SMOKE CONTROL

A Report

of the

JOINT STATE GOVERNMENT COMMISSION

to the

GENERAL ASSEMBLY

of the

COMMONWEALTH OF PENNSYLVANIA

SESSION OF 1951

The Joint State Government Commission was created by Act of 1937, July 1, P. L. 2460, as amended 1939, June 26, P. L. 1084; 1943, March 8, P. L. 13, as a continuing agency for the development of facts and recommendations on all phases of government for the use of the General Assembly.

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Joint State Government Commission
Subcommittee on Smoke Control

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Letter of Transmittal

To the Members of the General Assembly of the Commonwealth of Pennsylvania:

The study of smoke control by a subcommittee of the Joint State Government Commission was directed by Senate Resolution Serial No. 43, Session of 1949, which reads, in part: "Resolved that the Joint State Government Commission, through a subcommittee, is hereby directed to make a thorough and exhaustive study of the smoke and soot nuisance problem existing in the Commonwealth to the detriment of the health of its citizens and the depreciation in value of property, a study of the various smoke and soot control methods and devices and their relative costs and shall prepare model smoke control plans suitable for use by the various political subdivisions of the Commonwealth . . ."

"Resolved that the subcommittee make a report of its findings and recommendations to the Joint State Government Commission and the Commission report the results of the committee's study and recommendations to the General Assembly on or before the first day of February, one thousand nine hundred and fifty-one, together with any proposed legislative measures the committee might deem necessary or advisable to reduce or eliminate smoke and soot nuisances on a state-wide or local basis."

In accordance with the foregoing resolution, herewith are submitted the findings and recommendations of the subcommittee on smoke control.

Baker Royer, *Chairman.*

Joint State Government Commission
Capitol Building
Harrisburg, Pennsylvania

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SUMMARY OF FINDINGS

I. Smoke is defined as the products of combustion diffused in air. The products of combustion are both visible and invisible. The visible components are soot (carbon particles and tarry materials) and fly ash (noncombustible particles). The invisible products are compounds of sulphur and oxygen and carbon and oxygen. The most objectionable invisible combustion products are the compounds of sulphur and oxygen, since they combine with moisture to produce acids which act destructively on metal, paint, stone, and animal and vegetable fibers.

II. Because of the important part that coal has played in Pennsylvania's industrial development, smoke has come to be regarded by many as a symbol of prosperity. It should be regarded as a symbol of waste, since it is indicative of incomplete burning of fuel.

III. Damage to real property, damage to personal property and increased operating expenses (such as the expense occasioned by the need for additional illumination) are costs imposed upon the citizens of a community by the visible and invisible products of combustion. The costs of smoke to each individual are estimated to be sometimes as high as $30 a year.

IV. Smoke was recognized as a source of annoyance as early as the 13th century, and the first legal cognizance of this annoyance was taken in England in 1273. Early recognition was limited to the visible components of smoke and to visible effects. Recently the nature of smoke and the effects of its invisible components, as well as its visible components, have been recognized and analyzed.

V. Of the visible products of combustion, soot results from incomplete combustion. Of the invisible products, some are the result of incomplete combustion and others are the products of complete combustion.

VI. The visible products of combustion may be measured in terms of density and opacity, while the presence of the invisible components of smoke must be established by chemical analysis. The emission of both of these types of products may be abated by:

A. The proper mixing of fuel and air to accomplish complete combustion.

B. The use of "smokeless" fuels, such as oil, gas, and low-volatile solid fuels. Restricting use to these types of fuel would greatly alter the established patterns of coal production and coal consumption that prevail in Pennsylvania. As noted in A, above, any fuel can be burned smokelessly if complete combustion is accomplished and if the undesirable products of complete combustion are removed from the chimney exhaust. (See C, below.)

C. The use of specialized devices in furnaces and stacks.

VII. In Pennsylvania, enabling legislation permits second class counties, first class cities, second class cities, third class cities, boroughs and first class townships to adopt measures for the abatement of smoke.

VIII. The effectiveness of a smoke control program depends upon:

A. The establishment of one smoke abatement unit for all communities within a given smoke-affected area.

B. The legal authority of political subdivisions to join together for the purpose of establishing a control unit.

C. The establishment of standards to fit local needs.

D. The maintenance of a balance between direct costs to the citizens of the area, the equipment costs to producers and the savings accruing to the community at large.

E. The availability of information.

SUMMARY OF RECOMMENDATIONS

I. That the area for the control of smoke shall not be smaller than one county.

II. That counties be permitted and encouraged to cooperate in the establishment and operation of a joint unit for smoke control, and establish standards of emission at least equivalent to those prescribed by the American Society of Mechanical Engineers.

III. That in local control units, there be established a three-member board with hearing and advisory powers.

IV. That the Commonwealth provide financial assistance to the counties which maintain Commonwealth approved control units for the purpose of payment of salaries of technical personnel; and that the appointment of such personnel be subject to the approval of the Secretary of Health of the Commonwealth.

V. That a State Office of Smoke Control for the establishment of standards and the clearing of information be established in the Department of Health.

Section I

BACKGROUND AND HISTORY OF SMOKE CONTROL

Contrary to the common but erroneous belief that the smoke nuisance began with the industrial revolution, smoke was a recognized source of annoyance in the thirteenth century. Legal notice of the nuisance was taken in England in 1273 when the use of coal was prohibited in London as prejudicial to the public health.[1] This attempt at legal control failed. In 1661, the diarist, John Evelyn, wrote, "The immoderate use and indulgence to Sea-cole alone in the City of London exposes it to one of the fowlest Inconveniences and reproaches that can possible befall so noble and otherwise incomparable City. And that, not from the Culinary fires, which for being weak and lesse often fed below, is with such ease dispelled and scattered above, as it is hardly at all discernible, but from some few particular Tunnels and Issues belonging only to Brewers, Driers, Limeburners, Salt and Sope-boilers and some other private trades. Whilest these are belching forth their sooty jaws, the City of London resembles the face rather of Mount Aetna, the Court of Vulcan, Stromboli, or the Suburbs of Hell, than an Assembly of Rational Creatures and the Imperial Seat of our Incomparable Monarch. For when in all other places, The Aer is most serene and Pure, it is here Eclipsed with such a clowd of Sulphur, as the Sun itself, which gives day to all

[1] "Outline of Smoke Investigation," Bulletin No. 1, Aug. 1912, University of Pittsburgh, Department of Industrial Research, p. 12.

the World besides, is hardly able to penetrate and impart it here; and the weary Traveller, at many miles distance, sooner smells, than sees the City to which he repairs." [2]

An attempt to control smoke was made in 1819 when an investigating committee was named by the British Parliament. On the basis of the reports of this and succeeding committees, legislation was passed which set up standards of measurement, enforcement measures and prohibitions.

The United States, in the beginning of the present century, became conscious of the increasing nuisance of excessive smoke in its industrial areas and a number of authoritive studies were made and reports published. Prominent among the investigations are those made by the Department of Industrial Research of the University of Pittsburgh in 1912-1915 and by the Chicago Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals, in 1915. In 1912, the Department of Industrial Research noted that "Most of the larger cities of all industrial nations now have ordinances dealing with the subject. These ordinances, however, vary greatly in purpose, scope, character and stringency. They are, moreover, enforced with degrees of vigor that range all the way from zero to comparative efficiency." [3]

In the past 35 years smoke abatement movements have assumed the dimensions of civic crusades. Volumes have been written on the subject. Smoke abatement has been made a regular section in a number of technical engineering

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[2] John Evelyn, *Fumifugium,* Balliol College, Oxford, 1661. Reissued as an Old Ashmolean Reprint (VIII) in 1930 with comment by the editor, Dr. R. T. Gunther, Oxford, England, pp. 8, 9.

[3] "Outline of Smoke Investigation," Op. Cit., p. 12.

journals. Countless articles have been published by enforcement officers and others interested in smoke control methods. Smoke abatement has been widely discussed at engineering conventions and at meetings of enforcement officers. Interest in smoke abatement has stimulated the invention and production of new types of furnaces and control mechanisms and their voluntary adoption by industry.

Current interest in smoke control has been reflected in the passage of local smoke ordinances and in state legislation. The city of Boston has operated under state legislation for that area since 1910. In St. Louis, the present smoke control measures were adopted in 1937. Los Angeles' restrictions on smoke date from 1947. Chicago's smoke control laws were adopted in 1928 and since have been amended.

In Pennsylvania, cities, second class counties, first class townships, and boroughs have been permitted to adopt smoke ordinances through a number of legislative acts.[4] These acts and the political subdivisions which they affect are:

1. The First Class City Law (City Charter), 1929, March 25, P. L. 66, § 1, No. 75, 53 PS 3451, grants general power to make ordinances for the proper management, care, control of city . . . and maintenance of . . . good government, safety and welfare . . . and full powers in matters of police.
2. The Second Class City Law, 1911, June 6, P. L. 667, § 1, 53 PS 9691, grants power by ordinance to regulate the production or emission of smoke. 1901, March 7,

[4] For the provisions of selected smoke control ordinances in Pennsylvania and in other states, as Appendix, Reference Tables I and II.

P. L. 20, Art. XIX, § 3, Cl. xxxiii, 53 PS 9673, grants power to make regulations to secure the general health of the inhabitants and to remove and prevent nuisances. 1901, March 7, P. L. 20, Art. XIX, § 3, Cl. xxxvi, 53 PS 9678, grants power to regulate the construction and inspection of fireplaces, chimneys, etc. . . . and prescribe limits within which no dangerous, obnoxious, or offensive business shall be carried on. 1915, May 13, P. L. 297, § 1, [h], 53 PS 9718, grants power to regulate construction of chimneys, stacks, flues, smoke pipes and ventilators.

The act of 1927, Mar. 9, P. L. 18, § 2, 53 PS 3, provides that until otherwise provided by law, cities of the second class A shall continue to be governed, and shall have all the powers, privileges and prerogatives now provided by the laws of the Commonwealth relating to cities of the second class.

3. The Third Class City Law, 1931, June 23, P. L. 932, Art. XXIV, § 2403, Cl. 10, 53 PS 12198-2403-10, grants power to regulate by ordinance the production and emission of unnecessary smoke from any source except railroad locomotives.
4. The Second Class County Law, 1943, May 28, P. L. 793, §§ 1, 2, 3, as amended 1947, May 9, P. L. 182, § 1, 16 PS 4061-3, grants detailed powers to regulate smoke and equipment within the county and provides penalties.
5. The First Class Township Code, 1949, May 27, P. L. 1955, Art. XV, § 1502, Cl. xxix, 53 PS 19092-1502, Cl. xxix, grants power to regulate the emission of smoke from any source except railroad locomotive stacks. 1949, May 27, P. L. 1955, Art. XV, § 1502, Cl. xxvi,

53 PS 19092-1502, Cl. xxvi, grants power to prohibit and remove any noxious or offensive manufacture, art, or business or any other nuisance on public or private grounds prejudicial to the public health or safety, and provides penalties.

6. The Borough Code, as amended, 1947, July 10, P. L. 1621, § 40, 53 PS 13321, 13328, 13329, 13363, grants power to Boroughs to regulate the emission of smoke from chimneys, smoke stacks and other sources except locomotive smoke stacks; to prohibit and remove nuisances and noxious and offensive business; and to make regulations necessary for health and cleanliness.

All Pennsylvania ordinances must operate within the sphere defined by the courts. In the past, the courts of the Commonwealth have declared several of the earlier ordinances invalid because their requirements were considered to be unreasonable.

Generally an ordinance may be considered unreasonable if there are no practical methods or devices for control, or if there is some form of discrimination in the ordinance itself. Illustrating this line of thought are two Pennsylvania cases, each dealing with Pittsburgh in which the courts ruled on the validity of local ordinances. Both concerned the second class city law, 1901, March 7, P. L. 20, Art. XIX, Sec. 3, Cl. xxxiii, which authorized regulations to secure the general health of the inhabitants and to remove and prevent nuisances. In the first case, that of *Pittsburgh v. W. H. Keech Co.,* 21 Pa. Superior Ct. 548, (1902), the ordinance was declared unreasonable because the provision containing the penalty for violation stated that "smoke" should not be emitted from any smokestack, etc. The Superior Court held that it was unreasonable to forbid the emission of *any* smoke. The ordinance was therefore declared void. In the second case, *Commonwealth v. Standard Ice Co.,* 9 Just. 270, 59 P. L. J. 101, (1910), the Pittsburgh ordinance was declared invalid because it would, in effect, have required the use of a mechanical stoker and eliminated hand firing. The ordinance forbade "the emission of dense black or dense gray smoke from any chimney except that of a private residence, excepting for a period of eight minutes in any one hour during which the firebox is being cleaned, or a new fire is being built therein." This was held by the court to be unreasonable.

The majority of the modern smoke control ordinances declare the emission of a certain type or density of smoke to be a nuisance. The general rule is that a municipality by ordinance, or a state legislature by act can declare something to be a nuisance although it was not previously so recognized at common law, provided the action is not manifestly unreasonable or oppressive. According to the case of *Nesbit v. Riesenman,* 298 Pa. 475, (1930), the courts may adapt common law rules, as to nuisance, to new conditions, and such power is not inconsistent with the legislature's right to change the common law. (In some states the power to declare smoke a nuisance has been included in the police power, or made part of health and sanitary regulations.)

In *Commonwealth v. Baker,* 160 Pa. Superior Ct. 640, (1947), it was held that where an ordinance declares a thing to be a public nuisance and also provides a penalty, the penalty may be imposed without proof that a nuisance in fact exists, if the prohibited act has been committed. In *Bunkin et al. v. Miller,* 9 D & C 743, (1927), an injunction was granted restraining the owner of a laundry from "casting smoke upon the dwellings" of the complainants, contrary to the provisions of a 1904 Philadelphia ordinance.

The proof was that dense columns of black smoke came from the chimney of the laundry.

It has been held by the courts that, in the absence of a valid ordinance regulating smoke, smoke is not, per se, a common law nuisance.[5] It has been established, however, that smoke may be a private nuisance in the event that damage can be shown.[6] For example, when smoke from a manufacturing plant or mill damages the buildings, soil or crops of an adjoining landowner, or affects his health, the aggrieved may recover damages therefor.[7] However, the mere existence of smoke is not sufficient. When actual damage can be shown, the injured can obtain an injunction in a court of equity requiring the offender to abate the nuisance. Such injunction usually prohibits further operation of the plant until effective smoke control is accomplished,[8] or prohibits the use of the type of fuel causing the damage.[9] The manufacturer is not liable for injury, however, if he is using the most effective known means to prevent smoke and if he is otherwise conducting his business legally.[10]

In the case of smoke from railroads, Pennsylvania courts have ruled that an adjoining landowner cannot recover for inconvenience or loss occasioned thereby unless negligence, unskillfulness or malice is proved;[11] or that there is more

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[5] *Pittsburgh v. W. H. Keech Co.*, 21 Pa. Superior Ct. 548, (1902).

[6] *Davis v. Eagan-Rogers Steel and Iron Co.*, 13 Del. 411, (1915); *Geist v. Sadowsky*, 88 P. L. J. 224, (1940).

[7] *Robb v. Carnegie*, 145 Pa. 324, (1891).

[8] *Galbraith v. Oliver*, 3 Pitt. 78, 14 P. L. J. 565, (1867); *Biddle v. McCracken*, 13 W. N. C. 514, (1883).

[9] *Ballard v. Florey's Brick Works, Inc.*, 47 Montg. 250, (1931).

[10] *Eppley v. Naumann*, 5 Dist. 471, (1896).

[11] *Myers v. Pennsylvania Railroad Co.*, 245 Pa. 534, (1914).

smoke than necessity requires.[12] Damage, alone, will not be adjudged a nuisance, since railroads are affected with a public interest.

The courts have further ruled that in an industrial area, a certain amount of smoke must be tolerated. In *Hannum et al. v. Gruber et al.,* 346 Pa. 417, (1943), it was held that the owners of property residing in an industrial district are entitled to protection from smoke, odors, gases, smudge and noises, only to the extent that these things are unnecessary and unreasonable under the circumstances. A factory in an industrial area is not a nuisance per se, but failure to make a reasonable effort to avoid smoke may constitute a nuisance.

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[12] *Pennsylvania Railroad Company v. Lippincott,* 116 Pa. 472, (1887); *Bunting v. Pennsylvania Railroad Co.,* 203 F. 193, 121 C. C. A. 399, (1913).

Section II

THE COST OF SMOKE TO THE COMMUNITY

It appears obvious to every dweller in an industrial area that smoke causes him certain expenses which would not arise if the air were clear. Some of these costs can be expressed in terms of dollars, others are of such a nature that they may not be so determined. Such expenses as cleaning, maintenance, illumination, damage to property, etc., may be directly expressed in terms of the dollars they cost each member of the community in laundry and cleaning bills, repairs to buildings, larger electric light bills on dark days, etc. Such items as the loss to the community of citizens who prefer the suburbs to a smoky city, with resultant loss to the city in revenue and in property value, are not measurable in dollars although it is widely agreed that they are consequential.

The dollar value of the measurable costs, however, present a standard by which to judge the desirability of abating smoke in a community, even though it does not represent the cost of smoke alone, but of all air-borne dirt, a part of which is the product of combustion. (See Section IV, C. Dustfall Measurements.)

A number of attempts to ascertain the dollar costs of smoke per person have been made. Perhaps the most widely quoted even today is the survey made by the Pittsburgh Institute of Industrial Research in Smoke Investigation Bulletin No. 4, published in 1913. Other similar surveys tend to substantiate the findings of the Pittsburgh study.

The Pittsburgh survey in 1913 offered the following comment on the costs of smoke:

"Because of the important part that coal has played in the industrial development of Pittsburgh and because the coal has been so burned, or rather so poorly burned, that it has given off great quantities of black smoke, Pittsburghers have come to regard smoke as a sign of prosperity.

"That is a false conclusion, a superficial study of good engineering practice will show as combustion with heavy smoke always indicates loss." [13]

The 1913 survey itemized the measurable costs of smoke to Pittsburgh as:

1. Cost to the Smoke Maker	
(a) Imperfect Combustion	$1,520,740
2. Cost to the Individual	
(a) Laundry Bills	1,500,000
(b) Dry Cleaning Bills	750,000
3. Cost to the Household	
(a) Exterior Painting	330,000
(b) Sheet Metal Work	1,008,000
(c) Cleaning and Renewing Wallpaper	550,000
(d) Cleaning and Renewing Lace Curtains	360,000
(e) Artificial Lighting	84,000
4. Cost to Wholesale and Retail Stores	
(a) Merchandise	1,650,000
(b) Extra Precautions	450,000
(c) Cleaning	750,000
(d) Artificial Lighting	650,000
(e) Department Stores	175,000
5. Cost to Quasi-Public Buildings	
(a) Office Buildings	90,000
(b) Hotels	22,000
(c) Hospitals	55,000
	$9,944,740 [14]

[13] "The Economic Cost of the Smoke Nuisance to Pittsburgh," Mellon Institute of Industrial Research, Smoke Investigation Bulletin No. 4, University of Pittsburgh, 1913, p. 44.

[14] Ibid., pp. 44, 45.

By way of specifying the limitations of the above costs per year, the survey concludes, "It must be kept in mind that the cost of the items given is for the city of Pittsburgh only, and that no attempt has been made to estimate the cost for such items as depreciation in value of property, compulsory absence of certain industries, injury to health, impaired mental efficiency, etc." [15]

In 1909, the Smoke Prevention Committee of the Cleveland Chamber of Commerce fixed the loss for Cleveland at $6,000,000, or $12.00 per capita.[16]

A study of Chicago's losses due to smoke was estimated to be $17,600,000, or $8.00 per capita, in 1911.[17]

Property damage losses from smoke in the city of Toronto were estimated as recently as 1947 to be $15,000,000, or about $20 per person annually.[18]

Since the Pittsburgh smoke abatement program has been in effect, it is generally agreed that the damage attributed to smoke have materially decreased.

The citizens of St. Louis, another city which has been through a smoke prevention drive, and has operated for some years with a smoke ordinance, seem to consider the effort worth-while.

The smoke commissioner of St. Louis has observed that prior to the smoke abatement program it was estimated that smoke cost the city and its citizens $14,000,000 per year

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[15] Ibid., p. 44.

[16] Ibid., p. 8.

[17] Ibid., p. 9.

[18] Proceedings, Smoke Prevention Association of America, Annual Meeting, 1947, p. iv.

or $17 per person. After the smoke ordinance was adopted, a definite improvement could be noted, although the gain in dollars was difficult to estimate. Offered as indicative of the gain made through smoke abatement was the fact that before the smoke ordinance, the city had spent $2½ million for renewal of paint and sheet metal, and after the adoption of the ordinance the paint jobs were easier, one coat of paint instead of two was needed, and the wearing qualities were increased at least 25%. In addition, it was stated that "The sheet metal workers of St. Louis expect the metal to last longer (it lasts three times as long in the suburbs as it did in St. Louis before the ordinance). Fewer buildings need cleaning; housewives report that curtains stay clean longer; the Hotel Association of St. Louis says that savings to them in cleaning and redecorating were approximately $153,880, while the Electric Company estimated that the citizens saved about $75,000 a year in electric light bills." [19]

In large installations, the overall efficiency from a given amount of fuel might be entirely satisfactory, but yet it may be possible that the effluent be objectionable in the amount of solid matter other than soot dispersed to the atmosphere. Dark smoke is indicative of incomplete combustion, but the actual heat loss occasioned by the lack of complete combustion of the tarry matter and dark colored particles is not great. (See Section III, C. The Causes of Smoke.)

When the increases in the costs of materials and services, which have taken place since most of the above estimates were made, are considered, it seems reasonable to assume that, in a city or industrial area where the smoke nuisance is comparable to that of the cities mentioned previously, smoke

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[19] J. H. Carter, "Does Smoke Abatement Pay?" *Heating, Piping and Air Conditioning*, April 1946, Vol. 18, No. 4, p. 80.

costs each individual in that area between $10 and $30 annually, depending on the amount of particulate matter and sulphur gases contained in the smoke.

When the desirability of lowering the costs of smoke to the individual is considered, the costs of smoke abatement equipment to the producer should be borne in mind and a balance maintained between the cost of smoke to the citizen, and the cost to the producer of smoke abating equipment.

Section III

THE DEFINITION, CAUSES AND PREVENTION OF SMOKE

As used in this report, smoke is defined as the products of combustion diffused in air.[20] This definition is widely accepted and covers both the visible and invisible products of combustion.

Smoke represents the products of both complete and incomplete combustion, and it is the latter which most often produces the visible smoke described as "objectionable," which ordinances have sought to abate.

A division of smoke into its visible and invisible parts is required if the problems of smoke control are to be understood.

A. *Visible Products of Combustion*

The components of visible smoke are largely *soot* and *fly ash.* Soot represents the carbon particles generally agglomerated with tarry material and is black in color. Fly ash is

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[20] The Bureau of Industrial Hygiene, in the Department of Health, has maintained a Division of Air Pollution Control since 1949. The Division of Air Pollution Control is specifically concerned with the presence in air of chemical gases and fumes and other toxic materials. It is concerned with smoke control only in instances where the smoke may contain such toxic materials.

Investigations of conditions in given localities are instituted by the Division when deemed necessary or at the request of the citizens of the areas. From its experiences, the Division is working toward the establishment of standards of toxicity for various air pollutants. The work is carried forward by the collection of samples of air at various investigation points, and the analysis of these samples to determine the kinds and amount of contaminants contained therein. Recently, the efficient execution of the program of special investigations and formulation of standards has been enhanced with acquisition of a completely equipped mobile laboratory for on-the-spot investigations, a spectrophotometer for determining minute amounts of contaminants, and additional laboratory facilities.

the non-combustible material found in solid fuels and is generally gray to white in color, depending on the composition of the fuel. Cinders are the larger portions of fly ash and are non-combustible constituents of coal. The solid or visible particles in smoke may be classified as: (1) grit which can be collected by deposit from the atmosphere and (2) particles so small they may stay suspended in air almost indefinitely.

B. *Invisible Products of Combustion*

The invisible products of combustion are:

1. *Carbon dioxide,* which results from complete complete combustion.
2. *Carbon monoxide,* which is produced by incomplete combustion.
3. *Volatile hydrocarbons* (gaseous chemical compounds of carbon and hydrogen), i.e., the combustible gases in fuel which are distilled from the fuel but are not consumed because the temperature of the combustion chamber is not sufficiently high, and which are consequently vented as gases into the chimney.
4. *Gaseous combustion products of sulphur,*
   (a) Sulphur dioxide and (b) Sulphur trioxide, which combine with the moisture of the atmosphere to form sulphurous and sulphuric acids.
5. *Ammonia* in some fuels.

The visible products of combustion, soot, and fly ash, are generally considered the more objectionable and it is principally against them that smoke control ordinances have been drawn. Of the invisible combustion products, the most objectionable are the gaseous combustion products of sulphur which combine with atmospheric moisture to produce sulphurous and sulphuric acids. These acids are corrosive to most materials used in building construction as well as harmful to vegetation and animal fibers.

This report is confined to the smoke from fuels used for domestic and industrial heat and power generation; it does not include the specific air pollution problems created by the venting of chemical fumes and exhaust gases, metallurgical dusts and fumes, oil refinery gases and fumes, and the like. Although these contribute to air pollution, their problems and solutions are specific.

C. *The Causes of Smoke*

Although the fundamental chemical reactions of combustion are well understood, the mechanism of combustion is complicated by the physical difficulties of getting the chemical components, i.e., the fuel and the air, into intimate contact so that the reaction can take place. The absence of a fully completed reaction is the cause of the dark smoke nuisance. The fluid fuels, gas and oil, are more easily handled and adjustment of air more easily made than for the solid fuels. Poorly operated gas or oil furnaces may produce equally objectionable smoke as ever produced by incomplete combustion of a solid fuel. Coal is the most difficult fuel to burn completely and it is with the problem of the complete combustion of coal that most smoke abatement programs are concerned. The U. S. Bureau of Mines has observed, "To burn completely 1 pound of coal in a boiler furnace requires about 3 pounds of oxygen, or 15 pounds of air. One pound of coal will make a cube with 2¾ inch edges. Fifteen pounds of air at atmospheric pressure and temperature occupies a volume of about 200 cubic feet, which is approximately the volume of a 6 foot cube. The volume of these two cubes shows the relative volumes of coal and air that must be fed into the furnace to obtain complete combustion."[21]

This chemical union, or combustion, of the 2¾ inch cube of coal and the 6 foot cube of air is brought about in three zones in the ordinary hand fired house or small industrial furnace. These are (1) the oxidizing zone, (2) the reduction zone, and (3) the distillation zone. The air enters the bottom of a burning fuel bed through the grate. The oxygen of the air begins to combine with the carbon of the coal according to the following chemical reaction, with the liberation of heat.

C	$+$	O_2	$\rightarrow$	CO_2
Carbon in Coal		*Oxygen (21% in air)*		*Carbon Dioxide*

As the air progresses up through the fuel bed, the oxygen is consumed progressively at the surface of each lump of burning coal. This zone of the fuel bed is called the oxidizing zone and varies in depth with the depth of the fuel bed.

As the hot combustion gas from the oxidizing zone rises up through the coal bed, the hot CO_2 comes in contact with more combustible carbon, but there is no oxygen to continue the $C + O_2 \rightarrow CO_2$ reaction, and the carbon of this, the reduction zone, takes its oxygen from the CO_2 produced in the oxidizing zone. The introduction of more air to the bottom of the fuel bed would increase the rate of combustion in the oxidizing zone but would not make available any

[21] "Combustion in the Fuel Bed of Hand Fired Furnaces," Bureau of Mines Technical Paper 137.

more free oxygen for the reduction zone. The chemical reaction in the reduction zone can be shown as:

CO_2	+	C	→	2 CO
Carbon Dioxide		*Carbon in Coal*		*Carbon Monoxide*

The amount of carbon dioxide that is converted or reduced to carbon monoxide is dependent on the time of contact and temperature but is limited at any specific temperature by chemical equilibrium. In a hand fired fuel bed, the temperature of the bed is about 2400° F, a temperature which allows rapid conversion to carbon monoxide.

The combustion gases from the reduction zone now enter the distillation zone which corresponds to the depth of the fresh fuel. On entering this zone, the gases are hot carbon monoxide and carbon dioxide which heat and distill the volatile matter from the fresh fuel and carry it from the fuel bed. In the combustion of fuels such as coke and anthracite, which are primarily carbon, the problems of the distillation zone are of little or no consequence. The maximum volatile matter of an anthracite coal is 8 per cent. Bituminous coal, however, may run as high as 40 per cent volatile matter.

Unless steps are taken at this point to mix these volatile products of the distillation zone with additional air for their combustion and keep them above their ignition point, they will enter the flue to the chimney unchanged with a loss of combustion efficiency. These gases are hydrocarbons (i.e., containing both carbon and hydrogen). On combustion, the carbon is converted to carbon dioxide, as is the carbon of a solid fuel. The hydrogen of these gases combines with oxygen to form water vapor.

When one considers that, in a bituminous fuel, 35 per cent of its weight (which can represent 50 per cent of its heat value) may be driven off as combustible gas in the distillation zone, it becomes apparent that this stage of combustion is a critical one for the elimination of smoke and for the elimination of loss in heat. The loss into the flue of 35 per cent unburned volatiles may mean a 50 per cent loss in heating value.

The visible soot and tarry material in smoke accounts for very little of the heat loss mentioned above. It has been estimated that the carbon in the soot accounts for one to five per cent of the carbon burned. It has been estimated that the percentage of heat lost in soot to be 2 per cent for hand fired furnaces and 1 per cent for mechanical stokers.[22]

The foregoing discussion of combustion has been concerned with the combustion of carbon and hydrocarbons present in coal. However, in a discussion of combustion in connection with smoke abatement, sulphur, the principal impurity present in coal, must also be considered since it adds appreciably to the smoke nuisance. The sulphur content of Pennsylvania solid fuels is approximately as follows:

Anthracite—.4 per cent to 1 per cent
Coke—.6 per cent to 1.2 per cent
Bituminous—1 per cent to 4 per cent

When sulphur is burned in a furnace, it is combined with the oxygen of the air to form sulphur dioxide which, on further oxidation, forms sulphur trioxide. These oxides are acrid gases which combine with water to form acids.

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[22] William A. Bone, and Godfrey W. Himus, *Coal, Its Constitution and Uses* (London, 1936), p. 221.

Even though some of the sulphur finds its way into the ash, one per cent of sulphur in fuel can yield 60 pounds of acid per ton[23] of coal after combination with water.

It has often been said that any fuel can be burned efficiently and without undue smoke if proper precautions are taken. This presupposes that the furnace with auxiliary equipment, stack, etc., is adequate for its purpose. In the practical operation of a hand fired furnace, the lines of demarkation between the combustion zones mentioned above vary because the fuel is added periodically rather than continuously, resulting in the disturbance of the theoretical balance possible in an uniform bed.

During the addition of coal to a hand fired furnace, it is imperative that the addition be made so that part of the incandescent bed remains exposed. In this manner, the distillation zone is confined to one area, and its volatile products are brought to their ignition temperature by exposure to the incandescent area and are combined with additional air usually admitted through the small slots in the furnace door. In this way, the three requirements for complete combustion, (1) the temperature required to raise the products of distillation to their ignition point, (2) the admission of sufficient air for their combustion, and (3) the mixing of air and distillation products,[24] are met. A well constructed furnace is so designed that additional air is mixed with the gaseous distillation products and the mixture burned before it leaves the furnace.

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[23] E. A. Allcut, "The Smoke Problem," *The Engineering Journal,* Vol. 30, No. 4 (1947), p. 155.

[24] Mellon Institute of Industrial Research and School of Specific Industries, Smoke Investigation, Bulletin No. 8, *Some Engineering Phases of Pittsburgh's Smoke Problem* (University of Pittsburgh, 1914), p. 28.

Under theoretical conditions, complete combustion would result in the maximum production of heat and minimum smoke. Incomplete combustion resulting from improper firing and poor design of a furnace will cause a loss in heating efficiency through:

(a) combustible volatile gases vented through the chimney to the atmosphere, and

(b) soot and tarry materials carried through the chimney by these gases.

The loss in heating efficiency due to (b) above is of less importance than the loss due to (a) above.

Impurities such as sulphur, present in Pennsylvania solid fuels, particularly bituminous coal, account for an appreciable amount of the smoke nuisance although they are not visible and would not be measurable by any of the standards for visible smoke.

D. *Prevention of Smoke*

1. Furnaces and Auxiliary Equipment

In recent years, the progress in the design of both domestic and industrial coal burning furnaces has been notable. It may be expected that the results of technological progress will become increasingly apparent as old furnaces are replaced and the demand for smoke abatement continues.

The types of anti-smoke furnaces now on the market embody such features as continuous feeding of fuel at a regulated speed, forced air feed to the fuel bed, etc.

Many smoke prevention bureaus conduct educational programs to instruct operators in proper firing methods and provide lists of efficient equipment.

As old furnaces are replaced, the smoke problem will tend to decrease. However, the life of a furnace is long, and its replacement expensive. To permit owners of the older furnaces to comply with smoke regulations the following suggestions are offered by experts in smoke prevention:[25]

"1. Use a coal which gives off relatively little gaseous material.

"2. Adjust the rate of air flow to insure complete combustion. One way this can be done is by using "overfire jets" to inject additional oxygen into the furnace gas.

"3. Collect and reinject unburned material so it is burned. . . .

"The small plant, having relatively large-size particles of fly ash to cope with, may be able to keep fly ash emission within limits by installing a simple dust trap.

"Larger plants, using automatic stokers and maintaining high burning rates, and plants using powdered coal, have to turn to more complex—and more expensive—equipment. For these plants, fly ash collection is actually a major dust collection problem."[26]

2. Types of Fuel and Their Relation to the Smoke Problem

The smoke nuisance varies with the amount of volatile matter in fuel. However, the exclusive use of low volatile fuel will not necessarily eliminate smoke.

"It is probably not an exaggeration to say that in the popular mind, coal is the fuel usually associated with smoke. As a matter of fact, the fluid fuels, gas and oil, can produce just as dense a smoke, and perhaps a more offensive one, than coal. They have a common property greatly to their advantage, however, in that they are more uniform in character, permitting precise control of feeding devices or "burners" with perfect mixing with air for complete combustion.

[25] "Air Pollution," *Modern Industry,* September 15, 1949, p. 49.
[26] Ibid., p. 49.

This control is built into the burner, so that if once adjusted and then let alone, they will continue to function satisfactorily with periodic inspection. With coal, the infinite variety of size, moisture, . . . fusion, ash and fixed carbon, make each application a special study." [27]

For purposes of this discussion, six types of coal are of interest. These are:

	Fixed Carbon Content	*Volatile Matter*
(1) Meta-Anthracite	98% or more	2% or less
(2) Anthracite	92% to 98%	8% to 2%
(3) Semi-Anthracite	86% to 92%	14% to 8%
(4) Low-Volatile Bituminous	78% or more	22% or less
(5) Medium-Volatile Bituminous	69% to 78%	31% to 22%
(6) High-Volatile Bituminous	Less than 69%	More than 31%

SOURCE: *Typical Analyses of Coals of the U. S.*, U. S. Department of Interior, Bureau of Mines, Bulletin 446, p. 13.

It can be demonstrated that by controlling the type of coal used, a community can effectively decrease its smoke problem. Two of the larger cities which use this approach are Pittsburgh and St. Louis and, both have successful smoke abatement programs.

Pittsburgh forbids the use or sale of solid fuel of which the volatile content is more than 20%. However, if a fuel contains more than 20% volatile matter, it is acceptable under the ordinance if it meets the same standards in regard to smoke prevention as those for a fuel containing less than 20% volatile matter. This means that virtually all hand fired furnaces are required to use a smokeless fuel (either

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[27] Joseph T. Harrington, "Achievements in Smoke Prevention," *Manual of Instructions on Proper Firing Methods,* Smoke Prevention Association of America, 1947-48, p. 37.

oil, gas or coal containing 20% or less volatile matter) but that mechanically fed furnaces may use the higher volatile coals if they are of the anti-smoke type and are approved by the Pittsburgh Bureau of Smoke Prevention.

Thus, while Pittsburgh restricts the volatile content of fuel, it makes allowances for the use of higher volatile coals under conditions which are acceptable. The Pittsburgh market offers a specially treated low-temperature carbonization coal, processed from a coal of higher volatile content than allowed by the ordinance, which has been approved for use. In addition, Pittsburgh has specified combinations of anthracite with high volatile fuels, or combinations of coke and high volatile fuels, which may be used within the limitations of the ordinance. This is a case where the ordinance restrictions on the type of fuel are not arbitrarily limited to one kind of coal but acceptable substitutes are permitted.

In St. Louis, one of the fuel problems confronting the city at the time of the adoption of the smoke ordinance was the sulphur content of the coal used in that area. To eliminate some of the sulphur and excessive fly ash also present in the coal, the ordinance requires the use of washed coal and limits the amount of volatile matter in coal used in the city to 23%. As in Pittsburgh, control is effected through the coal dealers.

In New York, the smoke problem is not concerned with the volatile content of coal, since virtually all the coal sold in the city contains less than 20% volatile matter. However, complaints against oil burners have recently outnumbered the complaints against coal furnaces showing that unless properly controlled they, too, can be a source of nuisance.

Limiting the types of fuels which may be used would greatly alter the established patterns of coal production and coal consumption that prevail in the Commonwealth.

Section IV

STANDARDS FOR DETERMINING THE EXTENT OF THE SMOKE NUISANCE

The householder judges smoke abatement programs by the color of the sky and the dirt on his window sills. The expert uses the same method but his observations are controlled and his standards are fairly closely defined. The expert's standards are designed (1) to measure the density of smoke as it issues from individual chimneys and (2) to measure the amount of solid material, a part of which is the result of combustion processes, which is deposited on a given area over a certain period of time.

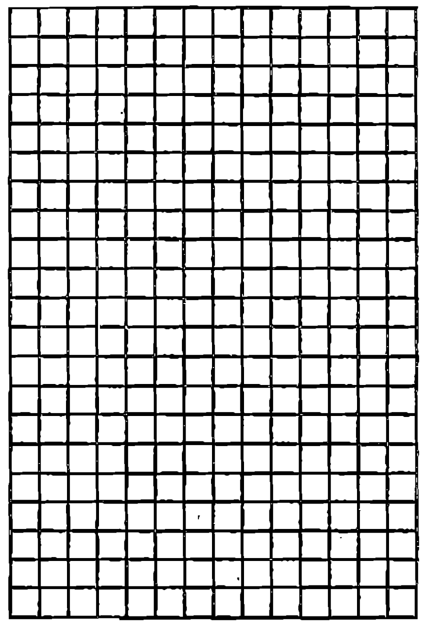
A. *Methods of Measuring Smoke Density*

Ordinances are generally directed against "black" and "dark gray" smoke. As a result, comparative standards of measurement, adopted for use in judging compliance with the ordinances, are generally limited to the visible products of combustion.

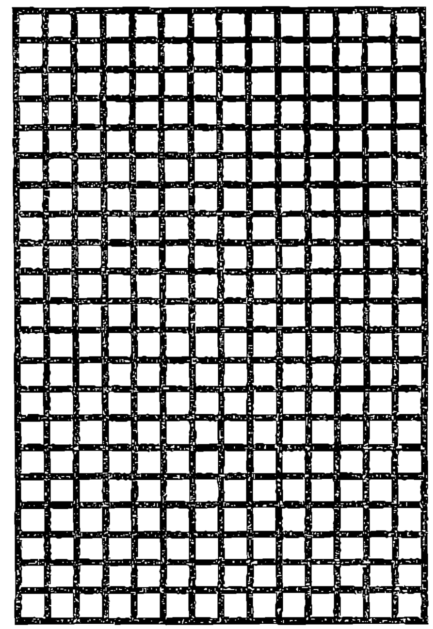
1. Ringelmann Chart

Today the most widely used standard of measuring smoke density is the Ringelmann chart which has been in use for the last half century. This chart, which is the standard required by most smoke ordinances, consists of a series of lined squares of varying black and white composition as follows: Square No. 1 is 80% white and 20% black; Square No. 2 is 60% white and 40% black. Square No. 3 is 40% white and 60% black; and Square No. 4 is 20% white and 80% black. (No smoke is recorded as zero and 100% black smoke is recorded as No. 5.) This chart is placed at

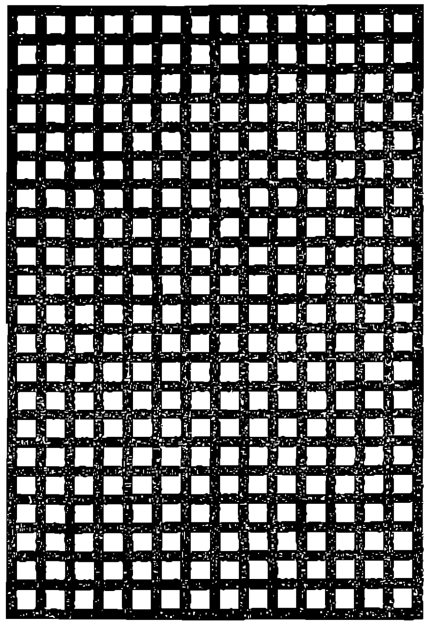
RINGELMANN CHART FOR GRADING SMOKE DENSITY



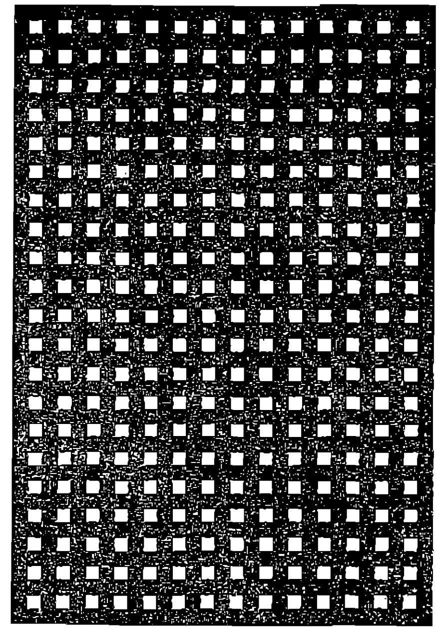
No. 1. Equivalent to 20 per cent black



No. 2. Equivalent to 40 per cent black



No. 3. **Equivalent to 60 per cent black**



No. 4. **Equivalent to 80 per cent black**

NOTE: No smoke is recorded as No. 0. 100 per cent black smoke is recorded as No. 5.

a distance from the observer at which the black and white areas seem to merge. The smoke issuing from a chimney is visually compared with the appearance of the squares of the chart, so that the observer may identify its density as No. 2, or No. 3, or whatever square the shade of the smoke most closely resembles. Prohibited densities are designated by reference to the numbers of squares, i.e., "density greater than number 2 on the Ringelmann Chart," or, "density equal to or greater than number 3 on the Ringelmann Chart."

2. Limitations of the Ringelmann Chart

The Ringelmann chart often has been criticized for its obvious limitations. Since it measures only the color density of smoke, a small number of dark particles will be shown to be objectionable, while a large volume of light colored particles will not be classed as undesirable, although the actual solids content of the latter far exceeds the former.

The superintendent of the Pittsburgh Bureau of Smoke Prevention, in discussing the Ringelmann chart observed, "There are many objections that can be brought against the use of a Ringelmann chart. For instance, there is the objection that the depth or size of the smoke stream has an influence on the light coming through. Obviously a column of smoke 1 foot in diameter would give a different reading from a column 10 feet in diameter. Some observers have tried to establish rules to correct and allow for the column depth. This is a matter of judgment and to establish a rule that will meet all conditions does not seem possible. . . .

"Perhaps one of the most troublesome things is to try to obtain the Ringelmann number of a smoke that has a color other than black. A smoke may be very thick and heavy and yet so light in color as to give a low Ringelmann chart number. The color prevents a true reading and it is a matter of judgment or estimate on the part of the observer as to how dense the smoke is and what proportion of light comes through it. . . .[28]

"When we consider all the factors bearing on the accuracy of a Ringelmann chart reading, there is no use in trying to read too closely. It is impractical to try to read between shades. For example, when some observer says he found smoke of No. 3¼ or 3¾ he better call it No. 3 or No. 4 and let it go at that.

"Whatever may be said against the Ringelmann chart as to its accuracy, nothing can be said against its usefulness when used as a qualitative rather than as a quantitative instrument. It will give simply and quickly a good idea of what a stack is doing. In view of the difficulty of the subject and the present state of the art, it is no wonder that it has become popular and is used by practically all smoke prevention bureaus.

"Just consider that such a chart can be put in the hands of almost anyone, independent of their educational background. In other words, it does not require a college education to use a Ringelmann chart. Compare this with the method of determining smoke by using a pilot tube, collecting a sample of smoke from a stack and then analyzing it. Here an understanding is necessary of the longitudinal stratification of stack draft, a training in both chemistry and physics, along with a chemical laboratory.[29]

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[28] *Manual of Instructions on Proper Firing Methods,* Smoke Prevention Association of America, Inc., "The Ringelmann Chart" by Sumner B. Ely, p. 8.

[29] Ibid., p. 9.

The Ringelmann chart is criticized by smoke control officers as being unfair to the users of large smokestacks since the smoke from a small stack may be as dense as that from a large stack, but the quantity of smoke delivered will be greater in the case of the large stack. Other scientific arguments may be advanced against the Ringelmann chart, but the fact remains that it offers a practical measure of smoke as far as quality (the Ringelmann chart number), the length of time the smoke was emitted, and, by calculation, of quantity.[30]

"In this matter of smoke and dust abatement it is impossible to overestimate the importance of simple cheap tests. There is always the danger that highly trained engineers, overlooking the human and economic problems involved, will make smoke prevention unworkable by insistence on over-precise methods." [31]

The fact that a certain amount of smoke is unavoidable has been recognized and a limited amount of a specified intensity of smoke is allowed within a designated period of time, or when a fresh fire is being made or flues being cleaned. To date, no more accurate standard of measurement, which at the same time is as simple, practical and cheap as the Ringelmann chart has been put into use. More accurate systems of measurement exist but are costly and limited in their usefulness.

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[30] While quantity is not directly read from the chart, it may be calculated under the definition of a smoke unit. A smoke unit is defined as No. 1 smoke lasting 1 minute. So, No. 5 smoke for 6 minutes would give 30 units of smoke.

[31] Philip W. Swain, *Stack Smoke and Dust as a Community Problem,* Smoke Prevention Association of America, 41st annual meeting 1948, pp. 5 and 6.

3. Other Instruments and Methods of Measuring Smoke Density

The umbrascope is an instrument which has been used by some observers to assist in obtaining Ringelmann chart readings. The umbrascope is a tube into which a half circle of smoked glass may be inserted leaving the other half of the tube area open. An observer can compare the shade of the smoke with the shade of the glass. By inserting different glasses, different density shades can be matched.[32]

Instruments for giving periodic recordings of smoke density are available. One of these operates on a principle similar to the "electric eye" which is used to count the number of cars passing a point on the highway. This instrument employs a beam of light which is thrown across the chimney stack to a photo electric cell. When dense smoke is emitted, the beam is broken and an automatic record made. This type of instrument often is used on large furnace installations to let the fireman know that the smoke coming out of the chimney high above him is more dense than allowed by law.

Another instrument for measuring the density of smoke consists of a permanent arrangement of a light beam across the chimney to a "thermopile" which is heated by the light. If the beam of light is completely unobstructed, the recording is zero. If the beam of light is completely intercepted by dense smoke, the recorder gives a reading of 100 per cent smoke density. Unlike the previously mentioned instrument, the thermopile gives continuous readings of the smoke density while the aforementioned only records those times when the upper limit of smoke density has been

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[32] *Manual of Instructions on Proper Firing Methods*, Smoke Prevention Association of America, 1947-49, p. 9.

reached. The thermopile method of measuring smoke density was used during the summer of 1948 in a test made in the Mechanical Engineering Laboratory at the University of Illinois.[33]

The use of the last mentioned devices is confined to large furnace installations.

B. *Measuring Invisible Components of Smoke*

Although it is recognized that the invisible products of combustion are destructive and undesirable, no simple, easily used, inexpensive method of detecting the emission of these products has as yet been found.

The testing of chimney gases for the undesirable invisible products of combustion is not simple and generally not feasible for the small enforcement staffs of smoke control units, which usually do not have the technical staff for chemical analysis of the gas. Some industries have installed devices in their chimneys which make it possible to take samples of flue gases for analysis. However, the expense of getting samples of flue gas and then analyzing them makes the detection of undesirable flue gases almost impossible for the average smoke control enforcement staff.

C. *Dustfall Measurements*

To measure the amount of solid particles actually dropped from the atmosphere on a surface of known size over a period of time, several standards have been developed, such as the deposit gauge, the Owens automatic air filter, the impinger dust counter, the Owens jet dust counter and the electric air pollution meter.

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[33] "Present Status of the Illinois Smokeless Furnace" by J. R. Fellows, *Smoke Prevention Society of America*, 42nd Annual Meeting, 1949, p. 124.

The deposit gauge consists of a "large glass vessel of standard dimensions, open at the top and having a funnel-shaped bottom which leads to an otherwise closed collecting bottle. . . . Rainwater and the impurities settling from the air are washed down into the bottle and once a month this is removed and the contents analysed. From the weights obtained and the catchment area of the gauge the rate of deposit over a given area can be calculated." [34]

The data provided by the keeping of continuous records of a community's dustfall over a long period are of great value to the community itself as a partial measure of the effectiveness of a smoke abatement program. The records of the City of Pittsburgh for 1912-1913, show that 1031 tons of soot, ash or other solid particles were deposited per square mile in a year's time. (See Table I, page 40.)

The total of 1031 tons per year would give an average of 85 tons of dust deposited per square mile per month in Pittsburgh in 1912-1913. A survey made of the city in October and November of 1937 showed the dustfall to average 65 tons per month and, in 1947, the same months showed an average of 55 tons per month per square mile.[35]

Dustfall data may not be used for inter-city or inter-area comparisons because the determinants of measurable dustfall may vary from locality to locality. For example, average temperature and variations in temperature affect dustfall. In the southern cities, where the air is warmed by the earth, it rises quickly carrying off with it much of the solid particles,

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[34] Arnold Marsh, *Smoke, the Problem of Coal and the Atmosphere,* London, (Faber & Faber) 1947, p. 44.

[35] Ernest B. Brundage, "Dust Fall Studies," Smoke Prevention Association of America, 1948, p. 14.

Table I

Results of Determinations of Settled Dust in Selected American Cities

City	*Survey Organization*	*Area*	*Year of Survey*	*Time Period*	*Average No. of Tons of Dust Deposited Per Sq. Mi. Per Year*				
					Carbon	*Ash*	*Total Carbon and Ash*	*Rust*	*Tar*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Pittsburgh, Pa.	Mellon Institute	Whole City	1912-13	Whole Year	317	714	1,031	261	10.1
Salt Lake City, Utah	U. S. Bureau of Mines	Whole City	1919-20	Sept.-April	122	227	349	...	...
Grafton, W. Va.	U. S. Bureau of Mines	Whole Town	1922	April-Dec.	871	1,005	1,876	...	...
Cleveland, Ohio	Health Council	Whole City	1927-29	Whole Year	228	552	780	120	...
Baltimore, Md.	Health Dept.	Center City	1926-28	Mar. '26-Oct. '28	990	810	1,800	...	8.7
Baltimore, Md.	Health Dept.	3 mi. from center	1926-28	Mar. '26-Oct. '28	...	...	800	...	...
Baltimore, Md.	Health Dept.	10 mi. from center	1926-28	Mar. '26-Oct. '28	...	...	340	...	...

Source: U. S. Public Health Bulletin No. 224, U. S. Treasury Department, Washington, 1935, p. 7.

whereas in the north, the earth is colder and the air remains closer to the ground. Wind, rain, the wear of paving by traffic, dust from leaves, open fields and the type of industry present in the community have varying influences on the amount of air-borne dust. At best, variations in measurable dustfall are indications of changes in dustfall—part of which is produced by smoke—within a given community.

Although smoke contributes the major portion of the particulate matter in the atmosphere, it is not responsible for all the material deposited on the window sills of a neighborhood. A report made by the Chicago Association of Commerce, covering a long study of dustfall in that city, reveals that refuse in alleys, dust in streets and vacant lots, dirt on rooftops, materials from tires, clothes, shoes and buildings contribute large amounts of dirt. When the wind velocity is high, dust is blown from farms and fields many miles away.[36]

It is on the basis of the measurements of dustfall that Pittsburgh officials say that after eight years of smoke control (1942-50) the following results have been produced:

1. The atmosphere today has 65 per cent less dirt of all kinds than in 1945.
2. No smog (mixture of smoke and fog) for two years.
3. Visibility conditions for aircraft improved 75 per cent.
4. Atmospheric dust reduced nearly as much in the last year as in ten previous years.[37]

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[36] "A Comparison of Seasonal Variations in Dustfall and Other Factors Related to Air Pollution," prepared by the staff of the Chicago Association of Commerce for the Association's Committee on Smoke Abatement, Proceedings S. P. A. A., 1946, p. 11.

[37] *Philadelphia Inquirer*, April 23, 1950, p. 16A, Col. 7.

APPENDIX

Reference Table I

THE REGULATION OF SMOKE EMISSION AND AIR POLLUTION BY TWELVE SELECTED ORDINANCES

		Regulation of Smoke Emission						*Air Pollution Prohibited*	
			General Exceptions		*Special Exceptions*				
Ordinance	*Year of Adoption*	*Smoke Density Prohibited* [1]	*Density Permitted*	*Time Period Permitted*	*Excepted Purposes*	*Density Permitted*	*Time Period Permitted*	*Pollutants Prohibited*	*Emission Limits*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ORDINANCES IN PENNSYLVANIA:									
Allegheny County	1949	More Dense than #2	Greater than #2	2 min. in 15	Locomotives or Other Vehicles	Greater than #2	4 min. in 60 min.	Fly Ash	.85 lbs. per 1,000 lbs. gases
					Cleaning and Building Fires				
					Locomotive Ready for Service	Greater than #2	1 min. in 15		
Easton	1916	#3	None	None	Cleaning and Building Fires	#3 or greater than #3	6 min. in 60	Soot, Fly Ash, Fumes and Odors	When nuisance, no specific limit
					Locomotives and Steamboats. Cleaning and Building Fires	#3 or greater than #3	10 min. in 60		
					Locomotives and Steamboats	#3	1 min. in 60		
Erie	1948	#3	#3	Less than 2 min. in 15	Cleaning and Building Fires	#3 or greater than #3	20 min. per day	Same as above	Same as above
					Locomotives and Steamboats	#3	Less than 1 min. in 7		
Harrisburg	1921	#3 [2]	#3	Less than 2 min. in 15	Stationary Plants. Cleaning or Building Fires	#3	20 min. per day	No Provisions	No Provisions
Norristown	1946	#2 [3]	None	None	Cleaning and Building Fires	#2 or greater than #2	9 min. in 60 60 min. in 60	Soot and Fly Ash	When nuisance, no specific limit
Philadelphia	1948	More Dense than #2	None	None	Locomotives and Steamboats. Cleaning and Building Fires	#3	6 min. in 60	Soot, Fly Ash, Fumes and Odors	When nuisance, and when more than .85 lbs. per 1,000 lbs. of gases
					Cleaning and Building Fires	#3	10 min. in 60		
					Locomotives and Steamboats	Less than #3	3 min. in 15		
Pittsburgh	1941 (as amended)	#2	None	None	Cleaning and Building Fires	#2 or greater than #2	9 min. in 60 6 min. in 60	Soot, Fly Ash, Fumes and Odors	.75 grains per cubic foot
					Locomotive in Service	#2	1 min. in 60		
Washington	1934	#3 [4]	#3	Less than 2 min. in 15	Cleaning and Building Fires for Stationary Plants	#3 or greater than #3	20 min. per day	No Provisions	No Provisions
ORDINANCES IN OTHER STATES:									
Boston, Mass.	1910 (as amended)	#2 and #3 [5]	See Footnote [5]		Locomotives. Cleaning and Building Fires	Not specified	10 minutes	No Provisions	No Provisions
					Locomotives	Not specified	5 seconds in 5 minutes		
Chicago, Ill.	1928 (as amended)	#3	None	None	Cleaning and Building Fires	#3	6 min. in 60	Soot, Fly Ash, Fumes and Odors	When nuisance, no specific limits
Los Angeles County, Calif.	1947	#2 [6]	Greater than #2	3 min. in 60	None	None	None	Air Contaminants	.4 grains per cubic foot [7]
St. Louis, Mo.	1937 (as amended)	#2	None	None	Cleaning and Building Fires	#2 or greater than #2	9 min. in 60 6 min. in 60	Soot, Fly Ash, Fumes and Odors	When nuisance, and when more than .85 lbs. per 1,000 lbs. of gases
					Locomotives Ready for Service [8]	#2	1 min. in 60		

[1] Densities as shown in Ringelmann Chart.

[2] Railroads and private residences of not more than 5 apartments are excepted from the provisions of the ordinance.

[3] Railroads are excepted.

[4] Residences are excepted.

[5] Densities prohibited and exceptions are classified according to size of stack as follows:
(Stacks range from small to large)

Stack Class	*Prohibited Density*	*Exception to Prohibited Density*
1	#2	May be exceeded for 6 min. in 60
2	#2	May be exceeded for 6 min. in 60 (Density of #3 permitted for 3 min. in 6 min.)
3	#2	May be exceeded for 25 min. in 60 (Density of #3 permitted for 5 min. in 25)
4	#3	May be exceeded for 3 min. in 60
5	#3	May be exceeded for 5 min. in 60
6	#3	May be exceeded for 15 sec. in 5 min.
7	#3	May be exceeded for 10 min. in 60

[6] Exceptions are as follows:

A. Fires set by or permitted by a public officer in the performance of official duties for weed abatement, prevention of a fire hazard, or instruction of public employees in the methods of fighting fires.

B. Agricultural operations.

C. Orchard or citrus grove heaters if not more than 1 gram of unconsumed solid matter is emitted per minute.

[7] Emission limits are contained in special table of rules and regulations for special types of combustion.

[8] All locomotives must use smokeless solid fuel or oil, mechanical stokers, or must be powered by diesel or electric engines when within city limits.

Reference Table II

SMOKE CONTROL METHODS OF REGULATION, FEES AND PENALTIES IN THIRTEEN SELECTED AREAS

Areas Under Smoke Control Ordinances Studied	Methods of Regulation — I. Regulation of Construction, Reconstruction, Alteration, and Major Repair of Fuel-burning Devices		II. Regulation of Sale and Use of Solid Fuel		III. Inspection of Fuel-burning Devices		IV.	V.	Fees			Penalties and Fines	
	Approval of Plans and Installation Permits Required	*Operating Permit Required*	*Sale and Use of Solid Fuel Regulated*	*Volatile Content of Solid Fuel Permitted*	*Required Inspections*	*Specific Authority for Inspection Officer to Enter Buildings*	*Regulation of Leasing and Sale of Fuel-burning Devices*	*Authority for Sealing Non-complying Devices*	*Inspection of Plans*	*Examination of Plant*	*Annual Inspection*	*Amount of Fine*	*Time Period Constituting a Single Offense*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
PENNSYLVANIA:													
Allegheny County	Yes [1]	Yes	Yes [2]	23%	No Provision	Yes	Reports by Sellers and Lessors to Bureau	Yes	Domestic Plants—$2.50 Other Plants—$2.50 to $20.00		No Provision	$25.00 to $100.00	One Day
Easton	Yes	Yes	No Provision	No Provision	No Provision	No Provision	No Provision	No Provision	Construction —$1.50 Alteration and Repair—$1.00	No Provision	No Provision	$5.00 to $50.00	One Day
Erie	Yes [3]	No	No	No Provision	Annual	Yes	No	No	Construction —$5.00 Alteration and Repair—$3.00	$5.00	$3.00	Second Offense $25.00 Third Offense $50.00 Fourth Offense $100.00	One Day (After Fourth Violation)
Harrisburg	Yes	No	No	No Provision	No	Yes	No	No	$1.00	No Provision	No Provision	$100.00	One Day
Norristown	No	No	No	No Provision	No	No	No	No	No Provision	No Provision	No Provision	Not More than $100.00	One Day
Philadelphia	Yes [4]	No	No	No Provision	Periodically	No	No	No	$5.00	No Provision	No Provision	$10.00 to $100.00	One Day
Pittsburgh	Yes	Yes	Yes	20%	Annual	Yes	Reports by Sellers and Lessors to Bureau	Yes	$1.00 to $5.00	$2.00 to $5.00	$2.00 to $5.00	$25.00 to $100.00	One Day
Washington	No [5]	No	No	No Provision	No	No	No	No	No Provision	No Provision	No Provision	$25.00	One Day
OTHER STATES:													
Boston, Mass.	Yes [6]	No	No	No Provision	No	No	No	No	No Provision	No Provision	No Provision	First Offense $10.00 to $50.00 Thereafter $20.00 to $100.00	No Provision
Chicago, Ill.	Yes	Yes	No	No Provision	Annual	No	No	Yes	$1.10 to $5.00	$5.00 to $15.00	$5.00 to $10.00	$5.00 to $200.00	One Day
Los Angeles County, Calif.	Yes [7]	Yes [7]	No	No Provision	No	Yes	No	No	$4.00 per hr.	$4.00 per hr.	No Provision	Violation Is Misdemeanor (No Penalty Prescribed in Law)	One Day
New York, N. Y.	Yes [8]	Yes	No	No Provision	No Provision	No Provision	No	Yes	No Provision	No Provision	No Provision	First Offense $25.00 to $100.00 Thereafter, $50.00 to $100.00	No Provision
St. Louis, Mo.	Yes	No	Yes	23%	No	Yes	Examination of Sales Records	Yes	$1.00 to $22.00	$1.00 to $3.00	No Provision	$25.00 to $100.00	One Day

[1] Unless secret process is involved. No hand-fired equipment may be approved except for domestic use. Locomotives and boats are exempt from this provision.
[2] Apply only to: Central station power plants, central station heating plants, industrial power plants, industrial heating plants, central heating plants, and domestic heating plants.
[3] Does not apply to residences housing fewer than four families.
[4] Does not apply to residences housing three families or less.
[5] Ordinance specifies that fuel-burning devices which will violate the ordinance may not be installed.
[6] Only if floor space of building is more than 5,000 sq. ft.
[7] No permits or approval of plans required for: Agricultural operations; orchard or citrus grove heater if not more than 1 gram of unconsumed solid matter emitted per minute; city, county, municipality, district or political subdivision; construction or repairs not more than $300.00.
[8] Except as rules and regulations may otherwise provide.