THE SMOKE PROBLEM

by

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KNOXVILLE'S GREATEST HANDICAP

The Smoke Problem

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PREFACE

The loss caused by smoke runs into millions of dollars in every city of any size, not in the waste of fuel alone but in the damage to goods in stores, property, destruction of vegetation, and in necessitating excessive cleaning and laundry bills as well, and in the ruinous effect upon health.

The elimination of smoke involves a study of combustion which is distinctly an engineering problem. The process of combustion is a simple one , but in practice the complete combustion of the fuel, resulting in the elimination of smoke , tends to complicate the process.

Naturally there is the objection that it cannot be done. The public must be aroused and educated to eliminate smoke.

A.H.C.

University of Tennessee
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January , 1938

THE SMOKE PROBLEM

INTRODUCTION

The pollution of the atmosphere has become a serious problem in the operation of our cities. The increase of the smoke nuisance in the United States has followed directly with the progress of industrial development. When towns were small, the smoke nuisance was not known, but as cities grew, a concentration of homes and buildings resulted, and there followed a tremendous increase of fuel used as a source of power and heat.

The nuisance of smoke was complained of and legislated against as early as the time of Edward I, who believed that smoke affected his health. He issued proclamations forbidding the use of coal while Parliament was in session.

During the last century the smoke problem has become more acute because of the enormous increased consumption of coal and the concentration of factories and homes. The smoke nuisance is a nuisance, 80% of which can be prevented practically, and in some instances a higher percentage can be reached.[1]

1. Smoke Abatement. Nickolson.

A proportion of the physical degeneracy of the human race, of which so much has been said, is directly traceable to the constant inhalation of impure air, and the nuisance is on the increase. [1] The amount of sunlight, which is of such great importance to our health and also to the growth of plants, is greatly reduced by the presence of smoke.

It is expensive to the owners of the furnace without considering the immense damage done by smoke. The waste of fuel alone, that is, the smoke that goes up the chimney is unburned fuel, costs Knoxville hundreds of thousands of dollars every year. Wasting unburned fuel is robbing the natural resources of the world and some day coal may be scarce. " The index of civilization is not the extent of the usage of natural resources but rather the degree of their efficient application." [2]

The question will arise " Will it pay to prevent smoke ?" " It costs money to make smoke". [3] The presence of smoke is a great menace to the health of the citizens and the cost of its prevention cannot be compared with its value in dollars.

" The huge and ever-increasing cities, the vast manufacturing towns belching forth smoke and posionous

1 Smoke Abatement. Nickolson
2 Smoke Abatement. Azbe

gases, with the crowded dwellings where millions are forced to live under the most terrible unsanitary conditions, are witness to a criminal apathy, an incredible recklessness and inhumanity. Yet this is one of the great and primary essentials of a peoples health and well being, to which everything should for the time be subordinate." [1]

Effect of Smoke as a whole.

Smoke interferes with the welfare of a community. The general effects of a smoky atmosphere are;

1. By conducing to the formation of fogs and rain.

3. By shutting out the sunlight and depriving certain qualities of light of great importance in regard to changes in organic matter.

3. By depositing soot and rendering houses and their contents dirty.

4. The acid content of smoke and the irritating particles suspended in it are harmful to the tissues of the nose, eyes, and especially the lungs and air passages whether these be in a health condition or not.

5. " A menace directly to the sick of the community. It aggravates to the discomfort of those suffering from all forms of heart trouble, increases the distress of those who are nervous, lowers the tone of general health, is a peril to the aged, diminishes buoyancy of spirit as w

1. Man's Place in the Universe. Russell Wallace.

as well as reducing still further an already lower resistance to disease." [1]

"Smoke has not merely taken the natural beauties of tone and color from our every outlook, but it has entered the chimney as wasted fuel and left it as a destroyer of property. In short, the smoke from the beginning to the end, throughout all phases of its baneful existence, takes from the pleasure, and adds to the labor as well as to the cost of living." [3]

Besides this enormous loss as fuel and damage, all sorts of valuable by-products are obtained by converting the coal into the smokeless fuels, coke and gas. Coal tar is obtained which is the source of endless valuable products as dyes, medicines, fertilizer, and explosives. All these products are worth many times than the mere making of fuel, which is all they are worth when burned as constituents of raw coal.

z With the smoke in the air, on our clothing and skin, in our lungs, and on the streets and buildings calling our attention to the tremendous "cost" both to health and money, the prevention of smoke should be a subject of vast importance and deserves the serious consideration and efforts of every citizen.

1 The Influence of Smoke on Health. Mellon #9
3 The Effect of Smoke on Building Materials. Mellon #6

The cities all over the country to-day are coming to realize that the smoke nuisance is the greatest handicap with which they have to contend.

"Smoke is matter in the wrong place".

PSYCHOLOGICAL ASPECTS OF THE PROBLEM OF ATMOSPHERIC SMOKE POLLUTION. [1]

1. The injurious organic effects exerted by smoke on human beings are both direct and direct. The direct effects are due to the injury caused by smoke content themselves, while the indirect effects arise from the meteorological changes produced by atmospheric smoke.

2. The mental effects of smoke and smoke produced weather states are likewise both direct and indirect. The indirect effects issue from bodily changes produced by smoke or smoke produced weather states, while the direct effects are due to influences of the mind's own states upon its subsequent thoughts, disposition and conduct.

3. Smoke fills the atmosphere with acrid, poisonous compounds and soot particles which may serve as carriers of the obnoxious products of human fatique, which irritates the sensitive membranes of the eyes, nose, throat, lungs, and gastro-intestinal tract, increase the susceptibility to gastro-intestinal, pulmonary, naso-pharyngeal disorders, diminishes the potential reserve, increase fatique, irritability and malcontent, and may tend to hasten premature decay.

1 Psychological Aspects. Mellon #3

4. Smoke lessens the duration and intensity of sunshine, reduces the intensity of daylight, the limit of visibility and the diurnal winter temperature; increases humidity, mists, the frequency and duration of fogs, and possibly alters the electrical potential.

5. Sunshine is an important bio-dynamic agent. It promotes anabolism, transpiration and perspiration, amd increases the percentage of hemoglobin. The blue and ultra-violet rays of sunshine exert a bactericidal effect on pathogenic bacteria, and a tonic vitalizing influence upon the human organism. Sunshine exerts an ebuberant influence on the feelings. Moreover, colorless daylight is superior for visual efficiency, optical health and affective quality.

6. Dark clouds have a depressing, devitalizing effect. They may cause fear in childmen, reduce working efficiency, and labor returns; give rise to eye strain, dioptric disorders; give rise to disquietude, restlessness and forebodings in the insane; and may increase drunkeness.

7. Humidity increases the solid, poisonous, bactericidal contents of the air, aggravates varbous pathological conditions of the body, reduces the sensitivity of some sense organs and depletes the vital potential.

Fogs, in addition, decrease the accuracy of mental work, increase the prevalence of diseases, and augment the death rate.

8. Clear, dry days are anabolic in character and thus produce a superabundance of energy. While this may lead , as statistics seem to show, to an increase of school misdemeanors, assaults, suicides and arrests for drunkenness in emotionally and nervously unstable individuals, it also tends to energize the human organism, augment its functional efficiency and enchance its achievement capacity. Negatively the data seem to indicate that smoky weather states (just because they deplete energy and thereby inhibit action) lessen rather than increase crimes of violence.

9. Smoke clouds are inimical to the highest aesthetic development of urban communities. They seriously limit not only the possibilities of municipal art, in respect to architecture, statuary, painting, and ornamental gardening, but also limit the possibilities of art education in the community in question. They begrime, deface, discolor, destroy and corrode interior and exterior artistic effects in color, brick, stone, marble or metal. They befoul the persons as well as the dress of t the inhabitants, limit the range of wearing apparel, and may foster habits of indifference. They obliterate the natural terrestrial panorama of art, the iridescent clouds

of the sky. Because of the murky, abject inartistic appearance of these cities, they are avoided by the wealthy tourists and the retired person of wealth who is in search of a desirable place of residence.

INFLUENCE OF SMOKE HEALTH

From statistical and experimental studies dealing with the smoke evil, Ascher[1] has given the following conclusions;

1. The mortality of acute lung diseases is certainly increasing, especially among children and old people. The cause of this increase is attributed to the impurification of the air by smoke because, the increase is greatest in industrial centers, and not in agricultural districts. Since 1875, the mortality from such diseases among infants has increased as much as 600%.

2. Within industrial districts a difference in mortality can also be noted, the death rate from acute lung diseases, in districts with a strong smoke development being higher than in other industrial centers.

3. The mortality among miners(coal) from acute lung diseases is much higher than among other population of the same age.(135%) Here also differences can be observed in that in districts with a larger native population the mortality from acute lung diseases is a higher one than in districts where the miners have lately moved

1 Influence on Health.on Mellon # 9

from agricultural districts.

4. The conclusion that the impurification of the air by smoke causes a predisposition to acute lung diseases and hastens the course of tuberculoses.

METEOROLOGICAL EFFECTS OF SMOKE

Black smoke is as effective in cutting out the sunlight as any material known. The intensity of daylight and consequently the cost of illumination in smoky cities is increased by the smoke nuisance in two ways. (1) By absorbing the light during the passage through the atmosphere and (2) by covering the skylights, windows, and light fixtutes with a black coat of soot.

Smoke in the atmosphere acts as a filter, preventing the best part of the sun's rays from reaching us, that is, the ultra-violet rays, the greatest disenfectant known, and thus indirectly affects health.

1. In the business section of Pittsburgh the limit of visibility was found to be one tenth the limit in the open country.

2. On days when the presence of smoke or fog is recorded the chemical action of daylight is only seventy-five persent of what it is on days when no smoke or fog is recorded, the other conditions being equal.

3. On smoky or foggy days with equal hours of sunshine the chemical action of daylight is closely related to the limit of visibility.

4. There is evidence that in general the chemical

intensity of sunlight in large cities is twenty-five percent less than in small towns.

5. City fogs are more persistent than country fogs, principally because of their increased density due to the smoke that accumulates in them.

6. Twenty-five percent of the fogs are due to smoke. Fogs are precipitated from the atmosphere, which is saturated with water vapor, by the presence of smoke particles.

7. In consequence of the above there are fewer hours of sunshine in the cities than in the surrounding country.

8. The sunshine is less intense in the city than in the country, the light of short wave length, of the violet ray, suffering the greater depletion.

9. Daylight which often depends entirely upon diffused light from the sky is depleted by smoke in a greater proportion than direct sunlight.

The loss of daylight means a larger cost of artificial illumination. In the morning, while the rays of light strike the earth obliquely and consequently have to pass through a thicker layer of smoke as well as a more dense smoke cloud than they do later in the day, a larger percentage of the light is cut off than in any other

time of the day and at a period when there is the least of it.

Experiments on the amount of light passing through skylights in buildings prove that they become practically worthless, losing about eighty-five percent efficiency in a comparative short time. The same thing is true, to a smaller extent, of all windows and light fixtures. To keep them clean is costly.

It is not difficult to realize what a factor the smoke nuisance becomes in increasing the amount of artificial light in a smoky city like Knoxville.

Smoke in the atmosphere, especially when combined with moisture to produce fog, brings about a very great lowering in the daylight. At the present time a great loss of light results in large cities from the effect of smoke. A study of the decreasing light by smoke, now being made by the United States Public Health Service in New York City. At the lower end of Manhattan Island where the air is very smoky, showed, an average loss of daylight due to smoke in January 1927, on sunny days, of forty-two percent at 8 am and eighteen percent at noon. These amounts of daylight decreased as the year advanced, to thirty-three percent at 8 am, and six percent at noon in June. These figures are for clear sunny days; for foggy days the loss is much greater.

T The loss of light due to smoke in the atmosphere is greatest early in the morning and late in the afternoon and least at noon. As would be expected, the loss of light is greater in the winter than in the summer. The figures given show the great importance of getting rid of the smoke in our cities.

In December the amount of illumination on cloudy days was found to be about twenty-three percent of that on sunny days. In June this rate was about twenty-six percent. Great variations in daylight take place when small clouds pass over the sunn on a clear day. In such cases the light rays fall from nine thousand or more foot candles to three thousand or less, in one minutes time and returns to the orriginal amount durring the succeeding minute.

Large increase of light may be produced by the reflection of light from banks of white clouds to the north of the sun, and very great decreases by the heavy clouds of thunderstorms.

Sunlight is of great importance since work in the office, shop, schoolroom or on the farm is performed under it, and the preservation of eyesight, the general health and the prevention of accidents, throughout childhood and adult life are largely dependant upon having plenty of sunlight both inside and outside the buildings in which we live and work.

Loss of daylight or the light rays, is not the only evil resulting from the presence of smoke in the atmosphere; Smoke also cuts out to a much greater extent, the ultra-violet rays which are so necessary for good health.

The amount of light reaching us at different times of the day, at different times of the year and under different conditions of weather is of interest. Records of daylight in Washington have been made since July 1924 by the United States Public Health Service. These records show that at noon on a bright day at midsummer the illumination seldom exceeds ten thousand foot candles. In the midwinter at noon on a bright day it seldom exceeds three thousand five hundred foot candles. The difference in illumination on sunny and cloudy days is illustrated by the average illumination for such days in December 1934 and June 1935.

THE EFFECT OF SMOKE ON BUILDING MATERIALS

When soft coal is thrown ont the fire, the volatile matter is driven off. This consists mainly of carbon, hydrogen and oxygen and are more or less dissociated by the heat producing free carbon as soot. If the furnace is properly constructed and operated, this volatile matter will unite with the oxygen of the air and form water(as steam) and carbon dioxide. The sulfur which escapes into the atmosphere is in two different ways, some escaping into the air free, the other occluded in the soot.

Smoke consists of minute particles of carbon, together with a sticky, tarry matter, which settles and sticks to everything it comes in contact with. Domestic soot, containing as it usually does, thirty or forty times as much tar as boiler soot, is much more injurious and it is produced in at least twelve times the quantity from the same amount of coal.

The injurious effect of soot is briefly as follows:

1. It soils all substances that it comes in contact with.

2. The coal tar which it contains makes the soot adhere to anything that it comes in contact with.

3. The coal tar contains many poisonous organic

compounds.

4. The carbon has the power of adsorbing injurious gases.

5. The sulfur forming sulfur dioxide and sulfuric acid causes corrosion on everything it comes in contact with.

6. The sulfuric acid occluded in the soot is much more active in its corrosive power than that which escapes in the air-free. This is especially true where metals are concerned as galvanic action is very likely to be started. In all cases the activity is increased because of the tar content, which causes the soot to adhere firmly to anything with which it comes in contact, thus retaining the acid where it can do the most damage.

Damage to Painted Surfaces

Paint coatings serve two purposes to the surface; First, decorative or ornamental, and second, protection from decay or corrosion. Disintegration of the paint film destroys the protective and decorative qualities. Its value as a decorative coating is absolutely destroyed by smoky atmosphere.

In localities where air is free from smoke, painting is only necessary ever seven years while in smoky districts it must be painted every three years for the sake of appearance. Besides the cost of the paint and its application, after the application of several coats it begins to crack, allowing exposure of the wood for decay. It makes the use of light colors unsatisfactory on account of the short time which they retain their true color.

The action of sulphuric acid on the organic compounds as linseed oil is very destructive, while that of carbonic acid is very slow, but produces a slight effect on the paint film. The darkening of the film is due to a tarry matter and carbon and is not due to the hydrogen sulfide. The hydrogen sulfide from the coal is easily oxidized by the air and will not effect the paint surfaces only in the immediate vicinities of large quantities. This is proved by the fact that there is no sulfides found in painted surfaces.

Damage to Stone and Stonework

It is not generally thought that much of our best building stone is more rapidly weathered in the atmosphere of a smoky city than it would be in the pure country air. Stone and stonework with its granular and porous surface is very sensitive to the smoke in our atmosphere. In a

short time buildings become covered with soot and present a very bad appearance. Not only does a new building readily take on a dirty coat of soot but the greatest injury, however, is that smoke products cause stone and other building materials to crumble and decay. The tar and soot which remains in contact with the surface holds the acids in contact with the material until the action is complete. The stone becomes porous, loses its cohesion and disintegrates with much greater ease under the action of the weather.

Mortar, on account of its rather porous structure and because it in process of chemical change for some time after it is placed in the wall, is especially subject to the action of the acids in the atmosphere. This causes the mortar to swell and become more porous so that it weathers and falls to pieces more readily.

The smoke and associated products of combustion are injurious to stone in two ways;
First, The soiling of the surface, so that in the course of a few months all the stone takes on the same grey, grimy color. This means either the loss of all artistic effect that may have been obtained by color contrast, or the frequent cleaning of the building, which is an additional expense and at the same time aids in the destruction of the stone.

Second, The actual destructive action on all stones by the acid products of the combustion of the coal. All material containing calcium or magnesium carbonates, as limestone, sandstone, and mortar, are readily disintegrated by the sulfuric acid.

The Damage to Metallic Surfaces.

The damage done to metallic surfaces by smoke and its associated products of combustion is in two ways; First, the soiling of the surface, and second, the Chemical action.

When soot and tar are deposited on metallic surfaces, its removal is a serious matter. In order that it be removed, the surfaces must be scoured, and this of course, is injurious to the metal as the surface is abraded to some extent. Even if the layer of soot did not contain corrosive acids and would act as a protective coating, the coating would not by any means be uniform and where the metallic surfaces are intended to be decorative the effect is entirely destroyed by the deposit of soot and tar.

The destruction of the metallic surfaces by the action of the acids deserves considerable attention especially in localities where the air contains much of this corrosive agent. Cases are known where the iron work has been eaten away to such an extent as to endanger the structure. This possibility will seem reasonable when the amount of acid in the atmosphere is considered. Finely divided carbon has the power to absorb gases to a high degree. This makes it

possible to retain a large amount of the corrosive acids. The carbon is continually absorbing more corrosive substances from the air as well as retaining moisture thus being a tremendous factor in the destruction of metals. The tar holds the soot and acids close in contact to the metallic surface, giving a much better chance for corrosion than if the acids were allowed to be dissolved by rain water and to come in contact with the metal. The acid in the rain water drains off rapidly and large amounts of rain wash the acid away, while the soot and tar hold the acid where it can react and is used up.

The rapidity and completeness of the corrosion by this method is further aided by the fact that carbon is an electro-negative element, while the metals are electro-positive. This causes galvanic action to take place in the presence of water and acids. Observations of metals have shown that corrosion occurs six times as fast in city air and ten times as fast in wet smoky places as in pure country air. Inquiries as to the effect of smoke on metallic surfaces and the length of their life have shown that in smoke free cities the metals last approximately twice as long as in smoky cities.

The Damage Done to The Interior of Buildings.

Fine soot will go almost anywhere air does, and on account of its tarry substances it sticks to everything

that it touches. The damage done to the interior is mainly destroying the appearance and increasing the cost of keeping it clean. White paint, one of the most desirable interior decorations, is subject to limitations on account of smoke. The use of darker colors for the interior adds to the increased cost of artificial light. Investigation has shown that white paint will last about twice as long in a clean city for interior work as in a smoky city. Wall paper is the most common material on which the effect of smoke shows. Not only is the life of the wall paper shortened, but it makes it necessary to be cleaned often in smoky cities. The savings that would result from the elimination of smoke would be one of the big items to decrease the cost of living and add to the more cheerful appearance of the interior of the home.

It is thus very evident that the smoke damages the interior of buildings, detracts from the appearance of the finished work and imposes many restrictions on the architect and decorator in the expression of their arts.

Smoke in the atmosphere, then, damages building materials in several ways;

Light colored paints for both interior and exterior surfaces in smoky cities are limited.

In the use of natural stones the limitations take a more material form than the merely soiling of the surface.

All stones containing calcium or magnesium carbonates, as limestone, and sandstone are readily disintegrated by the sulphuric acid.

The life of most metallic surfaces suffer the most and the protective coating must be renewed more often than in cities of a purer atmosphere.

SOURCES OF THE SMOKE NUISANCE

The smoke within the city limits of Knoxville may be attributed to

1. The business section
2. Manufacturing plants
3. Railroads
4. Homes and apartments

The Business Section

There is probably no section of the city in which causes more inconvenience and loss, besides affecting so many people, as does that made by the heating plants of office buildings and stores in the business district. The smoke which comes from the smaller buildings is carried directly into the windows of the surrounding buildings, causing inconvenience and loss both to the occupants and to the people on the streets from the smoke and soot fall. It so happens that the business section is one of the sections having a high rate of soot fall, thus affecting more people and is where it can do the most damage.

Railroads

The second most important source of smoke to the city is the railroads. The railroads burn over 25% of the bituminous coal produced in this country. The railroads, no doubt, contribute a large part of the smoke to our cities.

The smoke from this source is more objectionable on account of the low levels from which it is emitted. On this account the amount of damage done by railroad smoke is a higher percentage of the damage done by smoke from all sources than this smoke is of the total smoke produced.

Most of the smoke made by the railroads is the smoke made in the yards by switch engines. Contrary to popular opinion, a locomotive on a hard pull does not ordinarily give off as much smoke as one standing still.

Manufacturing Plants.

The smoke made by manufacturing plants constitute a large part of the smoke nuisance in Knoxville. A large number of these plants are either close to the business district or to the residental section, causing an inconvenience and nuisance to both, and to the city as a whole.

In general, it seems that the nearer the plants are to the center of the city, the smokier is their method of operation which is a result of the antiquated type of equipment methods of operation.

It appears not to be unreasonable to expect at least 30% decrease in the amount of fuel used provided the proper changes be made and care be taken in the operation. The manufacturing concern naturally hesitates to remedy such conditions unless it is sure of some return

on the investment. In these plants on account of the cheapness of fuel, little attention is paid to the efficiency of the boiler plant. If the necessary changes were made and the proper care taken in the method of operation a decrease in fuel consumption would result together with the elimination of the smoke nuisance.

The Residential Section

The public has generally thought of the smoke nuisance being caused by the factories. In the contribution of smoke, the homes of the city furnish not only a suprisingly large part, but also it is of a more harmful quality than factory smoke.[1]

Factory smoke is a serious and urgent question in certain sections. Modern equipment has helped to reduce factory smoke to some extent, but on the other hand smoke from homes is on the increase and in some respects more difficult to remedy. In order to get rid of the smoke nuisance in Knoxville, the cooperation of every home is needed.

Owing to the fact that coal is burned at a much lower temperature in the home than in the factory furnace, the particles that escape as soot are not so completely burned. Smoke from private homes contains a much larger

1. "The Smokeless City -Simon"

percentage of tar than that from factories. Therefore it sticks more readily to objects with which it comes in contact and its acid character corrodes and eats away the surface.

Factory smoke tends to concentrate its damage over a smaller area and to that extent is more serious where it occurs. Domestic smoke is diffused but it is of a far more harmful quality.

CONDITIONS AT KNOXVILLE

Knoxville is located in the heart of bituminous coal fields and the coal from which, being rich in volatile matter, is difficult to burn without smoke. Knoxville is situated between two mountain ranges which reduces our wind velocity. With the many manufacturing plants, railroads and buildings producing smoke, the wind, with its low velocity, is unable to carry the smoke away. Knoxville's irregular topography confines the smoke so that it cannot be readily carried away by the winds. A study of the topography will reveal the fact that the non production of smoke is the only solution of Knoxville's smoke problem.

The many hills and valleys, frequent fogs that hold the smoke that is made, together with a low wind velocity keep the smoke long after it would have been carried away in another locality having a more regular topography.

EVIDENCE OF THE SMOKE NUISANCE IN KNOXVILLE

The Study of Soot-fall

It isn't necessary to present evidences of the smoke nuisance to those who live in Knoxville. The interesting question is as to the extent of the smoke nuisance. Much of the soot that escapes from the stacks is light and is carried considerable distance by the circulating currents in the air before finally settling. The object of this is to compare Knoxville's smoke nuisance with other cities and also to determine the sections most affected.

Methods of Determination

1. Ringlemens Chart. For particular stacks.
2. Air filtration. Inaccurate because of the large volume of air and the relative small samples.
3. Soot-fall determinations.

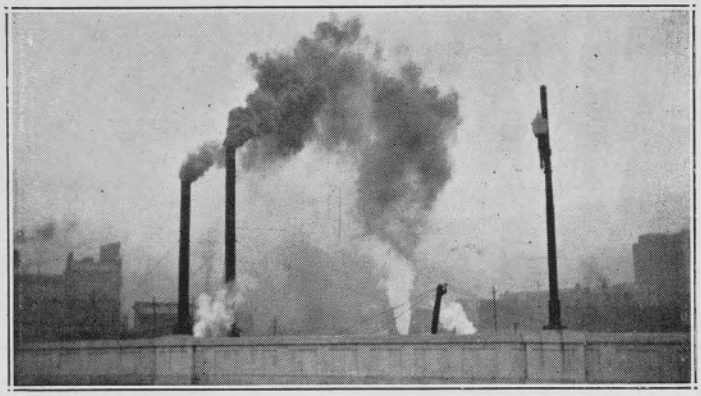
Soot-fall Determination

To determine the amount of solid matter in the atmosphere of Knoxville, its distribution and composition, 23 stations were selected in various parts of the city. A map of Knoxville was used and considered only as a geological area and stations were evenly distributed over the city disregarding any known sources of smoke, so as to

get a representative estimate of the soot-fall.

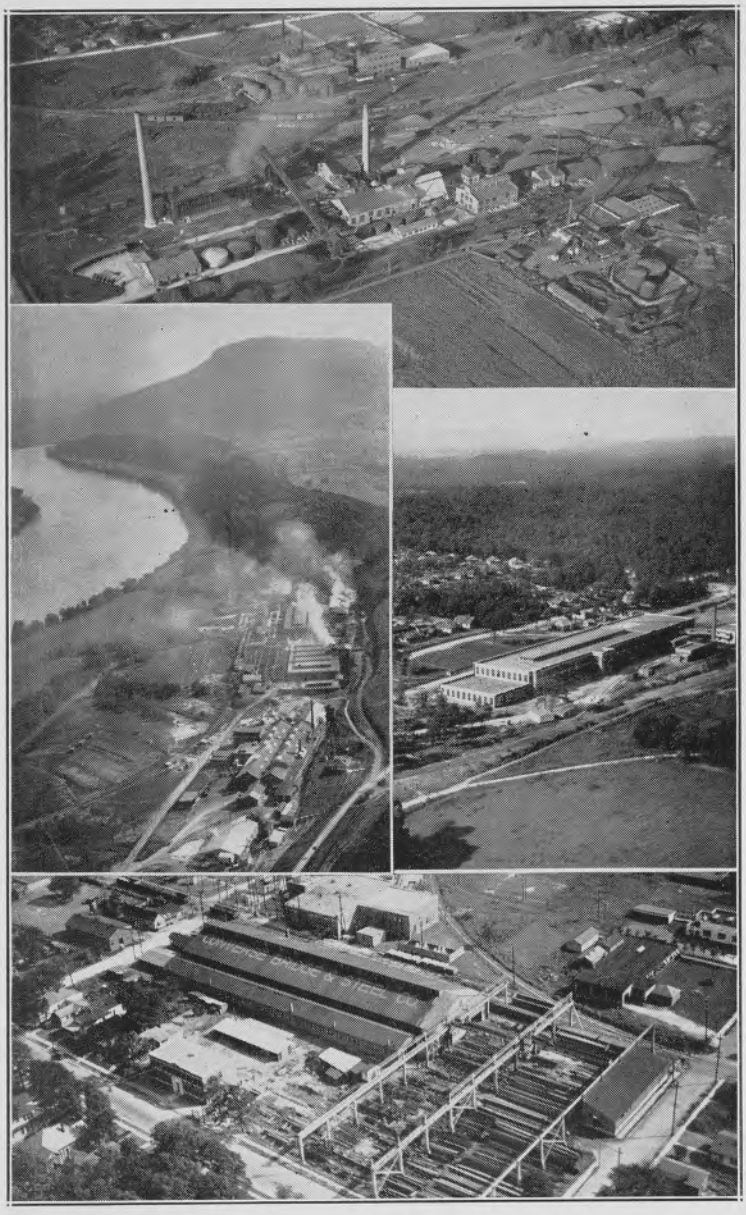
At the various stations over the city, glass jars were placed and allowed to remain for 30 days. At the end of the month these were collected and the amount of soot collected analized according to standard methods of analysis.

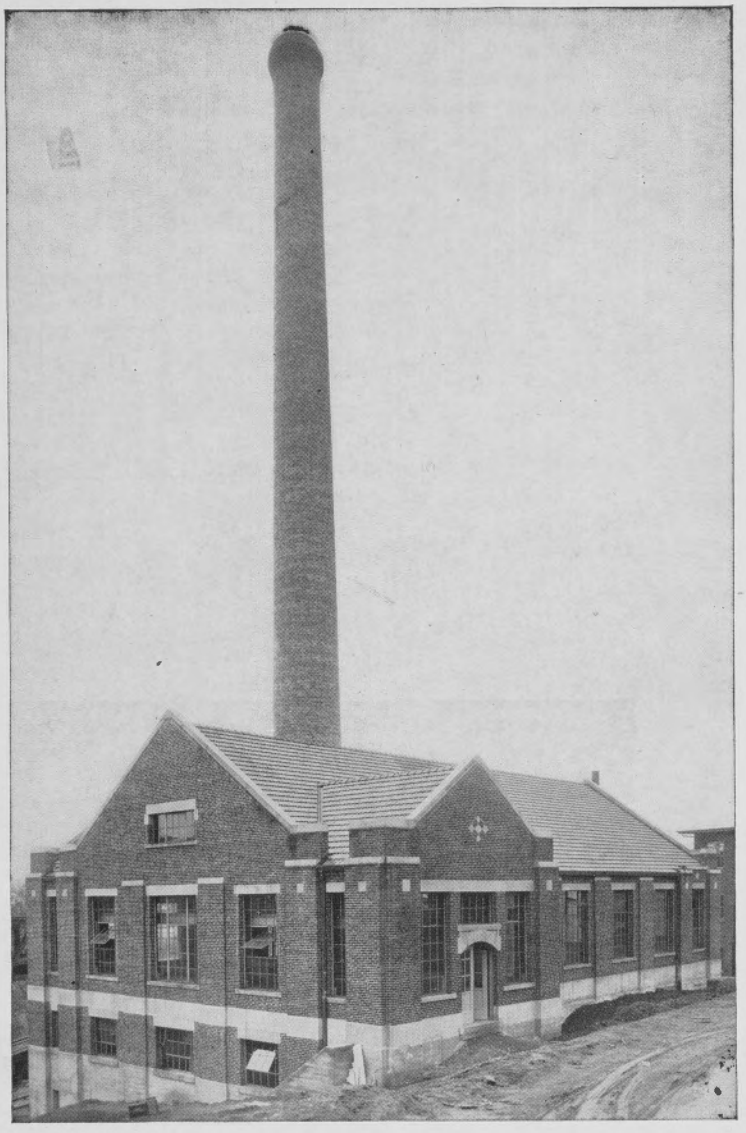
The results thus obtained, as recorded in the following tables, show that Knoxville has an average soot fall of about 275 tons per square mile per year. The highest rate of soot fall was found to be in the downtown section which includes the railroads and the business district. The next highest rate was found to be in sections near manufacturing plants. Even in the residential sections the rate of soot fall was found to be high.

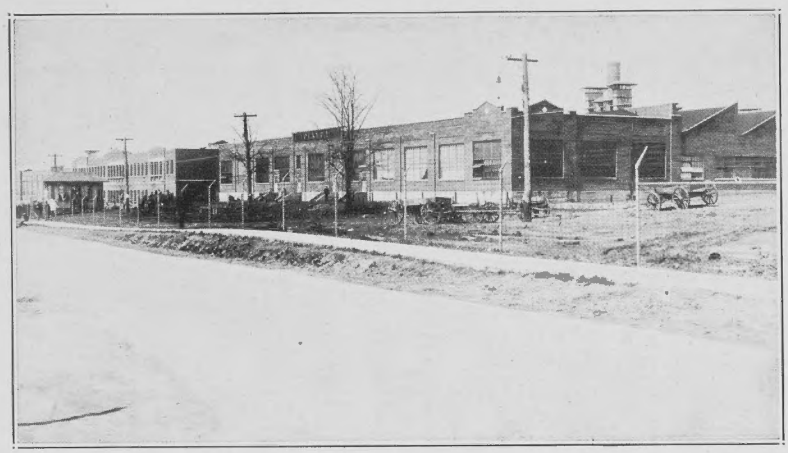


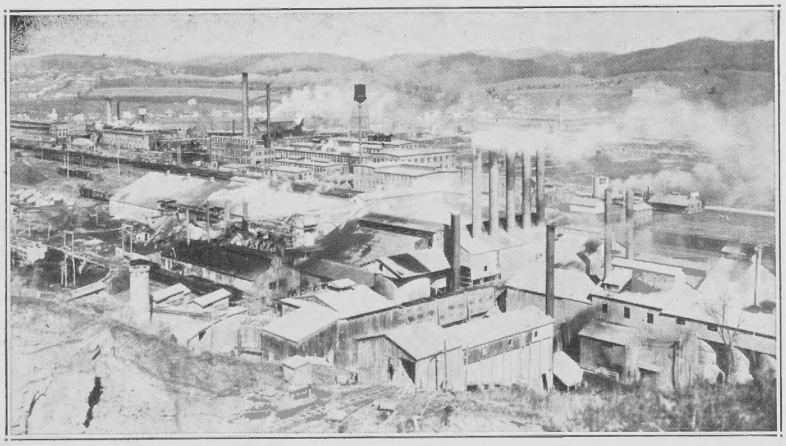



PRINTING









SMOKE SURVEY JANUARY 1927

	Tons/sq.mi./yr.	Percent Combustible
1. Baxter	237	49.7
2. Maplehurst	481	54.4
3. Atkin Hotel	780	50.1
4. U. T. Farm	213	54.3
5. Middlebrook	188	58.0
6. Magnolia Ave.	202	52.6
7. Laurel & 17th Sts.	395	51.4
8. Colored High School	465	54.9
9. Mississippi Ave.	542	45.2
10. Moses School	219	51.4
11. Beaumont School	188	51.6
12. Brownlow School	272	60.0
13. Rose Lumber Co.	287	67.9
14. Gulf Refining Co.	256	53.0
15. Texaco Refining Co.	105	47.7
16. Odgen Ave	245	59.1
17. Melrose Place	105	72.7
18. Woodlawn Pike	115	60.0
19. Deery St.	259	54.4
20. Flenniken School	168	58.2
21. Oakwood School	211	51.6
22. Lincoln Park School	198	52.6
23. Bell Morris School	155	61.4

SMOKE SURVEY FEBRUARY 1927

Station	Tons/sq.mi./yr.	Percent Combustible
1. Baxter Ave.	332	42.8
2. Maplehurst	647	31.7
3. Atkin Hotel	1044	28.8
4. U. T. Farm	227	51.3
5. Middlebrook	258	37.7
6. Magnolia Ave	251	42.6
7. Laurel & 17th Sts	375	53.3
8. Colored High School	443	34.9
9. Mississippi Ave	354	40.0
10. Moses School	220	42.1
11. Beaumont School	190	41.7
12. Brownlow School	---	---
13. Rose Lumber Co.	---	---
14. Gulf Refining Co.	188	39.2
15. Texaco Refining Co.	156	40.3
16. Ogden Ave.	264	66.3
17. Melrose Place	---	----
18. Woodlawn Pike	247	66.6
19. Deery St.	187	65.9
20. Flenniken School	345	26.4
21. Oakwood School	268	27.0
22. Lincoln Park School	331	32.3
23. Bell Morris School	199	33.2

SMOKE SURVEY MARCH 1927

Station	Tons/sq.mi./yr	Percent Combustible
1. Baxter Ave.	182	42.8
2. Maplehurst	752	59.3
3. Atkin Hotel	714	52.1
4. U. T. Farm	329	31.8
5. Middlebrook	229	28.2
6. Magnolia Ave.	256	38.2
7. Laurel & 17 th Sts	208	34.3
8. Colored High School	258	25.2
9. Mississippi Ave.	388	40.9
10. Moses School	144	38.2
11. Beaumont School	215	44.2
12. Brownlow School	173	54.5
13. Rose Lumber Co.	289	70.4
14. Gulf Refining Co.	240	23.0
15. Texaco Refining Co.	172	43.0
16. Ogden Ave.	262	55.8
17. Melrose Place	146	46.2
18. Woodlawn Pike	303	81.4
19. Deery St.	263	55.6
20. Flenniken School	240	24.1
21. Oakwood School	196	35.4
22. Lincoln Park	171	39.9
23. Bell Morris	177	49.3

SMOKE SURVEY APRIL 1927

Station	Tons/sq.mi./yr	Percent Combustible
1. Baxter Ave.	243	37.3
2. Maplehurst	188	30.1
3. Atkin Hotel	388	34.9
4. U. T. Farm	197	47.1
5. Middlebrook	220	44.5
6. Magnolia	160	39.7
7. Laurel & 17th Sts.	107	39.5
8. Colored High School	213	40.0
9. Mississippi Ave.	436	49.0
10. Moses School	155	37.9
11. Beaumont School	156	35.7
12. Brownlow School	164	37.3
13. Rose Lumber Co.	325	61.8
14. Gulf Refining Co.	482	33.9
15. Texaco Refining Co.	172	38.3
16. Ogdin Ave.	240	63.1
17. Melrose Place	95	49.2
18. Woodlawn Pike	267	54.4
19. Deery St.	196	52.6
20. Flenniken School	180	34.5
21. Oakwood School	235	38.9
22. Lincoln Park School	204	37.3
23. Bell Morris School	197	43.7

SMOKE SURVEY MAY 1927

Station	Tons/sq.mi./yr	Percent Combustible
1. Baxter Ave.	309	38.8
2. Maplehurst	292	49.3
3. Atkin Hotel	514	43.7
4. U. T. Farm	---	---
5. Middlebrook	248	48.5
6. Magnolia Ave.	---	---
7. Laurel & 17th Sts.	235	54.7
8. Colored High School	323	38.7
9. Mississippi Ave.	463	40.3
10. Moses School	143	31.0
11. Beaumont School	252	35.2
12. Brownlow School	208	39.7
13. Rose Lumber Co.	590	74.5
14. Gulf Refining Co.	269	26.7
15. Texaco Refining Co.	154	33.0
16. Ogdin Ave.	275	43.8
17. Melrose Place	192	48.3
18. Woodlawn Pike	284	62.0
19. Deery St.	---	---
20. Flenniken School	372	23.8
21. Oakwood School	221	35.7
22. Lincoln Park School	295	27.6
23. Bell Morris School	165	36.2

SMOKE SURVEY JUNE & JULY 1927

Station	Tons/sq. mi./yr.	Percent Combustible
1. Baxter Ave.	279	39.5
2. Maplehurst	173	39.0
3. Atkin Hotel	396	27.3
4. U. T. Farm	---	---
5. Middlebrook	124	46.0
6. Magnolia Ave.	200	31.5
7. Laurel & 17th Sts	94	38.0
8. Colored High School	1791	40.0
9. Mississippi Ave.	377	24.1
10. Moses School	---	---
11. Beaumont School	---	---
12. Brownlow School	134	34.8
13. Rose Lumber Co.	216	62.3
14. Gulf Refining Co.	306	27.7
15. Texaco Refining Co.	95	34.3
16. Ogdin Ave.	465	71.7
17. Melrose Place	70	44.7
18. Woodlawn Pike	149	57.5
19. Deery Street	459	45.2
20. Flenniken School	264	30.1
21. Oakwood School	137	26.3
22. Lincoln Park School	151	33.3
23. Bell Morris School	186	36.5

* June and July determined together.

SMOKE SURVEY AUGUST 1927

Station	Tons/sq.mi./yr.	Percent Combustible
1. Baxter Ave.	239	39.4
2. Maplehurst	189	34.2
3. Atkin Hotel	418	36.7
4. U. T. Farm	186	38.0
5. Middlebrook	161	40.7
6. Magnolia Ave.	178	35.3
7. Laurel & 17th Sts.	119	38.8
8. Colored High School	244	37.5
9. Mississippi Ave.	420	29.6
10. Moses School	140	34.5
11. Beaumont School	172	38.9
12. Brownlow School	142	40.4
13. Rose Lumber Co.	238	64.2
14. Gulf Refining Co.	324	24.0
15. Texaco Refining Co.	142	35.7
16. Ogdin Ave.	251	41.5
17. Melrose Place	81	47.5
18. Woodlawn Pike	162	53.0
19. Knoxville High School	204	47.6
20. Flenniken School	198	35.0
21. Oakwood School	184	32.8
22. Lincoln Park School	176	29.7
23. Bell Morris School	181	38.9

SMOKE SURVEY SEPTEMBER 1927

Station	Tons/sq.mi./yr	Percent Combustible
1. Baxter Ave.	288	41.2
2. Maplehurst	219	37.8
3. Atkin Hotel	456	38.9
4. U. T. Farm	227	41.9
5. Middlebrook	208	43.6
6. Magnolia Ave.	165	30.4
7. Laurel & 17th Sts.	150	36.2
8. Colored High School	291	41.8
9. Mississippi Ave.	379	34.3
10. Moses School	172	29.8
11. Beaumont School	218	34.4
12. Brownlow School	167	36.8
13. Rose Lumber Co.	271	56.9
14. Gulf Refining Co.	293	27.2
15. Texaco Refining Co.	161	37.6
16. Ogdin Ave.	268	48.7
17. Melrose Place	88	49.7
18. Woodlawn Pike	184	59.3
19. Knoxville High School	228	52.9
20. Flenniken School	236	29.8
21. Oakwood School	215	37.6
22. Lincoln Park School	188	33.8
23. Bell Morris School	194	34.7

SMOKE SURVEY OCTOBER 1927

Station	Tons/sq.mi./yr.	Percent Combustible
1. Baxter Ave.	214	44.9
2. Maplehurst	204	44.9
3. Atkin Hotel	720	40.9
4. U. T. Farm	359	43.4
5. Middlebrook	287	37.5
6. Magnolia Ave.	219	38.1
7. Laurel & 17th Sts.	188	44.3
8. Colored High School	214	45.6
9. Mississippi Ave.	356	25.4
10. Moses School	295	40.8
11. Beaumont School	566	26.7
12. Brownlow School	---	----
13. Rose Lumber Co.	511	53.8
14. Gulf Refining Co.	366	36.9
15. Texaco Refining Co.	258	33.3
16. Ogden Place	258	47.3
17. Melrose Place	118	38.7
18. Woodlawn Pike	101	53.5
19. Knoxville High School	237	34.7
20. Flenniken School	188	41.4
21. Oakwood School	191	32.7
22. Lincoln Park School	120	38.2
23. Bell Morris School	196	31.4

SMOKE SURVEY NOVEMBER 1927

Station	Tons/sq.mi./yr.	Percent Combustible
1. Baxter Ave.	305	32.3
2. Maplehurst	390	31.4
3. Atkin Hotel	1303	30.8
4. U. T. Farm	298	43.1
5. Middlebrook	218	49.8
6. Magnolia Ave.	167	49.5
7. Laurel & 17th Sts.	204	47.2
8. Colored High School	200	50.7
9. Mississippi Ave.	255	32.7
10. Moses School	---	----
11. Beaumont School	580	28.7
12. Brownlow School	---	----
13. Rose Lumber Co.	1208	43.6
14. Gulf Refining Co.	167	31.3
15. Texaco Refining Co.	164	44.5
16. Ogden Ave.	202	46.7
17. Melrose	152	52.6
18. Woodlawn Pike	122	26.3
19. Knoxville High School	---	----
20. Flenniken School	231	47.6
21. Oakwood School	202	46.9
22. Lincoln Park School	162	64.6
23. Bell Morris School	139	40.4

SMOKE SURVEY DECEMBER 1927 *

Station	Tons/sq.mi./yr.	Percent Combustible
1. Baxter Ave.	---	----
2. Maplehurst	420	48.2
3. Atkin Hotel	---	----
4. U. T. Farm	324	47.3
5. Middlebrook	---	----
6. Magnolia Ave.	249	48.4
7. Laurel & 17th Sts.	250	45.5
8. Colored High School	---	----
9. Mississippi Ave.	---	----
10. Moses School	---	----
11. Beaumont School	282	39.1
12. Brownlow School	---	----
13. Rose Lumber Co.	392	56.2
14. Gulf Refining Co.	---	----
15. Texaco Refining Co.	---	----
16. Ogden Place	---	----
17. Melrose	153	52.1
18. Woodlawn Pike	---	----
19. Knoxville High School	---	----
20. Flenniken School	---	----
21. Oakwood School	---	----
22. Lincoln Park School	---	----
23. Bell Morris School	152	36.4

* 15 Containers damaged by freezing weather.

Smoke Survey for 1927

	Yearly average
1. Baxter Ave.	263
2. Maplehurst	360
3.Atkin Hotel	648
4. U.T.Farm	262
5. Middlebrook	206
6. Magnolia Ave.	204
7. Laurel & 17 th. Aves.	303
8. Colored High School	295
9. Mississipi Ave.	395
10.Moses School	186
11.Beaumont School	282
12.Brownlow School	174
13.Rose Lumber Co.	413
14.Gulf Refining Co.	290
15.Texaco Refining Co.	152
16.Ogden Ave.	290
17.Melrose Place	115
18.Woodlawn Pike	189
19.Knoxville High School	277
20.Flenniken School	244
21.Oakwood School	199
22.Lincoln Park School	195
23.Bell Morris School	177

	Average
January	263
February	315
March	274
April	227
May	278
June &	225
July	225
August	207
September	229
October	280
November	315
December	300

From the results obtained from the soot-fall survey in Knoxville during 1927 the following conclusions were formed:

The wide variations in the amount of soot-fall in the various sections of the city indicated the sources of smoke. The highest soot-fall station was found to be, at Gay and Depot Streets, 648 tons per square mile per year. The lowest was found to be Melrose Ave., 115 tons. These results plainly show that a large part of the smoke can be attributed to the railroads, manufacturing plants and the business section.

If the private homes of the city were causing much of the smoke there would be practically none in the summer when the homes do not have fires. Comparison of results of summer and winter show that there is almost as much smoke in the summer as in winter, the soot-fall in summer being approximately 70% of that in winter. The comparison of these facts seem to prove that at least 50% of the smoke nuisance in Knoxville comes from the railroads, factories and the business section.

Comparison of Results

Knoxville	Average soot fall			275	Per Sq.Mile Per Year tons	
Memphis	"	"	"	600	"	1
Chicago (Residence)	"	"	"	150	"	1
(Business)	"	"	"	450	"	
St Louis (Residence)	"	"	"	450	"	1
(Business)	"	"	"	800	"	
Grafton, W.Va	"	"	"	1866	"	2
Pittsburgh	"	"	"	1044	"	3

1. National Meeting Report St Louis 1927
2. Smoke Abatement at Grafton, W.Va
   Monnet & Hughes
3. Effect of Smoke on Building Materials
   Mellon Bulletin No. 6.

THE ECONOMIC COST OF THE SMOKE NUISANCE

Owing to the fact that large quantities of black smoke are produced in large industrial cities it has come to be regarded as a sign of prosperity. A study of engineering principles will show this conclusion to be wrong, and that combustion with a heavy smoke means loss of fuel as well as the tremendous damage that is caused by this smoke to health and property.

In order that the city and its people shall recognize that such dense black smoke is not economical an attempt has been made to make a safe minimum estimate of the economic cost of the smoke nuisance.

Much of the data is of a comparative nature, for information has been secured from reports of the cost to other cities.

The estimate of the economic cost which have been made elsewhere will be reviewed first, to show briefly the process by which estimates have been reached.

The cost of the imperfect combustion.

Engineers have found from the data which they have secured at various plants, including every type of stoker and hand fired furnace, that the loss up the smoke stack is approximately 25 percent. In 1912 Pittsburgh used approximately 6,000,000 tons of coal with a value of $6,000,000. Today, with increased prices of coal, together

with increased coal consumption by more and larger industries, the value of the coal would be an enormous sum. According to these figures in 1912, the losses in the city of Pittsburgh due to imperfect combustion, amounted to $1,520,740. With the present prices of coal would make this sum three or four times this value.

Last year St. Louis consumed approximately 5,000,000 tons of coal. On this basis, the loss to St. Louis from loss of fuel alone amounts to over $4,000,000 per year.

Knoxville consumes approximately 250,000 tons of coal per year. Considering that 25% of the fuel is lost, the loss of fuel in Knoxville would amount to 62,500 tons per year, at a average price of $4.00 would mean a loss of $250,000.

The cost to the individual.

Laundry and dry cleaning.

It is a common observation that a citizen of a smoky city after a visit to a clean city does not have to wash his face and hands as often as at home, nor it isn't necessary for him to change clothes so often. Experience has shown that clothes do not last as long in dirty cities as cleaner ones because of the more laundering required. There can be no question but that laundry bills, because of

The atmospheric conditions, are larger for citizens of smoky cities than for cleaner cities, other conditions being equal. The cost of clothes in smoky cities would be high because (1) the increase in laundry bills, and (2) more frequent renewal due to wear by laundering. Laundry bills in Pittsburg and St Louis (1912) were found to be from $200,000 to $600,000 more than other cities. It was concluded that Pittsburg payed at least $1,500,000 more in laundry and home washing bills than if the city were as clean as it might be. Comparison of dry cleaning bills show similar facts. The total extra cost of dry cleaning in Pittsburg because of the atmospheric conditions was about $750,000.00 annually.[1]

1. Laundering and dry cleaning is found necessary more frequently in smoky cities than in other cities.

2. Because of this necessity of more frequent cleaning a greater supply of clothing is required.

3. As a result of frequent cleaning, clothes wear out sooner in smoky cities than cleaner ones.

4. The citizens are limited in their selection of clothing.

Cost to the Household.

There is little in that household that escapes the damage from smoke and soot in the atmosphere. Houses in Pittsburg were found to be painted about twice as often as in other cities. In Pittsburghit was estimated that painting of houses cost (exterior) about $330,000 more a

1.Economic Cost of Smoke -Mellon Bull. No. 4.

year than in other cities.[1]

From data on sheet metal work it was found that most of the metal work that is used on houses in Pittsburgh only lasted half as long as elsewhere, because of the effect of the smoke and soot in the atmosphere. There are very few buildings and homes that do not have sheet metal either for roofs or as gutters. In Pittsburghwith its 200,000 buildings (1912) it was estimated that it would cost Pittsburgh about $900,000 more a year than if the city was free from smoke. The cost of repainting the sheet metal was found to be about $108,000 a year more than repainting would cost other cities.[1]

It was found that wall paper was cleaned as many as two times per year, and the average was once per year. Cleaner cities never use wall paper cleaner. Wall paper was found necessary in Pittsburgh every two years, while in other cities it is only found necessary every six to ten years. Accounting for the cleaning done by the homer owners themselves and the professional cleaners Pittsburgh estimated the additional cost of cleaning wall paper to be about $150,000 annually to keep the wall paper in a presentable condition. The cost of repapering in Pittsburgh is approximately $400,000 more than other cities. The cleaning, and replacement of curtains, due to wear by cleaning, was

[1] Economic Cost of Smoke. Mellon Bull No. 4

estimated to be about $360,000 more than other cities every year.[1]

The artificial lighting in homes of Pittsburgh which is due to smoky atmosphere has been estimated $84,000 per year.[1]

Cost to Wholesale and Retail Stores.

Most of the estimates from this damage was from reports from the establishments. These losses were d ueto both the damage to merchandise and the additional cost for keeping the stores clean. An indirect loss results from the inability to display goods on the countersso as to present an attractive appearance. On account of the smoky atmosphere it is necessary to burn more lights longer hours. As the business section of the city happens to be about the heaviest in soot-fall, so that the soot-fall is greatest where it does the most damage. In Pittsburgh estimates from various establishments were from $75.00 to $700.00. The average was about $330.00. This makes the loss to merchandise in Pittsburgh amount to about $1,750,000 annually. (1912).[1]

Loss on account of precautions to avoid damage to merchandise has cost Pittsburgh about $450,000 every year.

The additional cost of cleaning the buildings was estimated to be about $750,000 annually.[1]

From smoke and soot, artificial lighting is necessary for two reasons, (1) the reducing of the daylight

[1] Economic Cost of Smoke. Mellon Bull. No.4.

by atmospheric conditions and (2) by making windows, skylights and light fixtures dirty, cutting out part of the light. Pittsburgh estimated the loss due to lowering the light to be about $650,000 annually.

Additional cost of keeping office buildings clean in Pittsburgh was estimated to be about $50,000 annually. Additional artificial lighting, due to atmospheric conditions for which the smoke is responsible, was estimated to be at least $40,000 annually.[1]

Additional cost to hotels of Pittsburgh was estimated to be about $22,000 per year.[1]

Additional cost of the hospitals of Pittsburgh was estimated to be about $55,000 annually, due to washing, laundering, and additional lighting.[1]

The decrease in the value of property was roughly estimated to be about 15 to 25%.[1]

No attempt was made to estimate the loss to the health of the citizens of Pittsburgh.

[1]Economic Cost of Smoke. Mellon Bull. No. 4.

THE ECONOMIC COST TO PITTSBURGH 1912[1]

Cost to the smoke maker	
Imperfect combustion	$1,520.000
Cost to the individual	
Laundry and dry cleaning bills	2,225,000
Cost to the household	
Exterior painting	330,000
Sheet metal work	1,008,000
Cleaning & renewing wall paper	550,000
Cleaning & renewing curtains	360,000
Artificial lighting	84,000
Cost to wholesale & retail stores	
Merchandise	1,650,000
Extra precautions	450,000
Cleaning	750,000
Artificial lighting	650,000
Cost to public buildings	
Office buildings	90,000
Hotels	22,000
Hospitals	55,000
Total	$9,994,740

[1]Economic Cost of Smoke-Mellon Bull. No.4.

ECONOMIC COST OF THE SMOKE NUISANCE TO KNOXVILLE

An attempt has been made to determine the economic cost of the smoke nuisance to Knoxville by comparison to the coal consumed in Pittsburgh and its economic cost with Knoxville.

Cost to the Smoke maker	
Imperfect combustion	$250,000
Cost to the Individual	
Laundry & Dry cleaning	370,000
Cost to the Household	
Exterior painting	55,000
Sheet Metal work	168,000
Wall Paper	90,000
Cleaning & renewing curtains	60,000
Artificial light	14,000
Cost to Wholesale & Retail Stores	
Merchandise	275,000
Extra precautions	75,000
Cleaning	125,000
Artificial lighting	100,000
Cost to Public Buildings	
Office Buildings	15,000
Hotels	3,000
Hospitals	9,000
Total	$1,609,000

80,136 Tons of soot fell in Cleveland costing $20,000,000

7,425 " " " " " Knoxville " 1,853,000

A conservative estimate for Knoxville would be about $1,750,000 for 1927.

METHODS OF PREVENTION

Two very important factors, both of which aim at efficient and smokeless operation of plants are;

1. The importance of proper installation and construction of the heating plant.

2. The need of exercising care and having constant intelligent supervision of the operations in the boiler room.

The process of combustion is a simple one, being a chemical union of the combustible material of fuel with the oxygen of the air, resulting in the development of heat. In practice, however, many difficulties are encountered which tend to complicate the process.

In the combustion of coal there are three seperate stages;

1. The absorption of heat; the temperature of the fuel must be raised to the kindling point in order to cause chemical combination.

2. The distillation and combustion of the volatile portion of the coal. The problem of smokeless combustion of coal lies in this stage. This depends upon the construction and operation of the furnace so as to completely oxidize the volatile products before they are cooled below their kindling point. This includes

(a) Sufficient quantities of air for complete combustion at the proper time.

(b) A thorough mixture of the air and gases.

(c) The temperature of the gases must be kept above

their kindling temperature until the chemical process of combustion is complete.

3. After the hydrocarbons have been driven off and oxidized, the remaining portion of the coal is mainly ash and carbon which is comparative simple to secure complete combustion.

A considerable portion of the smoke could be eliminated in the business section of the city by the establishment of central heating plants which would furnish the smaller buildings with heat and power cheaper as well as preventing the smoke nuisance.

It is useless to complain of smoky plants and allow new ones to be added every day. In order to stop smoke, smokelessness must be the first requirement in the construction.

With the introduction of modern ideas of efficiency, the plant owner will be forced to look, where so few have yet looked, into the boiler room to see what savings can be effected there. In doing this he will, moreover be prompted and urged by a sense of duty and responsibility to the community, which is more and more coming to demand that the smoke nuisance be abated as a menace to health, property, and the things which make for civic betterment.

A careless man will cause his furnace to produce smoke even if the equipment is best. If one plant can prevent smoke, the rest should.

What is needed is;

1. A realization by the public that smoke is harmful and to create a desire for cooperation to prevent it.

2. Technical direction which will point to the way to economic smoke prevention.

If we could only get into the peoples heads the realization of the tremendous cost of material damage by smoke each year and that the damage to health is greater than this, not to be estimated in dollars,- If the general public could be made to realize these undisputed facts, the cause of smoke abatement would be won.

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APPROVAL.

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

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