Area Per Family: Every building hereafter erected or structurally altered shall provide a lot area of not less than twenty-five hundred (2500) square feet per family.

SECTION 14.

HEIGHT AND AREA REGULATIONS

"F" Commercial and "I" Light Industrial District

In the "F" Commercial and "I" Light Industrial District the height of buildings, the minimum dimension of yards and the minimum lot area per family shall be as follows, provided, however, that buildings erected for dwelling purposes exclusively shall comply with the Front and Side Yard regulations of the "C" Apartment District.

Height: No building hereafter erected or structurally altered shall exceed three stories or forty-five (45) feet. See Section 18.

Rear Yard: In the "F" Commercial District there shall be a rear yard having a depth of not less than twenty (20) per cent of the depth of the lot, provided such rear yard need not exceed twenty-five (25) feet for interior lots nor fifteen (15) feet for corner lots.

In the "I" Industrial District no rear yard shall be required except where the "I" Industrial District abuts on a Dwelling District in which case there shall be a rear yard of not less than ten (10) feet.

Side Yard: Not required except on that side of a lot abutting upon the side of a lot zoned for Dwelling purposes in which case there shall be a side yard of not less than three (3) feet. In other cases a side yard, if provided for a business building shall be not less than three (3) feet.

Front Yard: Where all the frontage on one side of the street between two intersecting streets is located in the Commercial District no front yard shall be required. Where the frontage on one side of the street between two intersecting streets is located in the Commercial District and the Dwelling District the front yard requirements of the Dwelling District, including the side yard on a reversed corner lot only, shall apply to the Commercial District.

Lot Area Per Family: Every building hereafter erected shall provide a lot area of not less than six hundred (600) square feet per family, provided, however, that this regulation shall not apply to hotels or apartment hotels where no cooking is done in any individual room, suite or apartment. See Section 18.

SECTION 15.

HEIGHT AND AREA REGULATIONS

"G" Commercial District

In the "G" Commercial District the height of buildings, the minimum dimension of yards and the minimum lot area per family shall be as follows, provided, however, that buildings or portions thereof erected for dwelling purposes shall comply with the Side and Rear Yard regulations of the "D" Apartment District.

Height: No building hereafter erected or structurally altered shall exceed six stories or seventy-five (75) feet. See Section 18.

Rear Yard: There shall be a rear yard of not less than ten (10) feet.

Side Yard: Not required except on that side of a lot abutting upon the side of a lot zoned for Dwelling purposes in which case there shall be a side yard of not less than three (3) feet. In other cases a side yard, if provided for a commercial building shall be not less than three (3) feet.

Front Yard: Where all the frontage on one side of the street between two intersecting streets is located in a Business District no front yard shall be required. Where the frontage on one side of the street between two intersecting streets is located in the Business District and a Dwelling District the front yard requirement in the Dwelling District shall apply to the Business District, provided, however, that no side yard shall be required on the street side of any corner lot used for business purposes.

Lot Area Per Family: Every building or portion thereof hereafter erected or structurally altered shall provide a lot area of not less than four hundred (400) square feet per family, provided, however, that this regulation shall not apply to hotels or apartment hotels where no cooking is done in any individual room, suite or apartment. See Section 18.

SECTION 16.

HEIGHT AND AREA REGULATIONS

"J" Light Industrial and "K" Heavy Industrial Districts

In the "J" Light Industrial and "K" Heavy Industrial Districts the height of buildings and the minimum dimension of yards shall be as follows, provided, however, that buildings erected or structurally altered for dwelling purposes shall comply with the Side and Rear Yard and Lot Area per Family regulations of the "D" Apartment District. See Section 18.

Height: No building hereafter erected or structurally altered shall exceed eight (8) stories or one hundred (100) feet. See Section 18.

Rear Yard: No rear yard shall be required except where an Industrial District abuts on a Dwelling District in which cases there shall be a rear yard of not less than ten (10) feet.

Side Yard: Not required except on that side of a lot abutting upon the side of a lot zoned for Dwelling purposes in which case there shall be a side yard of not less than three (3) feet. In other cases a side yard, if provided for a business building shall be not less than three (3) feet.

SECTION 17.

HEIGHT AND AREA REGULATIONS

"H" Business District

In the "H" Business District the height and size of buildings shall be as follows, provided, however, that buildings erected or structurally altered for dwelling purposes shall comply with the Side and Rear Yard and Lot Area Per Family regulations of the "D" Apartment District. See Section 18.

Height: No building hereafter erected or structurally altered shall exceed a height at the street line of two (2) times the width of the street but above the height permitted at the sreet line four (4) feet may be added to the height of the building for each one (1) foot that the building or portion thereof is set back from the street line; provided, however, that the cubical contents of such building shall not exceed the contents of a prism having a base equal to the area of the lot and a height of one hundred and fifty (150) feet. See Section 18.

SECTION 18.

HEIGHT AND AREA EXCEPTIONS

The foregoing requirements in the height and area districts shall be subject to the following exceptions and regulations:

Height: (a) That in the thirty-five (35) and forty-five (45) foot height districts public or semi-public buildings, hospitals, sanitariums or schools may be erected to a height not exceeding seventy-five (75) feet when the front, side and rear yards are increased an additional foot for each foot such buildings exceed thirty-five (35) and forty-five (45) feet respectively, in height.

(b) One-family dwellings in the thirty-five (35) foot height district may be increased in height by not more than ten (10) feet when two (2) side yards of not less than fifteen (15) feet each are provided. Such dwellings, however, shall not exceed three (3) stories in height.

(c) Chimneys, towers, penthouses, scenery lofts, sugar refineries, monuments, cupolas, domes, spires, false mansards, parapet walls, similar structures and necessary mechanical appurtenances may be erected as to their height in accordance with existing or hereafter adopted ordinances of the City of Knoxville.

(d) On through lots one hundred and fifty (150) feet or less in depth the height of a building may be measured from the curb level on either street. On through lots more than one hundred and fifty (150) feet in depth the height regulations and basis of height measurements for the street permitting the greater height shall apply to a depth of not more than one hundred and fifty (150) feet from that street.

(e) In the "H" Business District for a building located on a lot at the intersection of streets of different widths the height permitted on the wider street shall be allowed along the narrower street.

(f) In the "H" Business District where streets are less than 50 feet wide, the same height regulations shall apply as on streets fifty (50) feet in width and on streets more than one hundred (100) feet wide, the same height regulations shall be applied as on streets one hundred (100) feet in width.

(g) Buildings may exceed the height limits where foundations or structural provisions have been made prior to the passage of this ordinance in anticipation of a definite height.

Area: (h) For the purpose of side yard regulations semi-detached (two-family) dwelling or a double duplex (four-family) dwelling shall be considered as one building occupying one lot.

(i) In the case of group houses or court apartments, buildings may rear upon the required side yard provided that:

1. For group houses the required side yard shall be increased by one foot for each building abutting thereon.
2. For apartment houses the required side yard shall be increased by one (1) foot for each stairway opening onto or served by such side yard.
3. The width of the place or court shall not be less than three (3) times the width of the side yard as required in this provision, provided that open, unenclosed porches may project into a required place or court not more than twenty (20) per cent of the width of such place or court.
4. Where a roadway is provided in the place or court the width allowed for such roadway shall be in addition to that required above.
5. All other requirements including front, side, and rear yards shall be complied with in accordance with the district in which such group houses or court apartments are located.

(j) The side yard requirement for dwellings shall be waived where dwellings are erected above stores.

(k) In computing the depth of a rear yard, for any building where such yard opens onto an alley, one-half of such alley may be assumed to be a portion of the rear yard.

(l) An accessory building not exceeding twelve (12) feet in height may occupy not more than thirty (30) per cent of a required rear yard.

(m) Every part of a required yard or court shall be open from its lowest point to the sky unobstructed, except for the ordinary projection of sills, belt course, cornices, buttresses, ornamental features and eaves; provided, however, that none of the above projections shall project into a court more than six (6) inches nor into a minimum side yard more than twenty-four (24) inches.

(n) No cornices shall project over the street line more than five (5) per cent of the width of such street, and shall in no case project more than four (4) feet.

(o) Open or enclosed fire escapes, fireproof outside stairways and balconies projecting into a yard or court not more than three and one-half (3½) feet, and the ordinary projections of chimneys and flues may be permitted by the Building Inspector where same are so placed as not to obstruct the light and ventilation.

SECTION 19. ADJUSTMENTS

Purpose, Jurisdiction and Approval

Where there are practical difficulties or unnecessary hardships in the way of carrying out the strict letter of this ordinance the City Planning Commission (hereinafter referred to as the Planning Commission) shall have the power to vary or modify any of the rules, regulations or provisions contained herein so that the spirit of the ordinance shall be observed, public welfare secured and substantial justice done. Provided, however, that any action or decision of the Planning Commission in permitting a variation of the application of the regulations herein established must be approved by the Council before such variation is allowed.

The Planning Commission shall also have the following specific powers provided, however, that before any variation is allowed or any permit is issued the same must be approved by the Council.

(1) To hear and decide appeals where it is alleged there is error in any order, requirement, decision or determination made by the Building Inspector in the enforcement of this ordinance.

(2) Permit the extension of a district where the boundary line divides a lot in a single ownership at the time of the passage of this ordinance.

(3) Permit a temporary building for commerce or industry in a Dwelling District which is incidental to the residential development, such permit to be issued for a period of not more than one (1) year.

(4) Permit public utility or public service uses and structures in any district when found to be necessary for the public health, convenience, safety or welfare.

(5) Permit the location of the following uses in a district from which they are prohibited by this ordinance; Cemetery, Amusement Park, Airport, Tourist Camp, Nursery, Greenhouse, Library, Museum, Community Center, Hospital and Institution of an Educational or Philanthropic nature.

(6) Permit a public garage in a Commercial District where it is deemed necessary for the public convenience or welfare

(7) Interpret the provisions of this ordinance in such a way as to carry out the intent and purpose of the plan, as shown upon the map fixing the several districts accompanying and made a part of this ordinance, where the street layout actually on the ground varies from the street layout as shown on the maps aforesaid.

(8) Adopt from time to time such rules and regulations as may be deemed necessary to carry into effect the provisions of this ordinance.

Appeal: The City Planning Commission shall hear appeals from the action of the Building Inspector and determine the rights of such applicant. Appeal to the Planning Commission may be taken by any person aggrieved and such appeal shall be taken within such reasonable time as provided by the rules of the Planning Commission by filing with the Building Inspector and the Planning Commission a notice of appeal specifying the grounds thereof. The Building Inspector shall forthwith transmit to the Planning Commission all papers constituting the record upon which the action appealed from was taken.

Meetings: Meetings of the Planning Commission for the purpose of considering zoning adjustments shall be held at least once a month or at the call of the chairman at such other times as the Planning Commission may determine. The Planning Commission shall adopt its own rules of procedure and keep a record of its proceedings showing the action of the Planning Commission on each question considered.

SECTION 20.

CERTIFICATE OF OCCUPANCY

No vacant land shall be occupied or used, except for agriculture uses, and no building hereafter erected or structurally altered shall be occupied or used until a certificate of occupancy shall have been issued by the Building Inspector.

Certificate of Occupancy for a Building

Certificate of Occupancy for a new building or the alteration of an existing building shall be applied for coincident with the application for a building permit and said certificate shall be issued within three days after the requests for same shall have been made in writing to the Building Inspector after the erection or alteration of such building or part thereof shall have been completed in conformity with the provisions of these regulations. Pending the issuance of a regular certificate a temporary certificate of occupancy may be issued by the Building Inspector for a period not exceeding six months, during the completion of alterations or during partial occupancy of a building pending its completion. Such temporary certificate shall not be construed as in any way altering the respective rights, duties or obligations of the owners or of the city relating to the use or occupancy of the premises or any other matter covered by this ordinance, and such temporary certificate shall not be issued except under such restrictions and provisions as will adequately insure the safety of the occupants.

Certificate of Occupancy for Land

Certificate of Occupancy for the use of vacant land or the change in the character of the use of land as herein provided, shall be applied for before any such land shall be occupied or used and a certificate of occupancy shall be issued, within three (3) days after the application has been made, provided such use is in conformity with the provisions of these regulations.

Certificate of Occupancy shall state that the building or proposed use of a building or land, complies with all the building and health laws and ordinances and with the provisions of these regulations. A record of all certificates shall be kept on file in the office of the Building Inspector and copies shall be furnished, on request, to any person having a proprietary or tenancy interest, in the building affected. No fee shall be charged for a certificate of occupancy.

No permit for excavation for any building shall be issued before application has been made for certificate of occupancy.

SECTION 21. PLATS

All applications for building permits shall be accompanied by a drawing or plat, in duplicate, showing the lot plan; the location of the building on the lot; accurate dimensions of building and lot and such other information as may be necessary to provide for the enforcement of these regulations. A careful record of the original copy of such applications and plats shall be kept in the office of the Building Inspector and the duplicate copy shall be kept at the building at all times during construction.

SECTION 22.

BOUNDARIES OF DISTRICTS

Where uncertainty exists with respect to the boundaries of the various districts as shown on the map accompanying and made a part of this ordinance the following rules shall apply.

(a) The district boundaries are either streets or alleys unless otherwise shown, and where the designation on the map accompanying and made a part of this ordinance indicating the various districts are approximately bounded by street or alley lines, said street or alley shall be construed to be the boundary of such district.

(b) Where the district boundaries are not otherwise indicated and where the property has been or may hereafter be divided into blocks and lots, the district boundaries shall be construed to be lot lines and where the designation on the map accompanying and made a part of this ordinance indicating the various districts are approximately bounded by lot lines, said lot line shall be construed to be the boundary of such district unless said boundaries are otherwise indicated on the map.

(c) In unsubdivided property, the district boundary lines on the maps accompanying and made a part of this ordinance shall be determined by use of the scale contained on such map.

SECTION 23.

INTERPRETATION, PURPOSE AND CONFLICT

In interpreting and applying the provisions of this ordinance, they shall be held to be the minimum requirements for the promotion of the public safety, health, convenience, comfort, prosperity or general welfare. It is not intended by this ordinance to interfere with or abrogate or annul any easements, covenants or other agreement between parties, provided, however, that where this ordinance imposes a greater restriction upon the use of buildings or premises or upon height of buildings, or requires larger open spaces than are imposed or required by other ordinances, rules, regulations or by easements, covenants or agreements, the provisions of this ordinance shall govern.

SECTION 24.

CHANGES AND AMENDMENTS

The City Council of the City of Knoxville may from time to time, on its own motion, or on petition after report by the City Planning Commission and after hearing and public notice of such hearing given by one publication in the official newspaper at least ten (10) days before the time of hearing, amend, supplement or change the regulations and districts herein or subsequently established. Whenever the owners of 50% or more of the area of all the property within a radius of two hundred (200) feet of any area proposed to be changed, shall present to the Council a petition duly signed and acknowledged by them, requesting any such amendment, supplement or change of the regulations prescribed for such district, or part thereof, the Council shall act upon such petition within ninety days after the filing thereof. No amendment, change or supplement of the regulations or of the boundaries of districts herein established shall be made except by a four-fifths vote of the Council, and if at the time of the hearing thereon a protest against such amendment, supplement or change is presented, duly signed and acknowledged by the owners of twenty per cent or more of the frontage of property which will be directly affected by the proposed amendment, supplement or change, or by the owners of twenty per cent of the frontage of property which is immediately adjacent thereto, either in the rear, on the sides, or across the street no such amendment, change, or supplement shall be adopted except by unanimous vote of the Council.

SECTION 25. VALIDITY

Should any section, clause or provision of this ordinance be declared by the Court to be invalid, the same shall not affect the validity of the ordinance as a whole or any part thereof, other than the part so declared to be invalid.

SECTION 26.

ENFORCEMENT, LEGAL PROCEDURE, PENALTIES

It shall be the duty of the City Manager through the proper department to enforce this ordinance.

Any person, firm or corporation who violates, disobeys, omits, neglects or refuses to comply with or who resists the enforcement of any of the provisions of this ordinance shall be fined not less than five (5) dollars or more than fifty (50) dollars for each offense. Each day that a violation is permitted to exist shall constitute a separate offense.

SECTION 27. WHEN EFFECTIVE

Be it further ordained that this ordinance shall take effect 17 days from and after its passage, the welfare of the city requiring it.

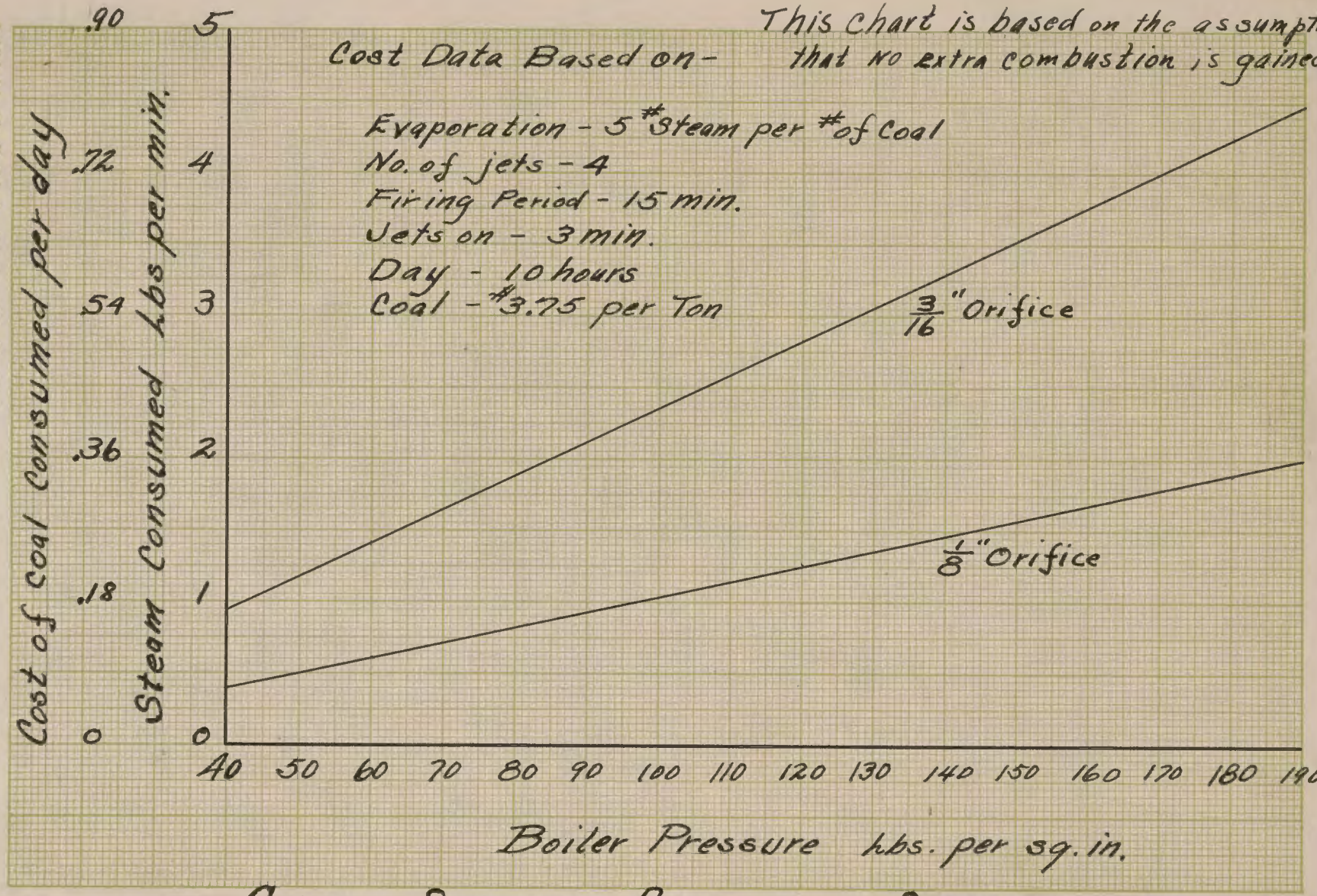


CHART SHOWING AMOUNT OF STEAM USED ON STEAM-AIR JETS

Published by The H. Cole Co., Columbus, Ohio. No. 299 G.

CUTS AND THEIR DISCUSSION

The following cuts, prints, diagrams, etc. show some of the various kinds of "Smokeless" fuel burning equipment that are on the market today. The presence of any of these cuts do not in any way mean that The Bureau of Smoke Regualtions sets these, or any portion of them, as a standard or the acceptable ones for installation in Knoxville. This bureau does not care what kind of fuel or fuel burning equipment is used so long as it will operate within the city ordinance. Discrimination is not made of any manufacturer's product nor is any concerns equipment aimed to be excluded. Discrimination is, however, made of certain types of equipment within a given size. (See city ordinance, page 77 of this paper) The reason for this specification of equipment and any other recommendations, suggestions, etc., are made with the sincere effort and sole purpose to carry on a successful smoke abatement campaign.

With a few exceptions of some of the mechanical stokers, especially the larger sizes and the Fitzgibbons Boiler, all of the equipment listed in the following pages are in use in Knoxville. The operations of these stokers as a whole have been the most acceptable to the bureau in respect to smoke emission, however, under heavy overloaded conditions, as discussed on page 40 where the stoker is not designed for the present load, bad smoke conditions prevail. It is felt by the engineers of the bureau that overfeed stokers will not carry the overload that an underfeed stoker will, and under

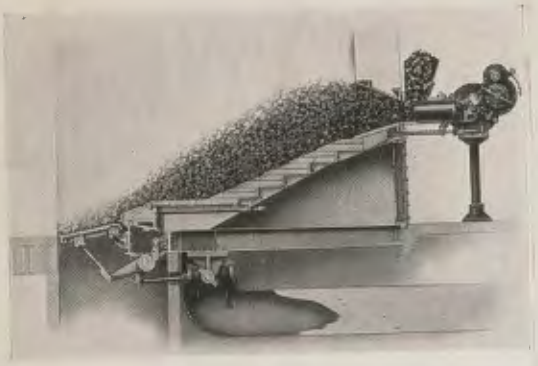
normal operating conditions must be watched much closer in order to keep the smoke down. Fortunately there are only a few stokers of the over feed type in Knoxville and these are all operated by experienced firemen who keep the smoke emission down to a minimum.

The down draft boilers are used to some extent and at first the bureau experianced some difficulty ingetting the fireman to operate them properly, but after a few instructions as to care of fire and with the use of the proper coal (Egg Size) these boilers, as a rule, were operated better than the other types of "Smokeless" boilers.

The type of boiler with the air entries on the sides gave considerable trouble as the firemen were negligent in the use of these ports and in using the coking method of firing, but after instruction and proper cooperation of the owners or operators in the use of proper coal or coke and supervision over the fireman, more satisfactory results were gained. The remaining smokeless types of boilers that were provided with an arch and the secondary air being admitting through the fire door gave about the same trouble as the above class and their solution was similar.

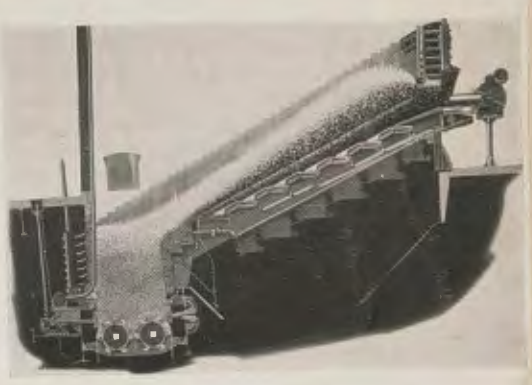
Underfeed Stokers—Multiple Retort Type

AMERICAN ENGINEERING COMPANY
Philadelphia, Pa.



Taylor Stoker
Type H—Steam Dump

AMERICAN ENGINEERING COMPANY
Philadelphia, Pa.

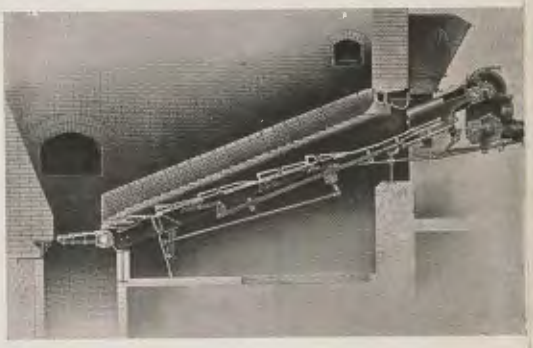


Taylor Stoker
Type J—with Steel Girders

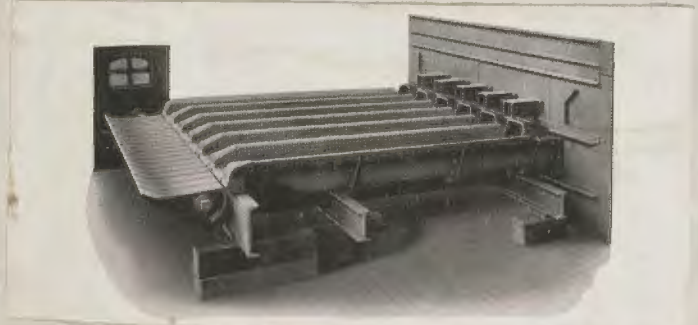
RILEY STOKER CORPORATION
Worcester, Mass.

Jones Automatic Cleaning Stoker

WESTINGHOUSE ELECTRIC & MFG. CO.
South Philadelphia Works



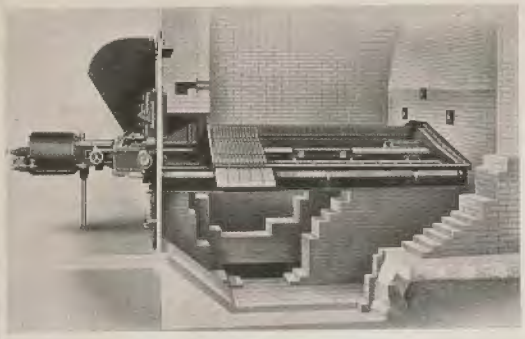
Westinghouse Stoker
Dump Grate Type



DETROIT STOKER COMPANY
Detroit, Mich.

Underfeed Stokers—Single Retort Type

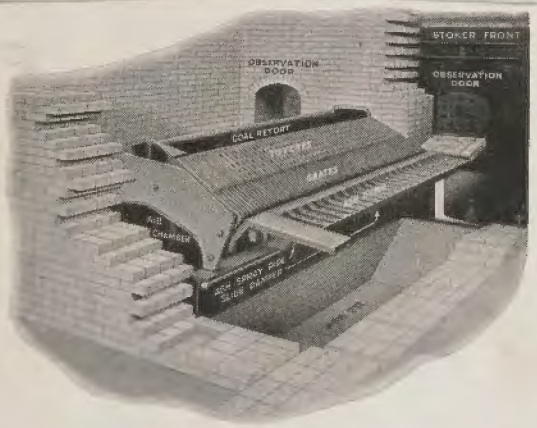
WESTINGHOUSE ELECTRIC & MFG. CO.
South Philadelphia Works



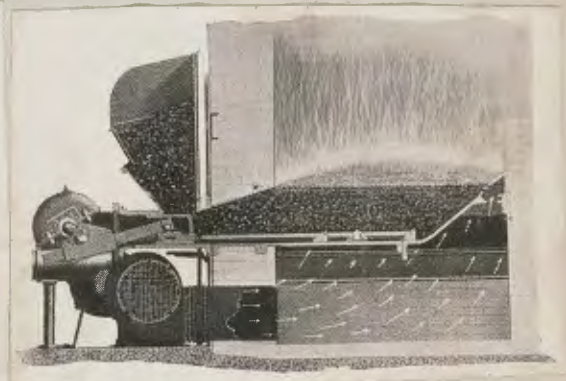
Westinghouse Stoker
(Center Retort)

WESTINGHOUSE ELECTRIC & MFG. CO.
South Philadelphia Works

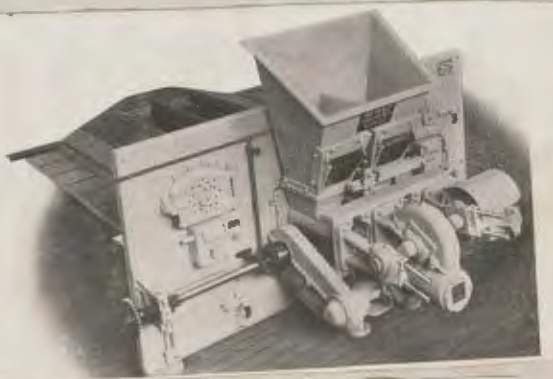
Westinghouse Stoker
(Side Retort)



Detroit Single Retort Stoker

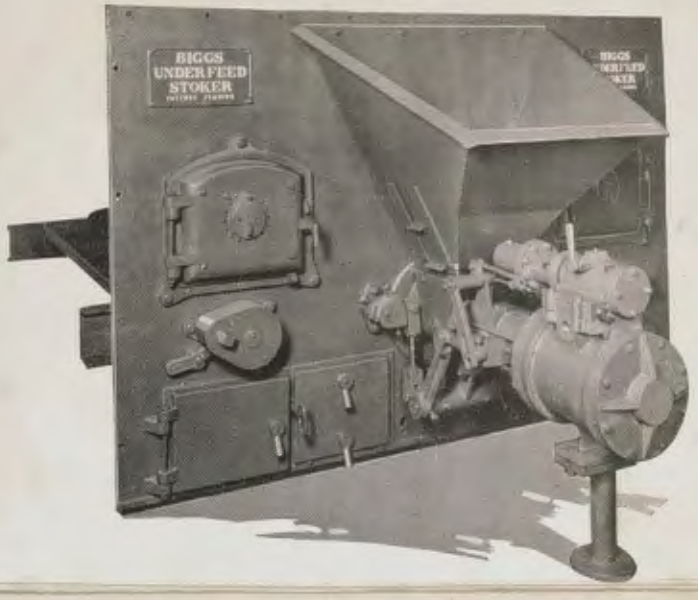


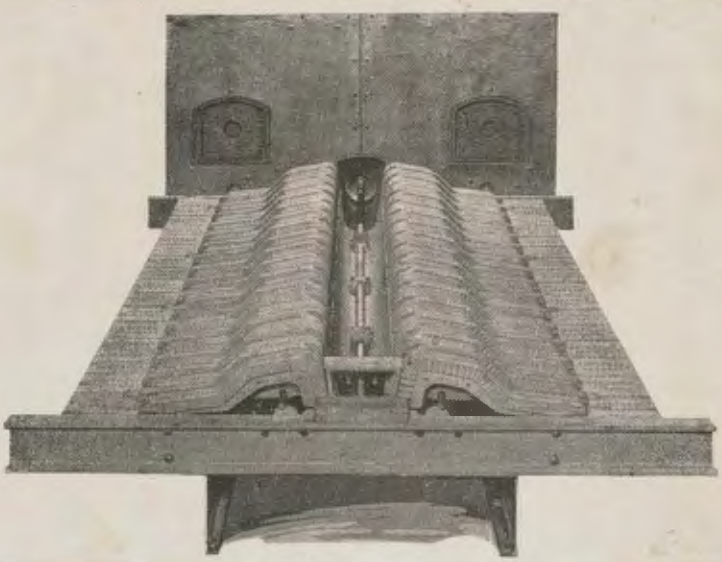
Detroit UniStoker

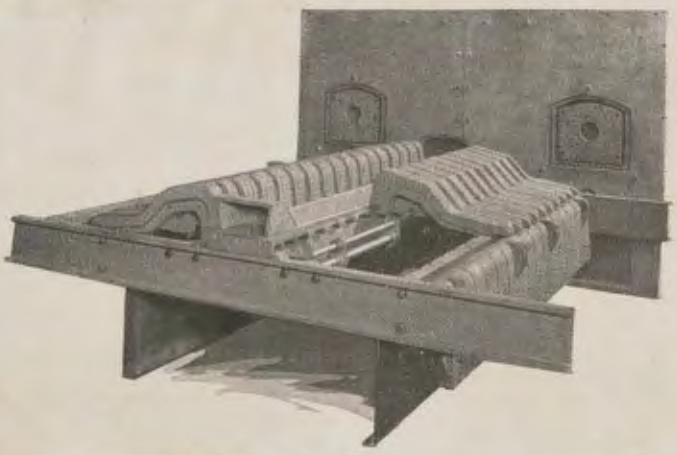


DETROIT STOKER COMPANY
Detroit, Mich.

Biggs Underfeed Stokers



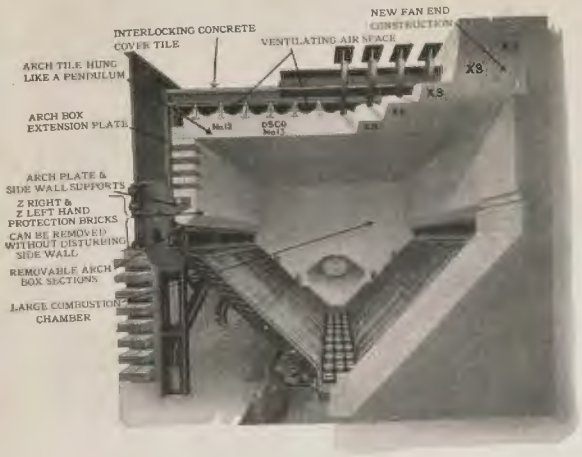




Overfeed Stokers

DETROIT STOKER COMPANY

Detroit, Mich.

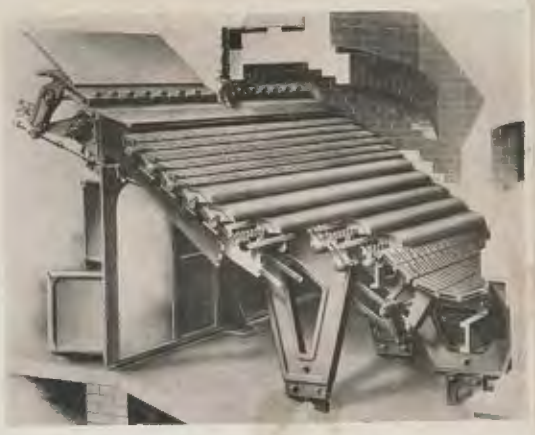


Detroit "V" Type Stoker

Rear View of Installation with Flat Suspended Arch

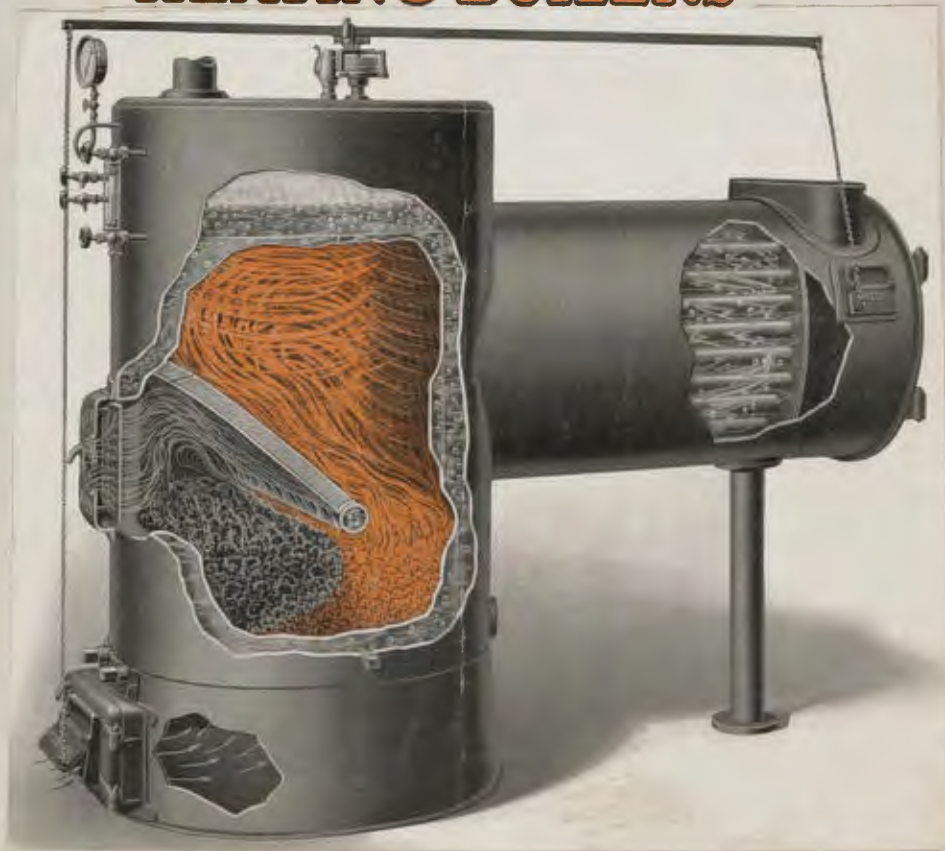
WESTINGHOUSE ELECTRIC & MFG. CO.

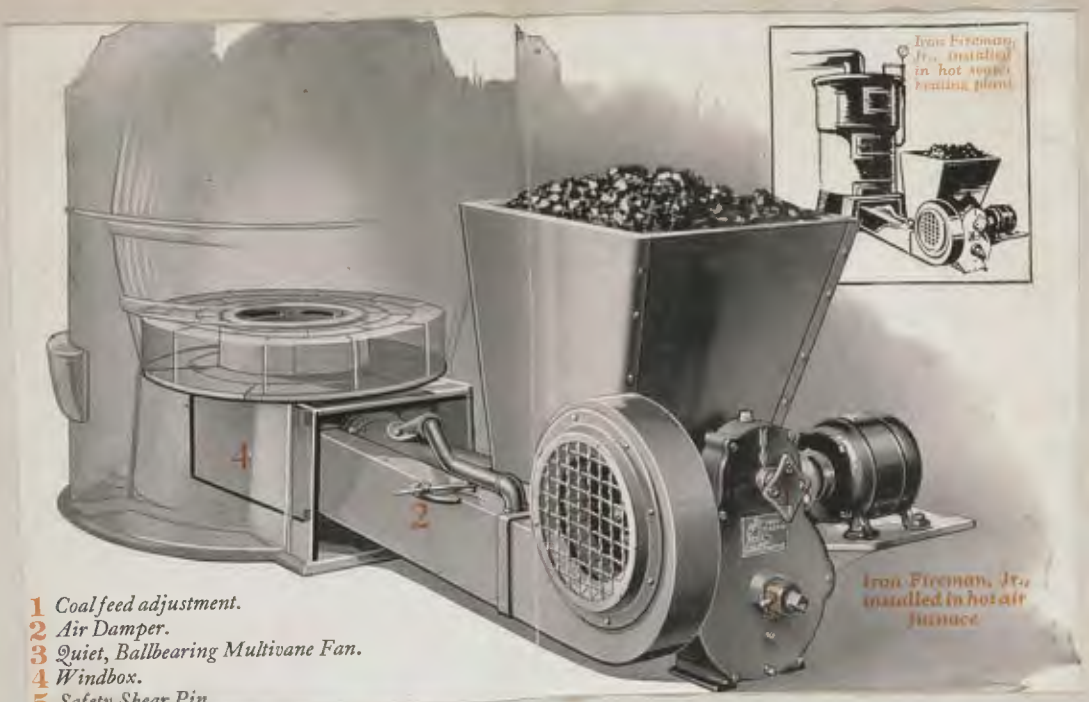
South Philadelphia Works



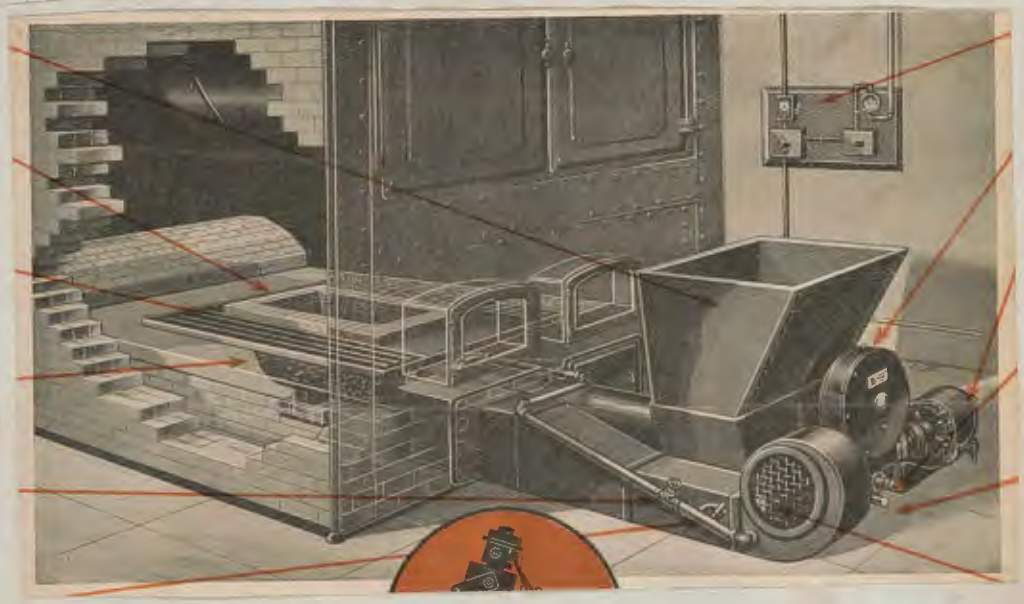
Roney Stoker

FITZGIBBONS STEEL SMOKELESS HEATING BOILERS





1 *Coal feed adjustment.*
2 *Air Damper.*
3 *Quiet, Ballbearing Multivane Fan.*
4 *Windbox.*
5 *Safety Shear Pin.*



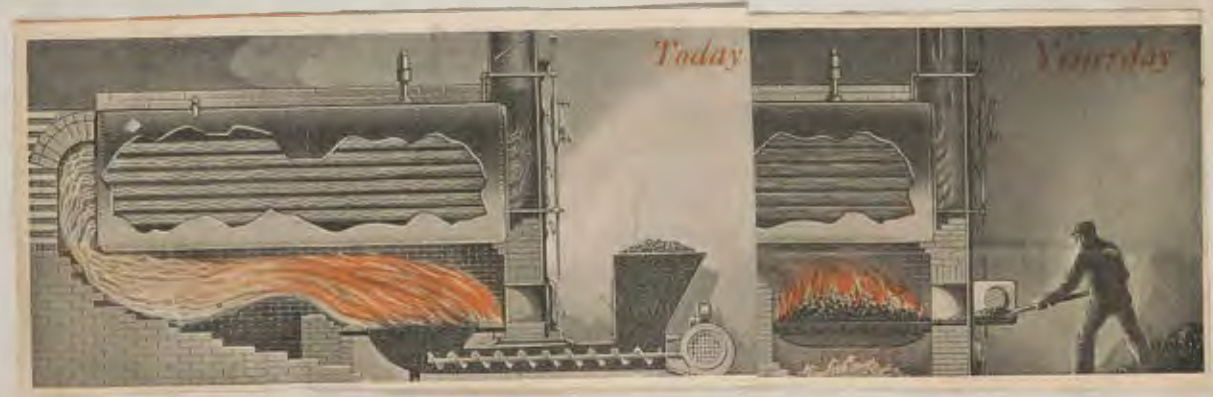
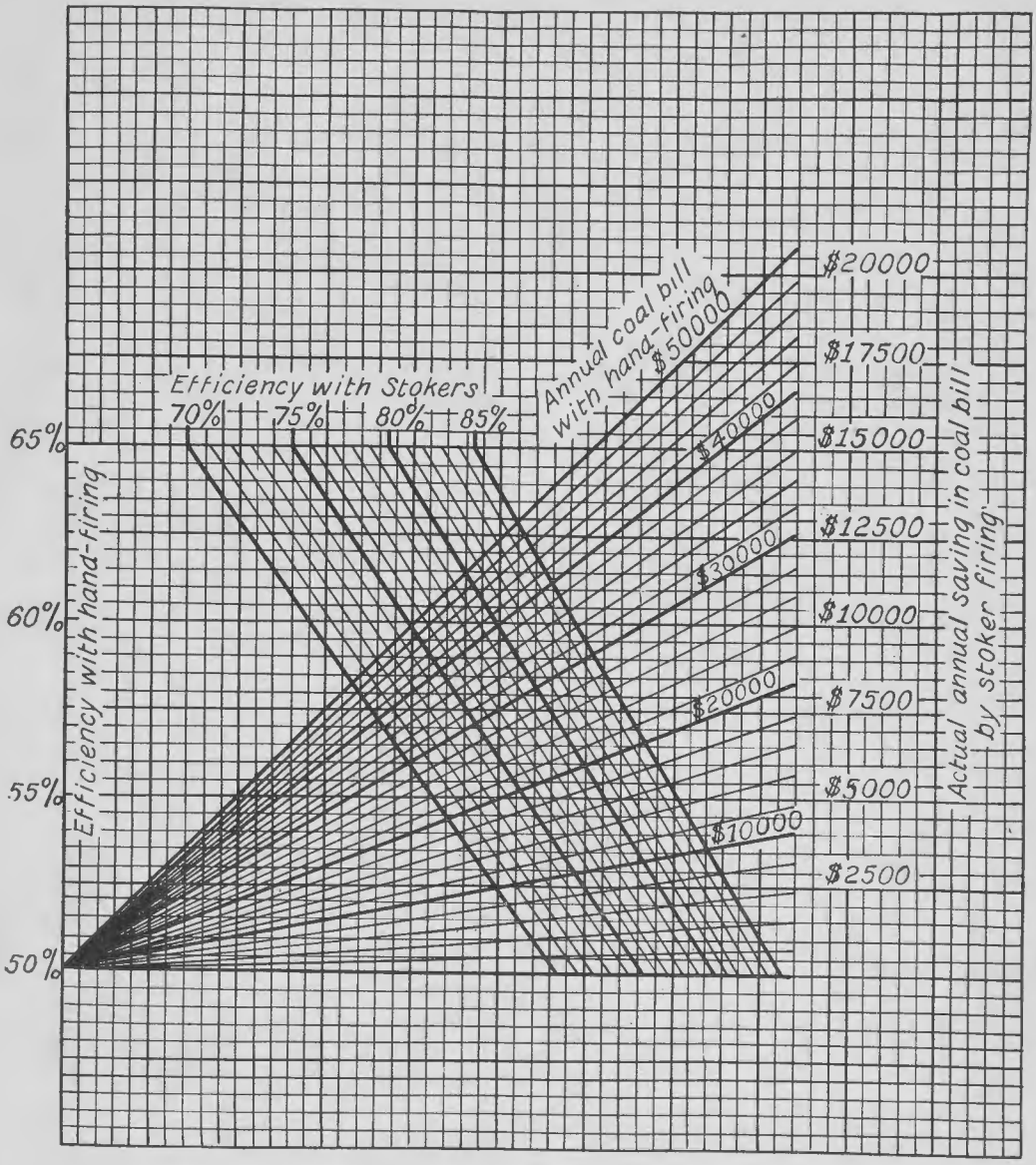


Chart for Determining Yearly Coal Saving in Dollars and Cents by Stoker Firing As Compared to Hand Firing



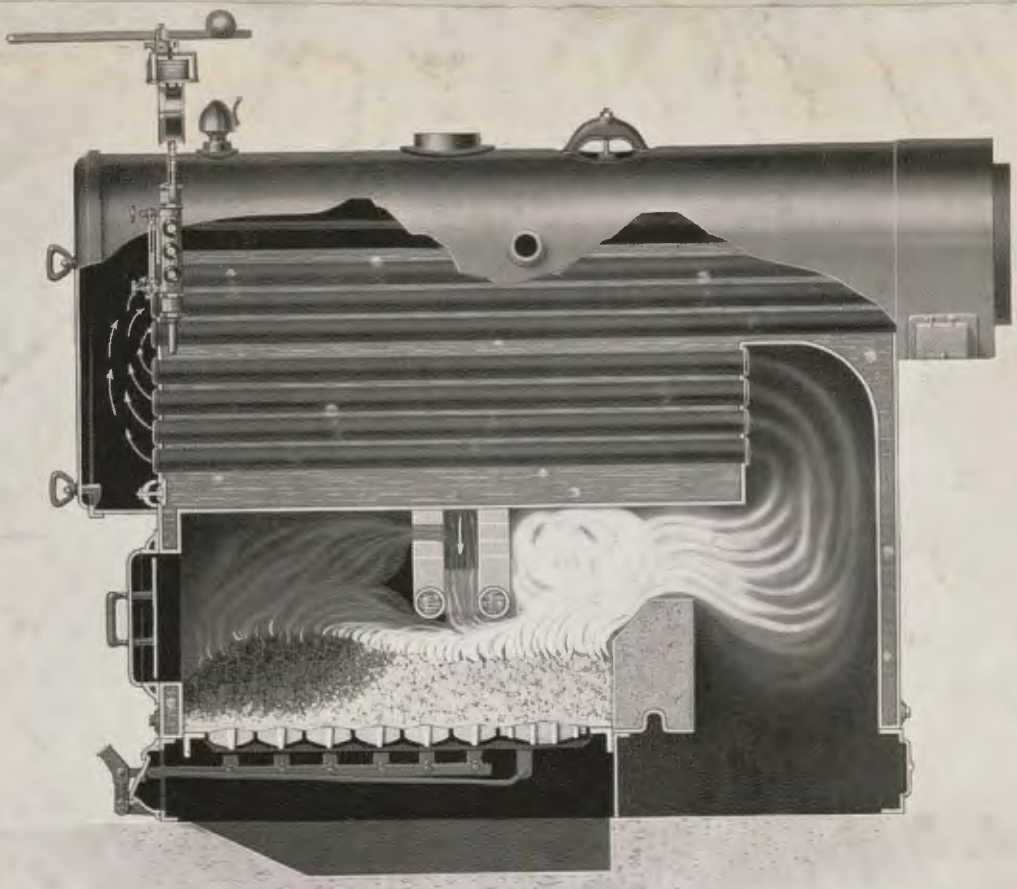
How to Use the Chart:

Start at the left with the present efficiency with hand-fired boilers; move horizontally to the right to the line corresponding to the expected efficiency with stokers; move vertically up or down to the line representing your annual expenditure for coal for hand-fired boilers; move horizontally to right and read the actual annual saving in coal bill resulting from the use of stokers.

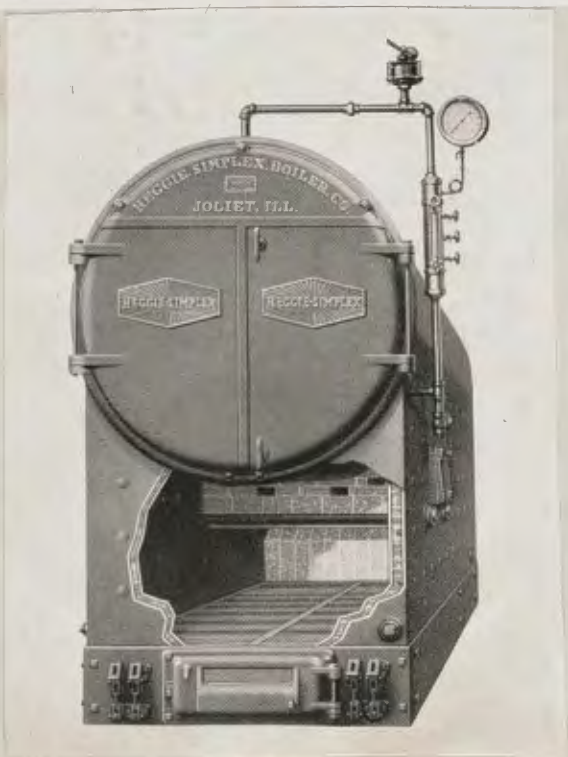
COMPILED BY THE

Stoker Manufacturers Association

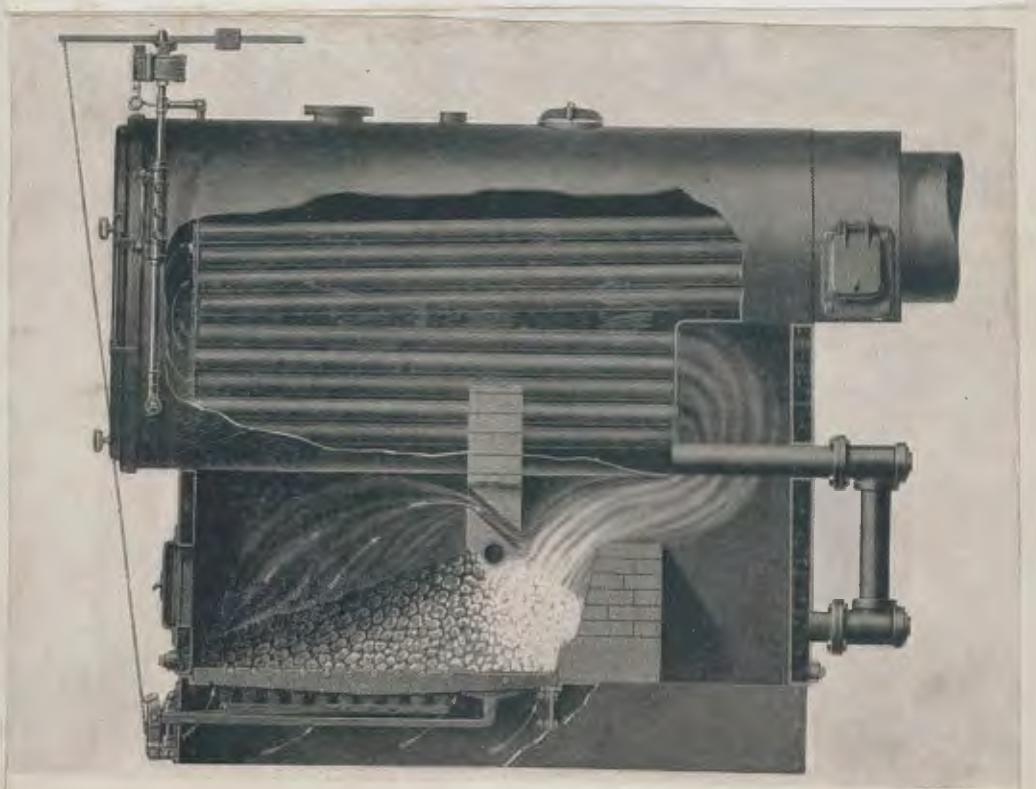
The catalogs of the manufacturers whose products are described in this book cover every prominent make of mechanical stoker. You can have any of these catalogs—without cost or obligation—by writing to the manufacturers whose addresses appear on the first page.



Smokeless operation is obtained in *this* Boiler by introducing heated air over the fire.



Pacific Down Draft Boiler for Burning Soft Coal Smokelessly



Pacific Smokeless Steel Boiler for Burning Soft Coal Smokelessly.


KEWANEE
PORTABLE SMOKELESS
FIREBOX BOILER


KEWANEE

Diagram of air travel

Diagram of air travel

a or coal.

Sectional view showing efficient combustion in 27-inch series

Sectional view showing efficient combustion in 40-inch series

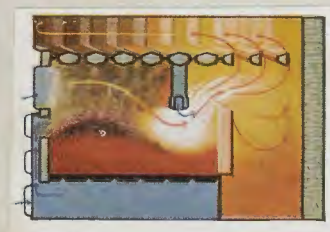


Diagram of air travel

Sectional view showing efficient combustion in 50-inch series

Sectional view showing efficient combustion in 20-inch series

SPECIAL SMOKELESS BOILER

Burns Soft Coal Smokelessly

IDEAL RED JACKET BOILER FOR SOFT COAL

THE Ideal Red Jacket Boiler (sizes 2, 3, 4 and 5) is available also with the famous Ideal Smoke Oxidizer for the burning of any grade of soft coal. The operation of this simple, perfected device is explained below. It is water-backed throughout, and cannot burn out.

The Ideal Red Jacket Boiler for soft coal does not require any special degree of skilled attendance. It is easily fired and cared for, assuring satisfactory service with ordinary attention.

How the Ideal Smoke Oxidizer Operates

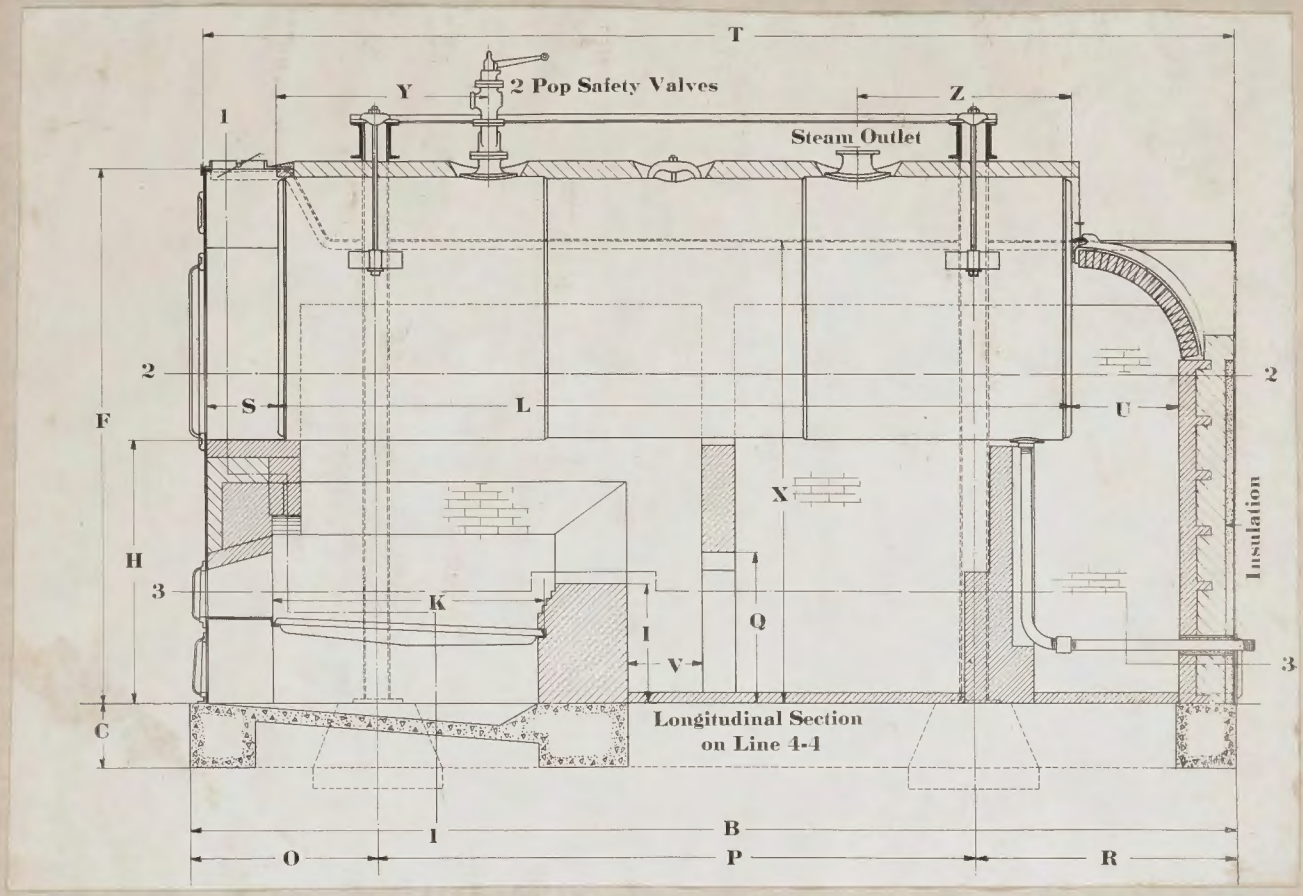
A Black volatile matter from the soft coal, driven off by the heat of combustion, in which are suspended the countless smoke-making particles of carbon.

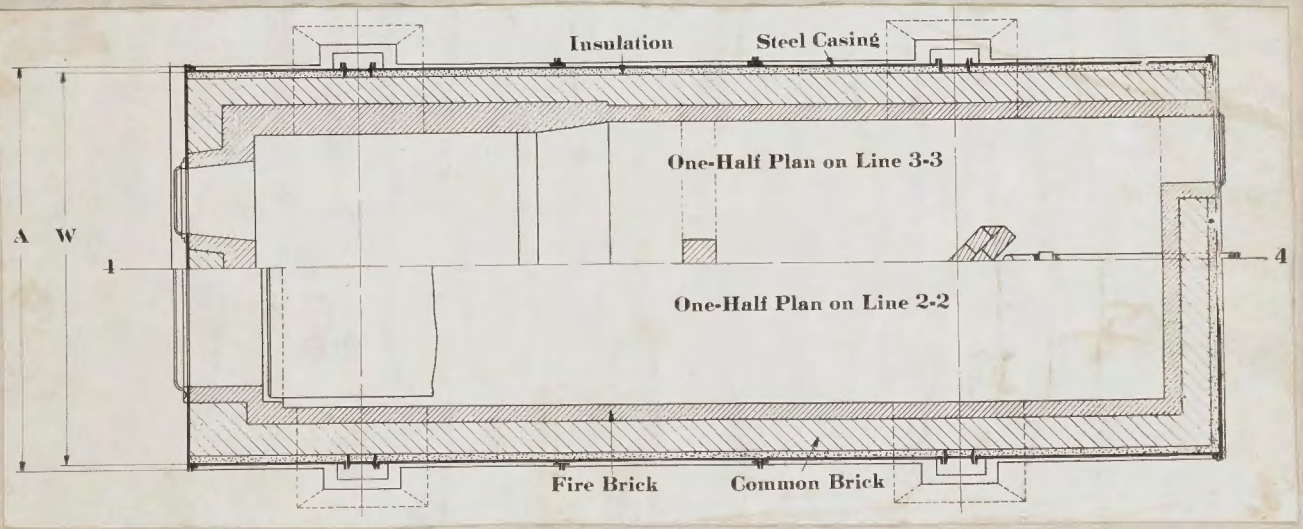
B Ideal Smoke Oxidizer—supplies the required amount of oxygen to the volatile matter in such a way as to effect a thorough, compressed and combustible mixture.

C Mixing channel—here the volatile matter and secondary air supply are thoroughly mixed and ignited.

D Secondary gas chamber into which the ignited mixture bursts with an intensely hot flame. In the heat of this flame the carbon particles are completely burned to the colorless gas, carbon dioxide CO^2. Thus smokeless performance is accomplished, and the latent heat of the smoke, instead of passing up the chimney, is utilized for practical service.

SECTIONAL VIEW OF IDEAL RED JACKET SMOKELESS BOILER


T
Y
2 Pop Safety Valves
Z
1
Steam Outlet
2
S
L
U
2
F
X
Insulation
H
3
K
Q
I
V
3
C
Longitudinal Section
on Line 4-4
I
B
O
P
R


Insulation
Steel Casing
One-Half Plan on Line 3-3
A
W
1
4
One-Half Plan on Line 2-2
Fire Brick
Common Brick

Smoke Abatement Ordinance

ORDINANCE No. 27

Passed on Second and Final Reading, March 13, 1928.
Minute Book No. 12,
Page No. 141.

CITY OF KNOXVILLE,
TENNESSEE

388

The Smoke Nuisance
and its
Abatement

HOW YOU CAN HELP
TO ELIMINATE IT

KNOXVILLE, TENN.

428

77.

ACKNOWLEDGMENT

I wish to express my appreciation to Professor W. R. Woolrich and to Mr. F. L. Wilkinson Jr. for the able assistance which they have rendered and for much valuable information they have contributed toward making this paper possible.

Thoughts and ideas have been gained through various sources and the writer has attempted to give full credit within this paper for all such material, but in many cases specific references could not be given. I wish to take this opportunity to give general acknowledgment for the use of any such outside material, including the cuts and diagrams in the appendix.

W. B. Chapman

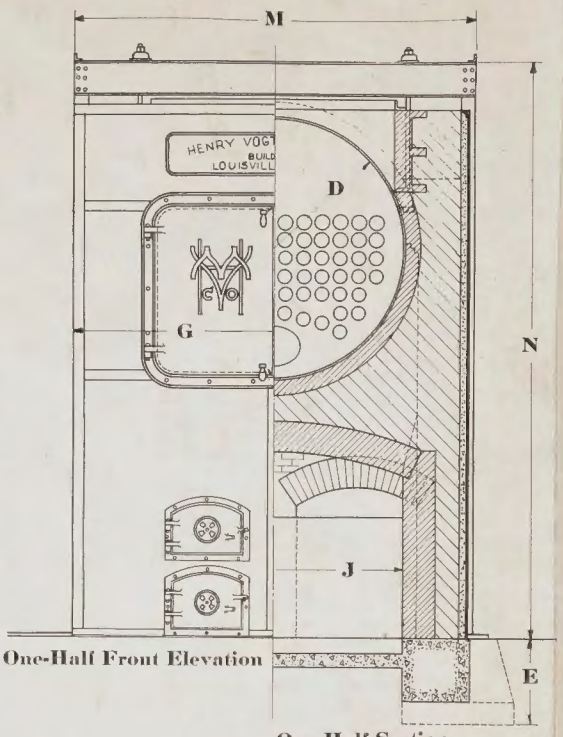
APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degrees for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn herein, but approves the thesis only for the purpose for which it is submitted.

Name W.R. Woolrich

Title Prof. Mech. Eng.

DIAGRAM OF STEEL ENCASED SETTINGS EQUIPPED WITH VOGT PLAIN GRATES



One-Half Front Elevation

One-Half Section on Line 1-1

REMARKS:

Detail Drawing of Boiler Settings are furnished with all Contracts.

The Square Feet of Grate Surface given is for Bituminous Coals, and may be varied according to kind of Fuel used.

Foundations may be varied according to bearing value of soil, if less than 1¼ to 1½ Tons per Sq. Ft.

Quantities of Brick given, are approximately correct only and may vary 1½ to 2½ per cent.

Setting Dimensions for Vogt Standard H. R. T. Boilers.

13″ Walls, 2″ Insulation — A. S. M. E. Construction

BOILER				FOUNDATION				FRONT		GRATES			SUSPENSION		SETTING												OUTLETS				BRICK			
SIZE, HORSE POWER	DIAMETER	LENGTH	FLOOR TO BOILER	TOTAL WIDTH	TOTAL LENGTH	DEPTH	DEPTH FOR COLUMNS	HEIGHT	WIDTH	WIDTH	LENGTH	SURFACE, SQ. FT	WIDTH	HEIGHT	FRONT TO COLUMN	COLUMN TO COLUMN	COLUMN TO REAR	EXTENSION DEPTH	TOTAL LENGTH	RETURN ARCH DEPTH	FLOOR TO BRIDGE WALL	FLOOR TO ARCH	BRIDGE WALL TO ARCH	TOTAL WIDTH	HEIGHT	SAFETY		STEAM		BEST GRADE FIRE BRICK	SECOND GRADE FIRE BRICK	COMMON BRICK	INSULATION SQ. FT. OF 2″ THICK
																										FRONT HEAD TO CENTER LINE	DIAMETER OF VALVES	REAR HEAD TO CENTER LINE	DIAMETER OF NOZZLE				
	D	L	H*	A	B	C	E	F	G	J	K		M	N	O	P	R	S	T	U	I	Q	V	W	X	Y		Z					
38	48″	12′-0″	6′-0″ Setting	7′-2″	17′-0″	18″	24″	10′-3″	7′-3½″	4′-0″	3′-6″	14	7′-3½″	11′-1″	3′-4″	7′-10″	5′-4″	15″	16′-6″	24″	3′-9″	4′-0″	2′-9″	7′-0″	9′-5½″	3′-1″	1½″	3′-1″	3″	1614	2256	6226	370
44		14′-0″			19′-0″						4′-0″	16			3′-6″	9′-6″	5′-6″		18′-6″							3′-7″	1½″	3′-7″	3″	1752	2430	6766	408
59	54″	14′-0″		7′-8″	19′-2″	18″	24″	10′-9″	7′-9½″	4′-6″	4′-0″	18	7′-9½″	11′-7″	3′-8″	9′-6″	5′-6″	17″	18′-8″	24″	3′-6″	4′-0″	2′-9″	7′-6″	9′-9½″	3′-9″	2″	3′-9″	3½″	1846	2616	7156	485
67		16′-0″			21′-2″						4′-6″	20½			3′-8″	11′-6″	5′-6″		20′-8″							4′-3″	2″	4′-3″	3½″	1990	2796	7714	475
81	60″	16′-0″		8′-2″	21′-6″	18″	24″	11′-3″	8′-3½″	5′-0″	4′-6″	22½	8′-3½″	12′-2″	3′-9″	11′-6″	5′-9″	18″	21′-0″	27″	3′-3″	3′-9″	3′-0″	8′-0″	9′-10″	4′-4″	2½″	4′-4″	4″	2093	3050	8103	486
92		18′-0″			23′-6″						5′-0″	25			3′-9″	13′-6″	5′-9″		23′-0″							4′-10″	2½″	4′-10″	4″	2237	3244	8659	525
98	66″	16′-0″		8′-8″	21′-7″	18″	24″	11′-9″	8′-9½″	5′-6″	4′-6″	24½	8′-9½″	12′-9″	3′-10″	11′-6″	5′-9″	19″	21′-1″	27″	3′-3″	3′-9″	3′-0″	8′-6″	10′-3″	4′-4″	3″	4′-4″	5″	2216	3283	8709	516
110		18′-0″			23′-7″						5′-0″	27½			3′-10″	13′-6″	5′-9″		23′-1″							4′-10″	3″	4′-10″	5″	2366	3481	9247	558
98	66″	16′-0″		8′-8″	21′-7″	18″	24″	12′-9″	8′-9½″	5′-6″	5′-0″	27½	8′-10″	13′-9″	3′-10″	11′-6″	5′-9″	19″	21′-1″	27″	3′-9″	4′-6″	3′-0″	8′-6″	11′-3″	4′-4″	3″	4′-4″	5″	2502	3629	9480	567
110		18′-0″			23′-7″						5′-6″	30½			3′-10″	13′-6″	5′-9″		23′-1″							4′-10″	3″	4′-10″	5″	2672	3837	10112	613
124	72″	16′-0″	7′-0″ Setting	9′-2″	21′-11″	18″	24″	13′-3″	9′-3½″	6′-0″	5′-6″	33	9′-4½″	14′-4″	3′-11″	11′-6″	6′-0″	20″	21′-5″	30″	3′-9″	4′-3″	3′-0″	9′-0″	11′-7″	4′-2″	3″	4′-2″	5″	2635	3422	9668	597
140		18′-0″			23′-11″						6′-0″	36			3′-11″	13′-6″	6′-0″		23′-5″							4′-10″	3″	4′-10″	6″	2811	4724	10232	643
157		20′-0″			25′-11″						6′-6″	39			3′-11″	15′-6″	6′-0″		25′-5″							5′-5″	3½″	5′-6″	6″	2991	4966	10852	687
173	78″	18′-0″		9′-8″	24′-1″	18″	24″	13′-9″	9′-9½″	6′-6″	6′-0″	39	9′-10½″	15′-0″	4′-1″	13′-6″	6′-0″	22″	23′-7″	30″	3′-6″	4′-3″	3′-3″	9′-6″	11′-11″	4′-9″	3½″	4′-9″	6″	2920	5505	10208	674
192		20′-0″			26′-1″						6′-6″	42½			4′-1″	15′-6	6′-0″		25′-7″							5′-4″	3½″	5′-4″	6″	3104	5825	10876	721
206	84″	18′-0″		10′-2″	24′-3″	18″	24″	14′-3″	10′-3½	7′-0	6′-0′	42	10′-5½″	15′-7″	4′-3″	13′-6″	6′-0′	24″	23′-9″	30″	3′-3″	4′-0″	3′-6	10′-0′	12′-5′	4′-9″	4″	4′-9″	6″	3032	6343	10524	711
227		20′-0″			26′-3″						6′-6″	45½			4′-3″	15′-6″	6′-0′		25′-9″							5′-4″	4″	5′-4″	6″	3218	7819	10760	760

*This dimension on all boilers is 1½″ less at rear end of shell.

DIRECTIONS FOR FIRING SOFT COAL

Approved by Bureau of Smoke Regulation
CITY OF KNOXVILLE

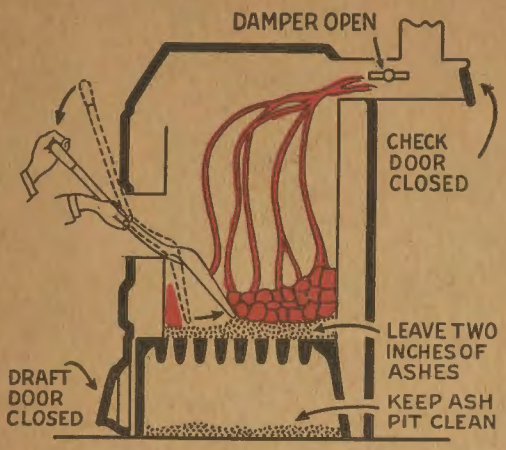


Fig 1.—Close the draft door and check door and see that damper is open. Shake down the ashes so as to leave a layer about two inches thick on the grate. Empty the ashpit. Then take your empty shovel and stick it down into the front of the fire bed, down to the top of ashes as shown above. Keep ashpit clean.

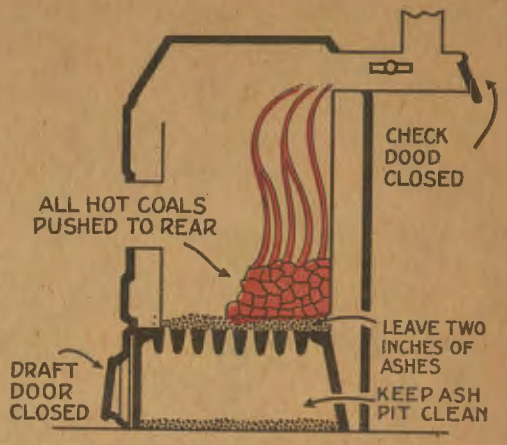


Fig. 2.—Move the whole fire bed back to the rear of the furnace, thus making a big hole at the front, Do not disturb the ashes any more than necessary. For best results always leave two inches of ashes on the grate. Keep ashpit clean.

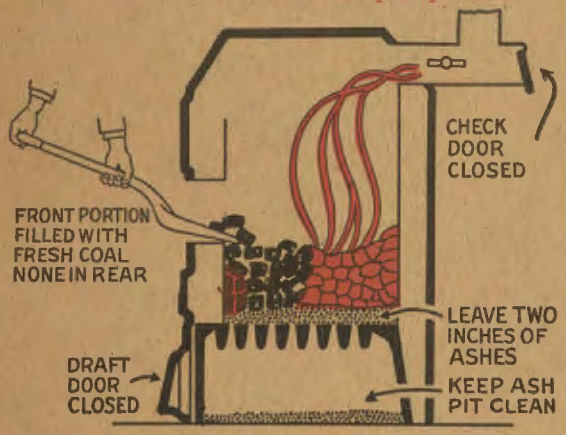


Fig. 3—Fill the hole at the FRONT of the furnace with fresh coal—small sizes are best. NEVER SCATTER the coal over the hot fuel bed. The fresh coal will begin to take fire from the hot fire at the rear. The gases from the fresh coal will be burned in passing over the hot fire in rear of furnace, producing great heat and little smoke. Keep ashpit clean.

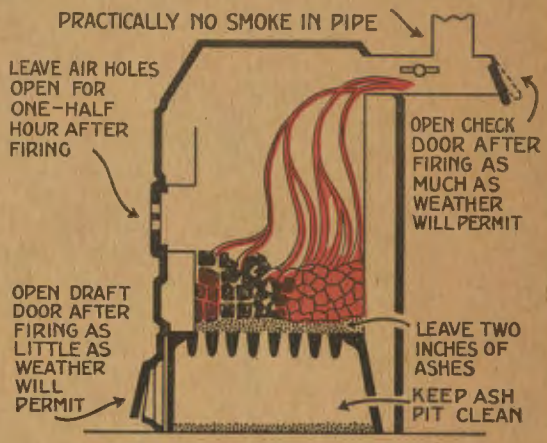


Fig. 4.—Here's what happens: Your fresh coal ignites only from the side touching the red hot coal. The fire creeps back through and over the top. The smoke gasses from the gradually warming fresh coal pass through the flame from the hot coal and are burned, producing heat which would otherwise be wasted. Keep ashpit clean.

BANKING FOR THE NIGHT.—Fire deep as above. A little fine coal or slack on top the fresh charge, but not over the red coal is desirable. Shut off drafts. Furnace size or Small Furnace size banked this way holds fire longer than Lump.

REGULATION OF DRAFT.—Most furnaces have a draft door into the ashpit, a damper within the smoke pipe, and a check door opening in the side of the smoke pipe. The draft door and the damper in the pipe are opened to permit air to pass through the furnace. The check door is opened when you wish to hold your fire (all drafts off). Its purpose is to kill the draft of air through the furnace. These must all be regulated according to weather conditions, and the requirements of each individual furnace. The more the draft of air, the faster the coal will burn. A little experimenting will soon show the proper amount of air necessary.

Follow These Instructions: Burn Smoke—Save Coal

ISSUED BY
BUREAU OF SMOKE REGULATION
CITY OF KNOXVILLE
Charts Obtainable at Office Department of Public Welfare

KEITH PRESS, PRINTERS, KNOXVILLE

Over

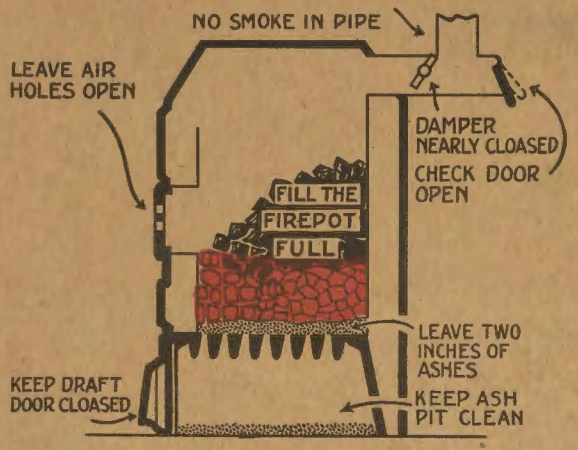
(430)

DIRECTIONS FOR FIRING COKE

Approved by Bureau of Smoke Regulation
CITY OF KNOXVILLE

There is really only one thing to be remembered to get the greatest good out of Coke, and that is BIG VOLUME OF FIRE UNDER VERY LITTLE DRAFT. Fill your fire-pot full of Coke, and as far as possible operate your furnace as shown in this diagram.

As soon as the fire is going well, fill the firepot full and open the drafts for a very few minutes. Then shut off all drafts, and open the check in the smoke flue. The check draft in the feed door should be left open as soon as the fire is under way.



It is advisable to keep about a 2-inch layer of ashes on the grate. This protects the grate irons from over-heating and also serves to help check the draft. Keep the damper in the ashpit closed, but do not allow the ashes to pile too high.

Note—No change necessary in design of furnace or grate to burn Coke.

No Smoke If You Burn Coke

Keep a large bed of fire, under check. It will require little or no attention under ordinary circumstances. With Coke it is much more economical to leave a large bed of fuel under a low draft than a small fire under a strong draft.

AT NIGHT

Fill the fire-pot, open all checks, and throw some ashes or coke screenings over the surface. This holds the fire in. You will have no trouble keeping your house warm all night, and there will be a good fire in the morning.

IN THE MORNING

Poke a few air holes above, throw on a couple of shovels of coke, open drafts, and the fire will pick up in about ten minutes. Then fill the fire-pit FULL and check.

IN SEVERE WEATHER

Leave drafts partly open until you get a large bed of fire. Then check. At noon fill the fire-pot again and again check after the new fuel is started. This mass of fire will keep your house warm in the most severe weather.

SIZE TO ORDER

Coke comes in lump and nut sizes. The nut size is recommended for base burners, steam and hot water boilers, and furnaces with small fire boxes. The lump size coke is recommended for regular furnace fuel.

Issued by
BUREAU OF SMOKE REGULATION
Department of Public Welfare
CITY OF KNOXVILLE

T. H. HAYNES, Director **F. L. WILKINSON, Jr., Chief Engineer**

DEPARTMENT OF PUBLIC WELFARE
Bureau of Smoke Regulation
KNOXVILLE, TENN.
SUPERVISOR'S REPORT

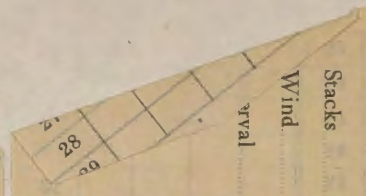
Date .....
Supervisor .....

Railroad ..... Engine No. ..... Location .....
Service ..... Pops ..... Blower .....
Running ..... Standing ..... Wind .....
Weather ..... Point of Observation .....
Observation Began ..... Smoke Prevention Device .....

Remarks

Record Sheets for Taking Ringlemann's Chart Readings

When these readings are sent to the violators they are transferred to the type of sheets used in this paper for showing the record of the observations.



DEPARTMENT OF PUBLIC WELFARE
Bureau of Smoke Regulation
KNOXVILLE, TENN.
SUPERVISOR'S REPORT

Date .....
Supervisor .....
Observation Began ..... Fuel .....
Name ..... Address .....
Stacks ..... Point of Observation .....
Wind ..... Weather .....
...rval ..... Smoke Prevention Device .....

Remarks