

**Report on the causes & prevention of smoke from manufacturing chimneys
/ by Harvey Littlejohn.**

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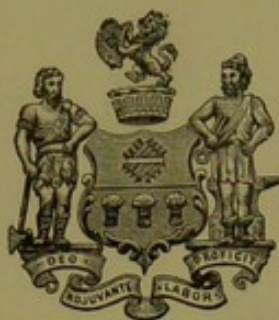
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CITY OF



SHEFFIELD

REPORT

ON THE

CAUSES & PREVENTION

OF SMOKE

FROM MANUFACTURING CHIMNEYS

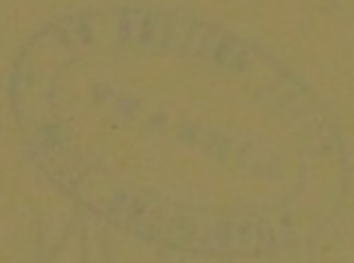
BY

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MEDICAL OFFICER OF HEALTH.





TOWN HALL, SHEFFIELD,

MARCH 20TH, 1897.

*To the Chairman and Members
of the Health Committee.*

GENTLEMEN,

In accordance with your request that I should report upon the subject of the Smoke Nuisance in Sheffield in its relation to the smoke arising from manufacturing processes, I beg to state that I have carefully considered the question, and have endeavoured in the following pages to lay before you information which I trust may be found of service in dealing with the question in the future.

I regret the delay which has occurred in the appearance of the Report, owing to various unforeseen causes, but I trust that this will not be considered altogether a disadvantage, looking to the fact that last year has seen a great revival of interest in the question of the Prevention of Smoke in Sheffield, resulting in useful correspondence in the daily Press on the subject, and has also witnessed the publication of the Report of the Committee for testing Smoke Preventing Appliances—a valuable document to which all those interested in the subject had been looking forward for a considerable time.

By your permission I was enabled to consult two eminent experts on the subject of Smoke Prevention—Mr. A. E. Fletcher, late H.M. Chief Inspector under the Alkali Acts, and Professor Ripper, of the Technical School, the latter of whom kindly undertook certain experiments in connection with the question, and to both of whom I am much indebted for advice and assistance.

Although it may almost seem superfluous after all that has been written and ascertained on the subject, to discuss at the present day the question of the nuisance arising from manufacturing smoke, and to enter into a consideration of its causes and the means by which it may be prevented, in so far at least as steam boiler furnaces are concerned; yet so many erroneous views are held upon some of the

most important points involved, and opinions frequently expressed in discussing the question betray such an absence of just appreciation of what has been already effected and of the difficulties underlying the subject, that I have ventured to go somewhat fully into it, and to lay before you, in the first instance, a short account of the official proceedings which took place in earlier years with a view to abate what was even then recognised as a great nuisance.

From a perusal of these proceedings it will be recognised how little knowledge of the subject has advanced, while on the other hand, the clearness with which the practicability of reducing the emission of smoke is acknowledged, ought to serve as a stimulus to every one in the present day to endeavour to secure the practical solution of the smoke problem.

Select Com-
mittee on Smoke
Prevention,
1819.

It is interesting in going into the past history of the subject to find how soon after the invention of the Steam Engine, the consideration of the question came to receive the attention of the public, and resulted in the appointment of a Select Committee of the House of Commons to deal with it. Such a Select Committee was appointed in 1819 "to inquire how far it may be practicable to compel persons using Steam Engines and Furnaces in their different works to erect them in a manner less prejudicial to Public Health and Public Comfort, and to report their observations thereon to the House."

Their Report was as follows:—"That from the advanced period of the session at which the appointment of your Committee took place, it was not to be expected that they could form any ultimate decision as to the precise object of their enquiry, but as far as they have hitherto proceeded, they confidently hope that the nuisance so universally and so justly complained of, may at least be considerably diminished, if not altogether removed.

"Your Committee have had under examination men whose minds have been long and practically directed to the extinction of the evil, and from their evidence as well as from the plans which will be found in the appendix, the House will be enabled to judge how far their opinions correspond with those of your Committee.

"The disinterested communications made by persons whose private interests might have led them to a different line of conduct, cannot be too highly valued or extolled."

Several forms of apparatus for preventing emission of smoke were submitted to this Committee, some admitting air at the bridge, and others being in the form of mechanical coking stokers; in fact, founded on the same principles which underlie most of the forms of apparatus of the present day. As a matter of general interest, in Appendix I, I

reproduce from the Report a letter from Mr. Wakefield, who invented an apparatus to consume smoke, from which it will be seen that at the end of last century the question of smoke abatement was receiving attention; and in Appendix II, the letter of Mr. Coombs shows how thoroughly, even at that time, the principles underlying smoke prevention were understood.

The same Select Committee continued its labours, and in the following year a further Report by them was published as follows: "The revival of your Committee has afforded a full opportunity of ascertaining how far the reduction of smoke in furnaces of different descriptions can be practically accomplished, and the evidence detailed in the Appendix will show that the object the House had in view has been satisfactorily and effectually attained."

In this publication evidence was given as to the success which had attended the application of various inventions for preventing smoke, and amongst others, that of Mr. Josiah Parkes, which for many years was extremely popular, and is stated to have been applied with complete success at Messrs. Barclay and Perkins' brewery, both to the steam boilers and to the brewing pans.

Select Com-
mittee on Smoke
Prevention, 1843

No legislation appears to have resulted from the labours of this Committee, and in 1843 a voluminous Report and Minutes of Evidence of another Select Committee was issued. This Committee was appointed "to inquire into the means and expediency of preventing the nuisance of smoke arising from fires or furnaces, and who were empowered to report their opinion, together with the minutes of evidence taken before them, to the House." The ground covered by the evidence submitted to this Committee was exceedingly wide, embracing nearly every point involved in dealing with combustion and the action of smoke, while evidence was given by eminent men in science, manufacturers, and persons who had devoted themselves to studying the question, amongst others being Dr. Muntz, Dr. Reid, Sir Michael Faraday, Dr. Neil Arnott, Mr. Houldsworth, of Manchester, and the Rev. Dr. Molesworth, the founder of the Smoke Abatement Association of Manchester.

The Report of the Committee states "that the attention of the parties called to give evidence has been principally directed to the consideration of the following heads on which their opinions were given:

1. "Whether it was practicable entirely to prevent, or very much to diminish, the nuisance now so severely felt in large towns and populous districts, from the smoke of furnaces or of steam engines.

2. "Whether, if this were practicable, it would be advisable to take any steps to prevent the nuisance, as so doing might interfere with the property or interests of manufacturers, or of proprietors of furnaces.

3. "If, in the event of the two former questions being answered in the affirmative, they would recommend some legislative enactment to be framed to prohibit the nuisance of smoke.

"In regard to the first of these questions, it appears from the whole of the evidence of scientific and practical men, including master manufacturers, that smoke, which is the result of imperfect combustion, may in all cases be much diminished, if not entirely prevented.

"It appears to be the unanimous opinion of the witnesses conversant with the subject, that imperfect combustion arises from a deficiency of atmospheric air to mix with and act on the inflammable matter at a proper temperature, and under circumstances which must ensure its effective operation; but this admission of air, properly regulated, is the great if not the only principle of preventing smoke which is generally applicable, and that all inventions for the prevention of smoke (except where the smoke has been separated mechanically by an artificial shower of water, produced from a flue constructed for the purpose), are only various applications in different forms of this general principle; even the flow or jet of steam which has been applied by some persons to prevent smoke in furnaces, being merely a modification of this general principle, as, though steam may modify combustion, air must necessarily flow in with it, otherwise the combustion in the furnace is arrested."

The Committee likewise urged the immediate introduction of legislation to prohibit the production of smoke from furnaces and steam engines.

A Bill had been prepared by Mr. Hall, in accordance with the suggestion of the Select Committee of 1843, and in consequence of the opposition it excited, yet another Select Committee was appointed in 1845, "to enquire into the means and expediency of preventing the nuisance of smoke arising from flues or furnaces."

The proposed Bill provided "for the appointment of any police officers or other competent persons as Inspectors of Smoke Nuisances in any district," and "that it should not be lawful for the occupiers of any furnace or chimney to permit opaque smoke to issue from such chimney for any longer period of time than is necessary for the kindling of the fire of such furnace in connection with such chimney, and previous to the running of any engine connected therewith, which time allowed for kindling such fire shall not exceed (?) minutes." Penalties were proposed of not less than 20/- for a first offence, 40/- for a second offence, and a larger penalty for each succeeding offence, while it was

also proposed that, if it could be shewn that the stoker or other person was at fault, the magistrates could order the part or whole of the penalty to be paid by such person, and, if necessary, deducted from his wages. The evidence before the Select Committee came largely from Leeds, and dealt more with the question of legislative interference, the persons upon whom responsibility should rest and the penalties, than with the general question of smoke prevention. The Report of the Committee was as follows:

“That opaque smoke issuing from steam engine chimneys may be so abated as no longer to be a public nuisance.

“That a variety of means are found to exist for the accomplishment of this object, simple in construction, moderate in expense, and applicable to existing furnaces and flues of stationary engines, as well as to those hereafter to be erected.

“That a sufficient body of evidence has been adduced, founded upon experience of practical men, to induce the Committee to be of opinion that a law making it imperative upon the owners of stationary Steam Engines to abate the issue of opaque smoke is desirable for the benefit of the community.

“That in the present knowledge and experience upon the subject, it is not desirable to extend the provisions of an Act beyond the furnaces used for the generation of steam for the working of stationary steam engines.

“That in the provisions of an Act for this purpose the offence will be best described as being ‘the issue of opaque smoke.’

“That a penalty shall attach to the occupier of the property or to the person employed in the care of the furnaces.

“That some public functionary or functionaries be appointed, as shall be provided, whose duty it shall be to take cognizance of the nuisance, and to bring the parties offending before the constituted authorities in the locality in which the nuisance shall be proved to exist.”

It is interesting to note that in the proposed Bill the term “Opaque Smoke” is used; opaque smoke being defined as smoke not transparent at the point of its exit from the chimney. This term was, I think, rightly taken exception to by some of the witnesses, who held that the use of the term would lead to differences of opinion, and a variety of interpretations, and it was suggested that the word “smoke” should be defined to mean smoke of a different quality and amount from that which would proceed from the chimney if the furnace were properly constructed with efficient apparatus, and proper attention were paid to the same by the stoker. In other words the offence would consist in omitting to provide a proper furnace and apparatus, or the negligent

use of it, and the evidence of this would be the issuing of the smoke of the character mentioned.

Further Report
of Committee,
1845.

In the same year, 1845, the Select Committee issued a further Report as follows: "Your Committee, in pursuance of the object for which it was revived, has examined the witnesses, whose evidence is hereunto appended, and it appears to your Committee inexpedient under existing circumstances to apply the provisions of the proposed Bill to furnaces connected with the manufacture of iron, copper, and coal works, and with distilleries."

The above exceptions were probably made on account of the opposition which the Bill elicited from manufacturers in those trades, of whom a large number gave evidence before the Select Committee after the publication of their first Report. Amongst others, I find that Mr. Thomas Dunn presented a petition from the Town Council of Sheffield against the Bill, on the ground that "the process of applying steam to the purpose of Sheffield manufacture is peculiar, the power of the engine being of necessity applied in an irregular manner, not in the same manner as in a silk or cotton or woollen mill, when after the steam is first got up the same amount is wanted till the engine is put down altogether. In Sheffield nearly all the processes to which steam is applied are powers that want irregularity, as in the rolling of iron or steel."

The proposed Bill was subsequently withdrawn upon an understanding that the subject should be left in the hands of Government, and that some general measure, having for its object the supervision of smoke in towns and populous districts, should be submitted to Parliament.

The Government considered that there were matters connected with the question which still required investigation, and therefore appointed Sir Thomas de la Beche and Dr. Lyon Playfair to make an enquiry into the means then adopted for the prevention of smoke in various parts of the kingdom, with the view of ascertaining how far those means are generally applicable to large towns and populous districts.

Report of Sir
Thomas de la
Beche and Dr.
Lyon Playfair,
1846.

The report of those gentlemen, which was published in 1846, is an extremely valuable one, and demonstrates clearly how well the difficulties of the subject were recognised at that time, and how little progress has been made during the last fifty years in dealing practically with the question.

In proof of this fact I give in Appendix III. extracts from the Report, from which it will be seen that the reporters were fully alive to the possible injury to trade from too exacting a measure for repression of the nuisance, and that they recognised the fallacies underlying many of the statements so frequently put forward as to the economy of smoke prevention.

They state, "as the prevention of smoke implies the complete combustion of fuel, the result, as an abstract statement, always is, that more heat is generated, and a saving of fuel effected, when it is so consumed as to prevent the emission of smoke; but although this theoretical conclusion is undoubtedly correct, the practical results are not always consonant with this statement.

"In consuming smoke in the usual way a quantity of cold air is introduced into the fire, and as this must be heated up to the temperature of the surrounding fuel, the loss of the latter may be equal to, or even greater, than the saving of the fuel from the products of the combustion of distillation."

The causes of the emission of smoke in manufactories are classed under three heads, and I think even at the present day a better classification could not well be submitted, and it might with confidence be recommended for the consideration of all manufacturers who have not yet succeeded in effectively dealing with the smoke from their chimneys.

1. "The want of proper construction and adjustment between the fire places and the boilers, and the disproportionate size of the latter to the amount of work which they are expected to perform.
2. The deficiency of draught and improper construction of the flues leading to a chimney of inadequate height and capacity.
3. The carelessness of stoking and management by those intrusted with the charge of the fire places and boilers."

Another point which has frequently been referred to in discussing the question of smoke abatement in this city lately, is also referred to, viz., the absence of power to fix responsibility on stokers. The Report states: "In all the towns referred to complaints were made of the absence of power to inflict a small fine upon the stoker for carelessness in managing any smoke consuming apparatus, or even in stoking ordinary fires. Upon this point the opinion is universally expressed that all Acts will be inoperative unless the stoker also, as well as the master, be made an interested party in seeing to the due execution of the Act."

No practical step appears to have been taken by Government to deal with the question by the introduction of a Bill as promised, although Parliament sanctioned clauses in Local Improvement Bills dealing with the abatement of the Smoke Nuisance. Among the towns which obtained such clauses being Leeds, Manchester, Liverpool and Derby.

In 1853 Lord Palmerston requested the General Board of Health to obtain information in regard to the consumption and means of prevention of smoke, and the following year the Board issued a long

report on the subject, in which many of the statements are naturally a re-iteration of those which had previously been made in the published Reports of Select Committees of Parliament, although founded upon more recent information and renewed investigations.

The document asserts the possibility of entirely preventing in many cases, or at any rate very considerably diminishing the smoke commonly emitted from boiler furnaces, without the use of any extraordinary care, by alterations neither expensive nor troublesome, if the furnace is not very badly constructed; and it is further stated, that smoke may be prevented in many cases by good stoking alone, and by slightly opening the furnace door after putting on coal, and that smoke from *all* furnaces may be much more greatly diminished.

From enquiries made from 56 firms which had adopted various means for the diminution of smoke, it was found that in answer to the the question—"Have you succeeded in diminishing smoke?" 23 replied "yes," and 18 replied "almost entirely," while only three seem to have entirely failed. Replies by the same firms to other questions, showed that in only 8 cases was there difficulty in maintaining the requisite heat without producing smoke, while, in the large majority of cases, it was stated that a considerable saving in fuel had been effected.

The Report states that "after such instances of success, it is impossible to deny that smoke may be prevented. Numerous cases, indeed, of partial and some of complete failure, have occurred, but these only show that proper means have not been used, or that the means employed have not been adapted to the particular cases."

Another point which is mentioned, and the importance of which cannot but be recognised by all who have had experience in connection with appliances for preventing smoke, refers to the importance of care on the part of the stoker. "From the communications received, it appears that nearly perfect success has been attained by various contrivances, and in many cases without any contrivance at all, by good stoking alone, and in others by the use of smokeless fuel; but that good success has rarely been attained without increased care by the stoker. Such care it is unreasonable to expect without, in some way or other, making it his interest to succeed, and at the same time providing him with a furnace by which he can succeed without very much additional labour."

In the Appendix IV. will be found the full detailed conclusions arrived at by the Board of Health, and I will therefore only quote one of them here, because it really touches the kernel of the question as applicable to the majority of steam boiler owners. It is: "That the chief impediment to the prevention of smoke in manufactories, is

the insufficient boiler surface in proportion to the steam required, a deficiency which causes waste in two ways: first, because much of the heat produced escapes up the chimney uselessly; and next, because this deficiency has to be made up by overfiring, whence imperfect combustion and consequent waste of fuel."

er to Local
ities, 1866

In 1866, the Secretary of State addressed a letter to the Mayors or Local Authorities of 14 large towns in England, with respect to the consumption of smoke, more especially asking for information as to the Act under which prosecutions were taken, the number of convictions obtained, and the effect produced in diminishing the smoke.

Almost all the towns, including Sheffield, stated that they proceeded under the "Towns Improvement Clauses Act," and that a diminution had taken place in regard to the nuisance. Birmingham, Liverpool, and Sheffield, show by far the largest number of convictions obtained; those in Sheffield, during the years 1855-1865 inclusive, amounting to 445, the smallest number in any year being four in 1860, and the highest, 74, in 1865. This shows a remarkable activity in dealing with the nuisance during these years, and it would be interesting to know what penalties were inflicted, and the cause of the reduction in the number of prosecutions undertaken after the introduction of the Public Health Act, 1875, under which proceedings are now taken.

In the preceding pages I have endeavoured to give an outline of what had been done towards a solution of the question of the smoke nuisance since the time when it first began to attract public attention, and assume such proportions that the legislature was compelled to deal with it. We have seen that so long ago as 1819, public opinion was so strong that the matter was considered by a Select Committee of the House of Commons; and in subsequent years Committees were appointed who took evidence from persons qualified to give an opinion, manufacturers and scientists, as well as those who had made the means of prevention the subject of special study. As year after year the steam power of the country underwent developments co-extensive with the enormous advances made in every branch of industry and manufacture, the nuisance arising from smoke in the large centres of population and mercantile activity became more and more felt, and Parliament was constantly being approached with a view to some restrictive measure being passed to abate what was in the belief of many not only acting deleteriously upon health, but also interfering seriously and unnecessarily with the comfort and amenity of town life.

The evidence adduced before the various Select Committees leaves nothing to be desired, either as regards the representation of the various trades of the country or a clear exposition of the elementary principles of combustion of fuel, and the fundamental lines upon which the

solution of the question must rest, while the many difficulties and obstacles in the way of practically enforcing any general law upon the subject without unjustly affecting certain of the trades and manufactures of the country received due consideration. Indeed after reading the evidence adduced before the various Committees, and comparing it with more recent publications and reports on the same subject I am unable to discover any material fact in relation to the prevention of smoke from steam boilers which is not recorded and fully dealt with in the Blue Books from which I have given extracts.

Legislation in
regard to the
Prevention of
Smoke.

Having regard to this fact and to the popular demand which must have existed for legislative action, as shewn by the enquiries carried out by Government, it is astonishing to find that the only results have been a clause in the Towns Improvement Clauses Act, 1847, and the sections of the Public Health Act, 1875, under which proceedings to abate the nuisance are at present undertaken. Indeed, so far as can be judged from the Return of the action taken in certain large centres of population quoted above, much more activity seems to have been displayed under the former Act than under the more recent powers obtained in 1875. The comparative indifference shewn to the question, except by a few local associations and private individuals during the last quarter of a century is a fact difficult to account for, since the nuisance can hardly have diminished, the evidence rather indicating a very large increase, both as a result of the smoke emitted by house fires, as well as from the chimneys of manufacturing premises.

One explanation of this circumstance appears to me to be, that both the Towns Improvement Clauses Act and the Public Health Act of 1875 failed to give due effect to the fact, which the evidence before the Select Committees clearly proved, that with certain restrictions smoke from steam boiler furnaces can be practically done away with. By leaving this point still a question of proof, in every case, before a bench of magistrates, often themselves personally interested in the subject, and who, not unnaturally, were out of sympathy with the efforts of the municipal officials charged with the carrying out of smoke prosecutions, the difficulties in the way of securing convictions with adequate penalties were increased, and the enforcement of the law became less and less frequent.

Various associations founded for the purpose of influencing public opinion on the subject have been formed in many of the large manufacturing towns, and undoubtedly have done good in stimulating opinion on the subject, and securing efforts at abatement. To my mind one of the great objects to be kept in view in dealing with this subject is to impress upon the manufacturer, who so far as my experience goes, is by no means unwilling to show practical sympathy with the movement,

that smoke from steam boilers can be almost entirely abolished, and this, if not with a saving of expense, at least at little or no appreciable extra cost.

Since, notwithstanding all that has been written on the subject, considerable ignorance and misapprehension still exists upon the subject of the smoke nuisance as regards its causes, its effects, whether on health or upon the comfort of the community, and the means and methods of prevention, I propose to deal shortly with each of these subjects, though I fear much of what I have to say will only be a re-iteration of what has been already published on the question.

THE CAUSES OF THE SMOKE NUISANCE.

The presence of smoke in the atmosphere of Sheffield is due to three causes. 1, house fires; 2, steam boiler furnaces; and 3, the combustion of coal in connection with various processes of metal manufacture.

Unfortunately Sheffield has acquired a very bad name all over the country on account of its smoke-laden atmosphere, and too often invidious comparisons are made contrasting it with other towns. For the purposes of agitation, and to excite an interest among the general public on the question such comparisons are all very well, but in any endeavour to deal seriously and practically with the undoubted nuisance, it has always appeared to me that more sympathy with the movement would have been created among those more especially implicated, had the special difficulties and circumstances of Sheffield been more generally recognised.

The special circumstances of the town to which I allude are, in the first place, the fact that Sheffield is probably unique in the large number of its manufactures which are of a kind depending almost wholly upon the combustion of coal, not so much in steam boiler furnaces as in other forms of furnace not readily adaptable for consumption of smoke. And in the second place to the fact, that even in the case of steam boiler furnaces, owing to the irregularity in the power required, difficulties exist which are non-existent in most other trades in which steam power is used.

Sheffield may be said to be the chief workshop of the heavy trades of England, if not of the greater portion of the world, and while doubtless no effort should be spared to reduce the emission of smoke, it is idle to set up as a standard of excellence other towns where the conditions are wholly different, and to compare their clear atmosphere with ours. As long as Sheffield trade consists in the manufacture of iron and steel and cognate processes, the atmosphere of Sheffield must necessarily suffer in comparison with that of other towns, and a certain amount of smoke and consequent discomfort is one of the penalties those who are

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connected with the trade of the town and who are compelled to reside in it will have to suffer.

In stating this, however, I do not wish to be understood to mean that much of the smoke at present emitted cannot be considerably diminished, and that a great improvement in the present state of the atmosphere cannot be effected, but I merely emphasise what by many appears to be ignored, that the manufactures of the town place it in an exceptional relation to the smoke question, and that the attainment of a clear and smokeless atmosphere is not practicable under the circumstances.

Nothing will bring the truth of this home to many of us better than a statement of the annual consumption of coal in the town. Roughly calculated, but sufficiently accurate for the purpose, the amount of coal consumed in Sheffield annually is about 1,250,000 tons, and this too, within an area of 30 square miles. Excluding, however, the rural and thickly populated portions of the City, the area in which this enormous consumption takes place, cannot be more than 20 square miles, while the great bulk is consumed in the districts of Attercliffe and Brightside, which have a combined area of about seven square miles. In a paper published in 1892, by Mr. A. E. Fletcher, it was estimated that the coal consumption of London was the same as in Sheffield, viz., 1,250,000 tons, spread, however, over an area of no less than 225 square miles. Such a fact as this brings home vividly one of the causes why the town has often a somewhat gloomy and depressing aspect, and at the same time draws attention to one of the obstacles in the way of attaining, notwithstanding the efforts which have been made, any striking and distinct purification of the atmosphere.

The sources of the smoke are those mentioned above :—house fires, metallurgical furnaces, and steam boiler furnaces. In dealing with the first two, difficulties are found which do not exist in the case of steam boiler furnaces; and although I propose later to refer to the question of smoke from metallurgical furnaces, any subsequent remarks relate to the third class, in connection with which no such difficulties arise under ordinary circumstances.

Smoke consists of vapours, produced by the partial combustion or distillation of coal, carrying up small particles of fuel in mechanical suspension, and depositing by the combustion of one of their constituents, carbonaceous matter in a fine state of division. The mode of preventing this smoke is to admit a sufficient quantity of air to effect the combustion of the carbonaceous matter when the vapours are of a sufficiently elevated temperature to unite entirely with the oxygen of the air. If the temperature be not sufficiently elevated, the hydrogen

Smoke from
Steam Boiler
Furnaces.

of the vapour alone is consumed, and the carbon is separated in the fine state of division referred to. The gases produced by the complete combustion of fuel are colourless and invisible, and therefore do not come under the definition of the term smoke.

The causes of the emission of smoke have been well classified by Sir Thomas de la Beche and Dr. Playfair, in the report previously referred to, viz. :

1. The want of proper construction and adjustment between the fire places and the boilers, and the disproportionate size of the latter to the amount of work which they are expected to perform.

2. The deficiency of draught, and improper construction of the flues leading to a chimney of inadequate height and capacity.

3. The carelessness of stoking and management of those entrusted with the charge of the fire-places and boilers.

These three causes deserve the careful consideration of every one interested in the use of steam power ; and there can be no question that a disregard of the conditions of work in connection with steam power as regards these three conditions, is the most fruitful cause of the production of smoke from such furnaces. It will be remarked also, that the remedying of defects such as are indicated, does not necessarily involve great cost to the manufacturer, except perhaps, under certain circumstances in the first case.

In many instances, however, the deficiency of boiler room is the fault of the manufacturer himself, who either has laid down a boiler insufficient for the work required in the first instance, or has gradually increased the calls upon the available steam power until the boiler can only be made to respond to what is required by over-firing.

One of the conclusions come to by the General Board of Health in 1855, was " That the chief impediment to the prevention of smoke in factories, is the insufficient boiler surface in proportion to the steam required ; a deficiency which causes waste in two ways, first, because much of the heat escapes up the chimney uselessly, and next, because this deficiency has to be made up by over-firing, when imperfect combustion, and consequent waste of fuel results."

Efficiency of
Boiler Room.

The great importance of this question of having sufficient boiler room has not been so fully insisted on in connection with the prevention of smoke as it ought to have been. It is a very common cause, apart from all others, of the nuisance in this town, and manufacturers, in many instances, instead of recognising it as the true cause of the smoke emitted from their chimneys, have sought to provide a remedy by adopting some form of so-called smoke preventing apparatus. No smoke preventing apparatus will act efficiently and prevent smoke

where the discrepancy between the boiler space and the work required is considerable, thus accounting in so many instances for the apparent failure of the apparatus. No doubt where the deficiency is not great, some form of apparatus will help to counteract the effects of hard firing, and thus show an improvement in the amount of smoke emitted, but I repeat that where boiler space is manifestly deficient, there is no apparatus in the market which can be relied on to counteract such deficiency.

It has been stated, and I venture to think that the statement cannot be gainsaid, that the safest, cheapest, and soundest principle to work on, is always to have such an excess of boiler room, more than is wanted for general work, that the fire never need be overloaded with coal, or forced in its work. Where the room is limited, the fire has constantly to be raked, and an excessive amount of coal is used, and heat is wasted.

No doubt there would be initial extra cost in providing the requisite boiler room, but the life of the boiler, which is not overworked, is longer, while economy would also be effected in other directions, sufficient probably to cover any expense incurred. In a few instances the compulsory provision of extra boiler room would be a hardship, as in small factories where the space is limited, and the cost of alterations might be unduly oppressive, but such cases would, I believe, be exceptional.

As the question of boiler room is of such importance in relation to the prevention of smoke, it would, in my opinion, be advisable that any future legislative enactment should deal (prospectively) with this subject, so as to ensure the provision of suitable furnaces, and a sufficient amount of boiler room for the power required.

Deficient
Draught

The second great cause of smoke emission is the deficiency of draught and improper construction of the furnace.

This source of smoke production is by no means uncommon, and although the proper admission of air is one of the elementary principles of economical steam production, the greatest ignorance prevails amongst firemen and stokers upon the subject. A knowledge of combustion and the method of providing the air required for the process underlies the whole question of economical steam raising, and practically all the inventions for the prevention of smoke are founded upon the admission or exclusion of air at certain points of the furnace, so as to aid complete combustion, and at the same time utilise to the best advantage the heat derived from it. The more complete combustion is, the less unburnt fuel escapes in the form of smoke, the greater is the heat derived from the same quantity of fuel, and hence the greater is the economy effected.

Mr. A. E. Fletcher, late H.M. Chief Inspector under the Alkali Acts, who has done so much to aid the advancement of the question of smoke abatement in this country, has put the conditions necessary for efficient combustion so clearly that I may be excused in quoting what he says: "*First*, there must be a sufficient quantity of air; *secondly*, the air must be brought into intimate contact with the fuel, whether solid or gaseous; *thirdly*, the mixture of air and fuel must be kept for the necessary time at an incandescent temperature."

"As to the admission of air. There must be enough of it, but on the other hand it must not be extravagantly supplied, for every cubic foot of air which passes through or over the fire unused goes away at a high temperature, thus causing a loss of heat. If possible the quantity of air should be so adjusted to the amount of fuel to be consumed that all the fuel is burnt, while there is no air in excess. Such perfect arrangements are of course not to be expected in practice, an excess of air must be allowed. The excess is sometimes brought as low as four per cent. of the gases of combustion, but more often ten per cent. or even fifteen per cent. is found, showing that two or three times as much air has been used as was necessary. Even the admission of this large excess of air to the furnace is, however, no guarantee that complete combustion has been effected unless rule No. 2 has been observed. That is to say, this air will be of little use unless it has been brought into intimate contact with the fuel. Too often sufficient arrangements effecting this are wanting.

"The air is allowed to flow over the fire, and to pass in parallel streams with the unburnt gases, yet never mixing with them, or often it is allowed a too free ingress near the bridge of the furnace, and to pass unmixed with the gases into the cooler flues, where combustion is impossible. The necessity indeed of keeping this rule is obvious, yet it is most difficult of observance. It is easy to admit the air, but not easy to insure that the whole of it should come in contact with the fuel, the furnace itself is comparatively small, the speed of the gases is great, and the air in an instant is carried away from the scene of combustion. The third condition essential to complete combustion is that if a mixture of the air and inflammable gases is effected, that mixture shall be heated to a temperature of incandescence. But too often the necessity of this is lost sight of.

"In steam boilers, usually the gases driven off from the bituminous coal of the fire, together with sufficient air for their combustion, are carried at great speed over the bridge into a flue surrounded with water, where the temperature is such that ignition is impossible.

"The flame that was started is quenched, with the result that the more combustible part, the hydrogen alone is burnt, while the carbon

is deposited in the form of soot. This is carried along by the stream of heated gases, and reveals itself at the chimney top as black smoke."

Nothing can be more clear than the above exposition of the principles of complete combustion, and I have quoted it at length, because due appreciation of the facts stated would in many instances, I feel convinced, where sufficient boiler room existed, prevent much waste of money by manufacturers in providing apparatus for preventing the emission of smoke by controlling the admission of air to the furnace. Such apparatus, while advertised with the most plausible statements of what they can accomplish, yet are often wholly unsuited to the particular case, and the promised improvement in smoke emission and economy does not result.

Carelessness
in Stoking.

Given however sufficient boiler room, and even provided that proper attention be devoted to the important question of the admission of air to the furnace, there still remains a third great cause of emission of smoke, viz.: Carelessness in stoking and management by those entrusted with the charge of furnaces and boilers. The question of the responsibility of the individual charged with the firing of a furnace, in the production of smoke has been long recognised and commented upon by various witnesses in their evidence before Select Committees, and also referred to in various reports upon the subject of smoke prevention. In many instances excessive emission of smoke is solely due to carelessness on the part of the stoker, and it cannot be too strongly insisted upon, more especially in the case of manufacturers who have been at the trouble and expense of making the conditions favourable, and providing apparatus to assist as far as possible the prevention of smoke from their furnaces, that there is no apparatus which entirely relieves a stoker of all responsibility in regard to the firing or management of his furnaces. Many forms of apparatus perform the firing, or admit the necessary air most advantageously at the proper time, automatically and independent of the stoker, but even under such circumstances the apparatus is liable to get out of order, and careful attention on the part of the person in charge is required at all times to ensure efficient working.

In many cases good and careful stoking is alone required to prevent undue emission of smoke, and if this were attended to, there would be no necessity for many of the expensive forms of appliances one sees constantly in use.

This evil might be largely overcome if the importance of good stoking were more fully recognised, and if men were employed for the purpose who had received a proper training, and were acquainted to some extent with the main principles of combustion and methods of smoke prevention. Too often men are employed as stokers who have

no qualification for the work, except the necessary bodily strength to throw coal into the furnace; while others, partly from ignorance and partly from not taking sufficient trouble, in the absence of supervision, stoke in such a manner as must necessarily produce smoke even with the best preventive arrangements.

In such cases the owner is no doubt largely to blame for the apathy shown by him in regard to the subject, and it can be confidently asserted that unless the management in any works is fully impressed with its responsibility in regard to the prevention of smoke, and has a sound knowledge of the means by which smoke can be avoided, it is little use expecting stokers to realise their responsibility in the matter.

The Sheffield Smoke Abatement Association last year recognising the important influence exercised by this class of workmen in the abatement of the nuisance, instituted a stoking competition, the results of which clearly showed that intelligent knowledge and skill on the part of such men were important factors in the question.

If a man is careless, and does not take trouble, he will make smoke with the best arrangements, but if he takes pains he will produce very little smoke indeed, under ordinary circumstances. It certainly, in my opinion, ought to be made his interest to succeed in preventing smoke by exercising skill and due care, and if some means were adopted to secure this result, a beneficial effect would doubtless soon become apparent, and in the end be to the advantage of the employer both from the point of economy and abatement of smoke. The question of making the stoker legally responsible for excessive emission of smoke has been frequently suggested, and there is much to be said in favour of such a proposal being given effect to in cases where it can be proved that the manufacturer has provided a furnace which, with ordinary care and attention, can be fired without causing smoke, and *per contra* it is shewn that the emission of smoke must have been the fault, not of the manufacturer, but of the want of care and attention of the fireman.

Many cases could be cited of works where every condition favourable to smokeless firing exists, and where in addition, the manufacturer in his anxiety to prevent any possible transgression of the law, has provided apparatus to assist smokeless firing, and yet owing to indifference and carelessness on the part of the stoker, excessive amounts of smoke have been recorded as issuing from the chimney. In such cases, no doubt the man who is directly to blame ought to be made to suffer, and possibly the provision of power to summon the stoker would have a beneficial effect.

On the other hand it may be urged that the same result would be produced if the master were fined, and retaliated on the stoker, either by a fine or dismissal, and I know of several instances where an

arrangement between the employer and employed on such terms has worked with a markedly beneficial result so far as the emission of smoke is concerned.

There can be no doubt however, that in the majority of cases the master is rightly held responsible for transgression of the law in regard to smoke, and until he in the first place, shows a greater interest in regard to this part of the question, by insisting on employing a class of men better educated for the work he has to do, educated to some extent in theory, and trained to a larger extent by practical experience, it will not be fair to make the stoker legally responsible to the exclusion of his master. It must be recognised that stoking is not the work of an ordinary untrained labourer, but skilled work requiring patience, and a not inconsiderable amount of technical knowledge, for which no special smoke preventing appliance can act as an efficient substitute.

EFFECTS OF THE SMOKE NUISANCE.

It is much to be regretted that in referring to the prevention of smoke from steam boiler furnaces, persons who have the cause at heart, and who have done much to stimulate public opinion on the subject, should frequently allow themselves to exaggerate the part played by this class of smoke, and ascribe to it effects for which it is by no means wholly or even chiefly responsible. The nuisance arising from excessive smoke production from such chimneys is undoubted, and ought to be prevented by every available means in our power; while success in this direction would assuredly help to improve the general condition and welfare of the community. But to affirm that success in dealing with manufacturing smoke from such furnaces, will render the atmosphere of the city free from pollution, giving it back its rural clearness, abolish fogs, or produce an appreciable effect upon the health of the inhabitants, is a result not to be attained, however desirable.

In the first place, it must be borne in mind that house fires contribute very largely to the nuisance, and owing to the multitude of house chimneys in a town such as this, each emitting at a comparatively low altitude, considerable quantities of smoke, the attainment of a clear atmosphere, except in the higher portions of the town, or in exceptional atmospheric conditions, is practically an impossibility. That this is so can be seen in all large towns, and in London, where for a longer period than in any other town, effective legislation for the prevention of smoke has existed, and where manufacturing smoke is reduced to a minimum, the atmosphere becomes yearly more smoke laden, if the increase in number of fogs experienced is to be taken as an index.

It should also be borne in mind in considering the effects of smoke, that the visible smoke consists of by far the least injurious products of combustion; and I fear that too many have the idea that with the abolition of what we see being emitted from chimneys, the solution of the smoke question will have been reached. This is not so however, even if such a desirable result be attained as the prevention of all black smoke, it must not be supposed that all pollution of the atmosphere by such chimneys has ceased. Black smoke is merely unconsumed carbon in a fine state of division, while, along with it, much more injurious, although invisible, products of combustion are being poured forth, and it is unfortunate that the attainment of more complete combustion of the carbon does not materially influence the composition of the other gases, nor reduce the quantity of the injurious invisible products poured into the air.

Those other products to which I refer, are carbonic acid, sulphur, and chlorine compounds. Few people realise what an enormous amount of sulphur and chlorine are given off in the combustion of coal, but if we take the quantity of coal consumed in Sheffield to be 1,250,000 tons yearly, the amount of sulphur given off by it, stated as sulphuric acid, is not less than 37,500 tons. The sulphuric acid is washed out of the atmosphere during rain, so that considerably over 1,000 tons per square mile is annually deposited in Sheffield.

There is little wonder then that complaints are frequently heard of the difficulty of growing plants, or even grass, in the centre of the town as in former days, when we consider the amount of sulphuric acid, which is little less than poison to vegetation, being thrown down from the atmosphere; and in towns less smoky than Sheffield, it has long been found impossible to maintain healthy trees owing to the bark being constantly killed by the sulphuric acid. The plane tree alone seems able to withstand the effects of town life, and is now generally planted in preference to all others. The whole amount of sulphuric acid is not however deposited in the town, as a considerable quantity is carried away by the winds, and affects vegetation in surrounding districts. In towns the effect is also not confined to vegetation, but extends to almost every exposed substance, and more especially affects the stone of our buildings, causing it to crumble and decay.

The visible smoke or particles of carbon undoubtedly aid the more serious effects of the acids in destroying vegetable life, by deposition as smuts, thus closing the pores through which all plants must respire if they are to lead a healthy existence, and in the case of buildings, by rendering everything black and dirty. The direct effect of smoke upon our daily life is, however, of more importance for us to consider. And here again, without wishing in any way to detract from the impor-

tance of the subject, as it affects us all, it is only fair to state that, in my opinion, the effect of what is popularly known as smoke upon health has been much exaggerated. We constantly hear it stated that visible smoke is the cause of high death rates, and has a serious influence upon the health of the community. In my opinion this has still to be proved. That a smoke-laden atmosphere very considerably interferes with the comfort and thrift of the inhabitants, that it to a varying extent, depending upon certain climatic conditions, has an influence upon the general vitality of a portion of the population, and even acts detrimentally on a small proportion, affecting their health I must admit, but that black smoke has a directly prejudicial influence upon health has not been conclusively proved. That the mere inspiration of carbon has by no means such a prejudicial effect upon us is shown from the fact that those persons whose lives are necessarily spent in a carbon-laden atmosphere (I refer to miners) do not show any special disposition to disease of the respiratory organs; indeed, so healthy as a class is this section of the population of the United Kingdom, that their general mortality rate is less than any other, with the single exception of agricultural labourers. Yet, when the lungs of a miner and of an agricultural labourer are compared after death, the latter are found to be of a natural and beautiful pink colour, while those of the former are of an inky blackness, due to innumerable particles of carbon having become deposited in the tissues.

So marked is the difference in the healthiness of miners from respiratory disease, and especially from consumption or phthisis, compared with other trades, and particularly trades connected with the production of dust, that it has been the subject of general remark among statisticians both in this country and abroad; while Hirt, a great authority on trade diseases and vital statistics, states that "it is in the highest degree probable that coal dust possesses the property of hindering the development of tuberculosis (consumption) and of arresting its progress." If then, such are the conclusions in regard to coal dust, where the particles of carbon are larger and more liable to cause irritation, it can scarcely be held that black smoke, where the carbon is in a very fine state of division, has a directly deleterious influence upon health.

The other products of combustion possibly have a more injurious effect, and it is within the knowledge of us all that during fogs a taste of sulphur is most distinctly perceptible, and often a certain difficulty of breathing and sense of constriction of the chest. This is caused by the carbonic acid, sulphur and chlorine compounds which, owing to the fog overhead, cannot escape and diffuse into the upper strata of the atmosphere, and quickly become collected in larger and larger

proportion in the air we breathe. It must be admitted, therefore, that the products of combustion do, under certain conditions, interfere materially with the welfare of a community, and the ways in which they do so may be classified roughly as follows:—

1. By conducing to the formation of fog and rain.
2. By shutting out sunlight, and depriving us of certain qualities of light of great importance in regard to changes in organic matter.
3. By depositing smuts and rendering houses dirty, thus causing an otherwise unnecessary expenditure of labour and soap in cleansing.

The subject of the production of fogs is one of great interest, and of increasing importance in all our large towns, and popularly they are supposed to be entirely caused by smoke.

Smoke, or the combustion of coal, undoubtedly plays a large part in the production of fog, but it has been shown by Dr. Aitkin in a series of beautiful experiments, that we are not destined to free ourselves from this winter scourge, even when our atmosphere has become free from smoke, not only by its prevention in connection with manufacturing processes, but also when the much greater problem of house fire smoke has been satisfactorily solved. He showed that the determining cause of fog production was the dust present in the air, and that the aqueous moisture separated out from the atmosphere with a dust particle for a nucleus. He showed further that the products of combustion, even when the combustion is perfect, are powerful fog producers, a fact of great importance in considering the question of the causation of town fogs, and that sulphur alone burnt in the air is a most active producer of fog. So minute are the particles capable of inducing fog that he was able to produce a visible fog by heating the $\frac{1}{1000}$ of a grain of iron or copper wire, when sufficient dust was evolved to produce the above result.

The atmosphere, apart from the products of combustion, is full of dust particles, hence, therefore, we must admit that the smoke nuisance cannot fairly be held wholly responsible for what is so often laid at its door. Unconsumed carbon certainly gives colour to the fog, and generally of course, there can be no question that smoke very much intensifies the amount and quality of fog, although it is not the chief cause of its production.

In connection with the effect of fogs upon health, it is often stated that this can be very well seen by observation of the increased death rate, which is nearly always the concomitant, but on the other hand it must be remembered that the determining cause of a fog, given the general atmospheric conditions which induce fog, viz., a still and

moist air and a high barometer, is usually a sudden and considerable fall of temperature, and hence in considering the effect of fogs on health we must remember that there is no more potent cause of an increased death rate than a sudden fall in temperature. Dr. W. J. Russell, F.R.S., in a paper read before the International Congress of Hygiene and Demography, held in London in 1891, showed that the majority of fogs occur when there is a great fall of temperature, and that this is closely followed after a few days by a great increase in the death rate. On the other hand, when fogs occurred without any fall of temperature they did not appear to be followed by an increased mortality, while, he states, that there is no case of depression of temperature not followed by increase of death rate. And again he says: "That many people suffer much both physically and mentally from the effects of fog there can be no doubt, but as far as I can interpret these returns of the Registrar General they do not confirm the popular impression that fog is a deadly scourge; at the same time it is beyond doubt that an atmosphere charged with soot, dust, and empyreumatic products is an unwholesome atmosphere to breathe, although I think that the principal cause of the great increase of mortality when fogs occur is attributable rather to the sudden fall of temperature which usually accompanies fog than to the fog itself."

If, however, from what has been stated a doubt may arise as to the chief responsibility of fog production being properly ascribed to smoke, and to its thus exercising a directly injurious influence upon health, there is no doubt that the presence of smoke in any quantity in the atmosphere has a prejudicial effect upon us by depriving us of sunlight, and this, in my opinion, is a sufficient reason in itself for stimulating every one to effect, so far as possible, and by every means in our power, a diminution of the nuisance. Apart altogether from fog, smoke hanging over a town forms a barrier to the sun's rays, and although the heat rays may pass through readily, the blue rays, which are of the greatest importance to healthy vitality, are kept back. This opacity of smoke to light is one of its most detrimental characters, and neither animals nor plants can thrive when deprived of light. We are all aware of the inspiriting effect of sunshine upon our mental and physical energy, and how diminution of light tends to depress and lower vitality, thus rendering, no doubt, the body more susceptible to influences which otherwise would produce no impression. Practical demonstration of this can be seen in the poorer districts of every large town, where, owing to the narrowness of streets and over-crowding of dwellings, the inhabitants, deprived of light to a large extent, show a lower vitality and capability of resisting attacks of disease. Within the last few years

another important action of light in this respect has been demonstrated, viz., the powerful destructive influence sunlight has upon various forms of bacteria and disease germs, and in the case of one form in particular, the tubercle bacillus, which is the cause of a disease of great prevalence and fatality, it has been shown that this organism succumbs after a short exposure to light. Organic changes, or oxidations, which are impossible in darkness readily take place in sunlight, and this fact also is of great importance in the economy of human life.

Smoke and
Cleanliness.

The third undesirable effect of smoke is the dirt which results from the deposition of the unconsumed particles of carbon as smuts. These not only descend upon buildings, blackening and disfiguring their surfaces, but find their way into the houses, with the result that a considerable amount of extra labour has to be expended in keeping the inside of houses clean; and the additional expense occasioned in the provision of soap and other cleansing materials expended in washing, must, in a town such as Sheffield, amount yearly to a very considerable sum, as compared with household expenditure for the same purpose amongst those living in rural districts and a purer atmosphere. Amongst the poor, especially, cleanliness of surroundings is an important factor in influencing their lives both morally and socially, and it must be admitted that the smoke nuisance, where it exists to any large extent, has an important bearing upon the welfare and social condition of this class of a community.

The conclusion, therefore, that must be come to from a consideration of the effects of the smoke nuisance in relation to the health and welfare of a community is, in my opinion, that while smoke, *i.e.*, visible smoke, has not such a directly deleterious influence upon health as many suppose, yet it very materially influences the general welfare and comfort of a community, and is undoubtedly a nuisance in every sense of the word, and hence its prevention, especially in relation to manufacturing processes, is a result earnestly to be desired in the interests of the inhabitants.

In considering the means by which this result is to be attained, the three great sources of smoke production must be kept in mind as they exist in Sheffield, viz., house fires, steam boiler furnaces, and lastly, furnaces used in various processes of metal manufacture or production, which, whether truly or not, it has always been held must be considered separately in the discussion of any proposals for the prevention of smoke.

The question of smoke from house fires is one full of special difficulties, and involving economic considerations outside the scope of the subject of this Report, and it may safely be said that any proposal for dealing with it can never be a local measure, but must be national in its scope and enforcement.

The remaining two sources of smoke are in a different category, and as I have previously shown by extracts from the various Reports of Select Committees have always been so regarded by the public at large.

Legislation enabling local authorities to deal with smoke produced in manufacturing processes has existed for many years, and considerable progress and improvement has taken place in nearly all large industrial centres in consequence.

Smoke Observations in Sheffield.

In our own town, notwithstanding occasional statements to the contrary, and unwillingness on the part of a few to recognise the fact, good work in the direction of diminishing the amount of smoke produced has been accomplished, and if only the special circumstances existing in Sheffield tending to cause smoke were fairly allowed for, such as the great concentration of works in low-lying portions of the town, and the fact that a very large amount of the smoke is caused by metallurgical furnaces, which deliver dense volumes of the blackest smoke at a low altitude, if these circumstances are taken into account, together with the practical difficulties which have been found to exist in dealing with the smoke from metallurgical furnaces, it must be acknowledged by any observant person that some material progress has been effected in the prevention of smoke during recent years.

In further proof of this fact I need only refer to the record of smoke observations carried out since 1876. In that year they numbered a little over 500, and during the next nine years did not exceed 2,000 in any one year. After this period the number of observations of chimneys extending over one hour for each observation increased every year, and since 1890 the average has been about 6,000. The mere fact of an increased number of observations having been taken would signify very little, were it not for the fact that *pari passu* with the greater activity of the smoke inspectors, the average amount of black smoke emitted as shewn by these observations has diminished, until from an average of ten minutes dense smoke per observation, it is now little over two minutes; thus, to take the year 1895 as an example, the total amount of dense smoke emitted during nearly 5000 hourly observations was 10,000 minutes, which before 1889, when the yearly average of dense smoke was ten minutes, would have represented no less than five times this amount, or over 50,000 minutes of dense smoke.

Estimated Number of Chimneys in Sheffield.

I have endeavoured to arrive at an estimate of the number of chimneys connected with manufacturing processes in the city, but have found considerable difficulty in making an accurate estimate, owing to the fact that we have no record of many small chimneys connected

with metallurgical furnaces or used in connection with various processes in the metal trade, so that the following statistics considerably understate the number of trade smoke-producing chimneys.

There are over 600 tall chimneys to which about 850 steam boiler furnaces are attached, while there are 138 chimneys into which the smoke from 266 steam boiler furnaces, together with 383 metallurgical furnaces is discharged, and lastly, there are 965 chimneys discharging smoke from metallurgical furnaces alone. These figures are, as I have mentioned, under-estimated, and the last class does not include a considerable number of steel-melting, cupola, and other small furnaces, which I have not been able to enumerate, but which all add very considerably to the amount of smoke produced.

The magnitude of the volume of smoke sent forth every day from these sources can be imagined, and furnishes a sufficient reason for the improvement which has been undoubtedly effected in recent years, in regard to the smoke from steam boiler chimneys, not being markedly perceptible to the casual observer.

Another reason for the scepticism of many on this point, is occasioned by the fact of a large number of chimneys which have been noted as special offenders in respect of smoke emission, having attached to them not only steam boiler furnaces, but also other forms of furnaces, such as re-heating furnaces, so that the manufacturer has been able to proffer the excuse, when his attention has been called to the nuisance caused by the chimney, that it was not the steam boiler furnaces which were at fault. Considerable difficulty is experienced in dealing with this point by means of legal proceedings, but there can be no question that it is a decided advantage to the community to have the smoke which might otherwise be discharged at a low level, carried into the shaft of a tall chimney. Of course, before such an excuse is held to be valid in the case of such chimneys, proof is required that the probability really is in favour of the smoke having been caused in the manner indicated, and that the steam boiler furnaces are constructed in a manner consonant with what is required for the least possible emission of smoke.

I have ventured to draw attention to these points because I think they explain to some extent the opinion which I have heard expressed that little or no improvement has been effected in the City in reducing the smoke nuisance, and too little credit has been given to a large number of manufacturers who have honestly endeavoured at very considerable expense to deal with the question so far as their works were concerned. Only a due appreciation of the causes and circumstances can lead to a fair judgment being formed upon the subject. No one will, however, deny that great room for further

improvement still exists, and that such improvement can without doubt be effected in the case of steam boiler furnaces with the knowledge and experience at present at our command.

Reports of Mr.
Fletcher and
Mr. Ripper.

In accordance with your request that in reporting on the subject of the smoke nuisance, both in relation to steam boiler furnaces and metallurgical furnaces, I should place myself in communication with Mr. A. E. Fletcher, late H.M. Chief Inspector under the Alkali Acts, and with Mr. Ripper, M.I.C.E., Principal of the Technical School of this City, I have to state that I communicated with both these gentlemen, from whom valuable reports have been received, and with whom, in addition, I have had the advantage of personal interviews.

These reports are given below, and are introduced at this point, since, in the remarks I have to make upon the procedure of the Committee in dealing with the question in the future, the opinions of two such distinguished experts must to a large extent influence both your judgment and my own.

I would only add that the reports were based upon letters from me suggesting the points to which special attention should be given, and that the letters were not identical, thus accounting for some of the points being more fully dealt with in one or the other of the Reports, but a consideration of both together will show that on the chief questions involved a definite expression of opinion has been received.

MR. FLETCHER'S REPORT.

'Delmore,' Caterham Valley, 22nd June, 1896.

Dr. H. Littlejohn, Medical Officer of Health, Sheffield.

Dear Sir—I have your letter of the 15th inst. concerning Smoke abatement, and will reply to the points in the order in which you suggest them.

- (1.) There are two methods of observing smoke, both of which have their own advantage, namely (a) the special and (b) the constant.
 - (a.) The special method would apply to any chimney that had become notorious as an offender. Then during several successive half hours the emissions of smoke should be noted and timed. Three gradations of colour should be distinguished, having the values 1, 2, and 3, so that a chimney that persistently emitted a faint smoke would be fairly registered, as would also one which emitted a denser or a very dense smoke, by considering three minutes of faint to be equal to one minute of dense smoke.

A little practice gives the Inspector accuracy in determining these shades.

- (b.) The constant method of observation should, however, be the one usually employed. For this purpose two or three stations from which a large number of chimneys can be seen in fairly clear weather, should be chosen. Two men should be employed together, one to observe and call, the other to note in the book. The book should be ruled as in sheet **A**, appended. (Appendix V.) Each chimney is known to the observer, and is distinguished by a number, counting in the order of vision from left to right. There may be as many as 30 chimneys in view at a time. The observer passing his eye rapidly from one chimney to the next in position, calls out the words "one, two, three or more," indicating the amount of smoke observed. This is done and noted so rapidly that all are viewed during the space of one minute, or even less. In the specimen sheet attached I have allowed two minutes, but one minute may suffice. The assistant can, however, in any case note the time at the commencement of each line of observations. The intervals of time should be kept nearly uniform.

A few hours spent thus by practised observers every week would furnish a better report of the general behaviour as to smoke than would be afforded by many special observations of single chimneys, and such a report would be less partial. Also when it has been found that a large proportion of the chimneys discharge but a certain limited amount of smoke, it will be felt reasonable to accept this as a standard for the remainder.

It is perhaps not important that the standard should be fixed at intervals of half-an-hour rather than of an hour, the latter is more usual.

- (2.) The perusal of a few report sheets such as I have suggested would, I think, give ground for fixing the standard to be now adopted. The standard may probably be raised from time to time. At present the following standard would perhaps be thought reasonable:

1	Boiler Furnace	...	1 minute	dense smoke	per hour.
2	"	...	2 minutes	"	"
4 or more	"	...	3 "	"	"

Thus the chimney of two boilers with two furnaces apiece would be within the limit, if faint smoke were emitted during nine minutes in the hour, but a chimney from which faint smoke is constantly discharged would rank as one emitting $\frac{60}{3}$, or twenty minutes dense smoke.

- (3.) For regular work, and where several boilers are used, a mechanical stoker is certainly to be recommended. It is then a source of economy in that (a) a cheaper coal may be used than where hand firing is relied on; also in that (b) a stoker may attend to one more boiler than when he has all the work of firing to do; and again in that (c) the wear on the boiler is less destructive than with hand firing. Manufacturers should be urged to take every precaution against the discharge of smoke, not on account of economy, but as a duty to their neighbours.

Of machine stokers the cokers are to be preferred to sprinklers, for the latter, by throwing some coal very far on the fire, keep up a bright smoke constantly. Also when the draught is good, small particles of coke are thrown off through the chimney. On the other hand the sprinklers are said to raise more steam than do the others. Of these Bennis, Hodgkinson, Proctor, and Whittaker are known as good makers.

Of coking stokers, that is of machine stokers, where the coal is all admitted in front of the fire, where it cokes and is gradually worked on towards the bridge, the following are best known: Cass, Vicars, Hodgkinson and Sinclair.

Hand firing may be smokeless by the exercise of skill and by the proper admission of air. Hollow bars and the split bridge are very useful in this respect. Mr. Oates, of Sheffield, has been successful in introducing a combination of these, with a perforated furnace door, and in adapting an automatic regulator to the air supply.

Of the metallurgic furnaces in use in or near Sheffield, those most likely to cause black smoke are the furnaces for puddling and reheating iron. In these operations it is necessary to keep a reduced atmosphere, or one free from oxygen, about the metal. This may be done by making a very smoky fire, and thus filling the furnace with imperfectly burnt coal gases; or the same protection may be afforded the metal by first gasifying the coal in the well-known "producers," and by keeping the furnace filled with the gas, which is chiefly carbon monoxide. On issuing from the doors and flues of the furnace, this gas burns with a smokeless flame. These gas furnaces are already used in three of the Sheffield ironworks, where iron sheets are reheated previous to being rolled, or otherwise worked. Gaseous fuel so employed is far more convenient of application than is crude coal. Where large quantities of fuel are consumed, an economy may be effected by separating the tar and ammonia

from the gas before it is burnt. This system is carried out on a large scale by Messrs. Brunner, Monk and Co., of Northwich, Cheshire.

In metallurgic factories, where crude coal is still used in preference to gas, it would seem possible to bring the smoke of waste gases from a group of furnaces into a chamber where the combustion would be completed, and the heat developed be used for heating a steam boiler. I cannot, however, point to any place where this system has been carried out.

In the above I think I have dealt with the points raised in your letter, but I shall be happy to go into more detail if thought necessary.—I am, dear sir, your obedient servant,

ALFRED E. FLETCHER.

PROFESSOR RIPPER'S REPORT.

Wellesley Road,
Sheffield, Nov. 11th, 1896.

*Harvey Littlejohn, Esq., Medical Officer of Health,
Town Hall, Sheffield.*

Dear Sir,—In reply to your letter of the 7th ult., I beg to give you my views on the points on which you request my opinion.

- (1.) First as to whether the emission of black smoke from engine chimneys is entirely preventible.

It is now generally admitted, even by smoke makers, that the emission of dense black smoke from boiler chimneys is entirely preventible; though it will not be admitted, of course, that it is possible in practice to do without smoke altogether. But the emission of smoke of any kind, in quantities at all likely to be a nuisance, may be reduced by reasonable effort to within the time limits laid down by the Corporation, namely, one boiler, two minutes' black smoke per hour; two boilers, three minutes; three boilers, four minutes; and four or more boilers, six minutes.

This is accomplished in some cases without any special appliances; but in other cases special appliances are required, and there are well-known firms, of good reputation and wide experience, who regularly undertake, under guarantee, to fix such appliances as will enable increased duty to be obtained from the boiler, burn a cheaper fuel, and prevent black smoke;

and it is well known to all observers of boiler chimneys, that these firms are able to justify their claim to abate smoke.

It might here be pointed out that the difficulty or otherwise of preventing black smoke or of keeping within the time limits, varies very considerably as the conditions vary; and while in the majority of cases, with ordinary effort and simple appliances no great difficulty need be found, in other cases the problem has proved a more difficult one, and though known to be capable of solution, has often led to much experiment and expense before the solution could be found.

It is also well known that in some branches of the Sheffield trades the demand for steam is very variable, and so also is therefore the rate of firing, and under these circumstances it is not so easy a matter to show the same freedom from smoke emission at all times of the day, as in trades where the demand for steam is more regular. On these grounds I would not recommend a further reduction of the time limit at present.

In reply to your further question as to half-hourly *versus* hourly observations, it may be stated generally that the more irregular the nature of the conditions of working the longer should be the time during which observations should be taken, but in any case it is doubtful whether observations of less than one hour's duration would be a sufficiently accurate measure of the average performance of the chimney.

- (2.) Secondly, as to the best means at present known for preventing the emission of smoke.

It is impossible to state definitely any one particular method which will be suitable for all the numerous conditions that occur in practice, as each particular case requires its own special treatment. It is through want of appreciation of this fact that so many of the thousands of patents which have been taken out for preventing smoke have proved failures. Each of them may have had merits for special cases, but when the attempt has been made to use them under other conditions they have obtained a bad reputation and have eventually been allowed to lapse.

Smoke may be prevented entirely by burning fuels such as anthracite or coke, which contain little or no volatile matter; but these fuels are expensive. Thus the price of anthracite is 29/- per ton; gas coke, 12/- per ton; while the price of the ordinary engine slack used in this district, varies from 5/- to

8/- per ton. The latter coal is also much more satisfactory for steam generating than anthracite or coke.

Ordinary steam coal contains about 30 per cent. or more of gaseous products, and when thrown on a boiler furnace such coal, though burning with abundance of bright flame, emits considerable volumes of smoke, which must either be consumed in or near the furnace itself, or be intercepted between the boiler and the chimney, and treated in some way as by means of a smoke washing device.

It should be remembered that smoke, even in dense black volumes, contains an extremely small amount of solid matter by weight, probably seldom more than one per cent. of the fuel burnt in the grate, and usually much less than this.

Smoke washing, though it extracts a fair proportion of this solid matter, requires a large quantity of water for the purpose, and needs the addition of a fan, with some means of driving it, if the draught is to be maintained, as the cooling of the gases by the cold water tends to destroy the draught.

It is a remarkable fact how easily smoke defies the action of water, and though the smoke be first saturated with steam from a steam jet, and afterwards treated with a plentiful spray of cold water, it passes through the ordeal without apparently losing much of its blackness.

The sulphurous acid present in the gases is extracted from the smoke, but this acidulated water so formed has a corrosive action on any iron with which it comes in contact. The application of this system is, in the writer's opinion, not likely to find much favour.

The most successful methods of preventing smoke consist of those which consume the smoke in or near the boiler furnace, and for this purpose the following essential conditions for smokeless combustion must be fulfilled:—

- (1.) The presence of a high furnace temperature.
- (2.) A sufficient supply of air to the furnace, or, in other words, a good draught.
- (3.) A judicious application of the air supply.

To expose the smoke-laden gases to a sufficiently high temperature, it is necessary to keep the fire in a bright incandescent glowing condition over as large a portion of the furnace bars as possible, especially at the back, and to adopt one or other of the following methods of firing:—

- (1.) Firing on alternate sides of the grate, so as to always have one side of the fire bright.

- (2.) Before firing, pushing the front portion of the fire back and putting fresh coal on the front of the grate, so as to keep the back of the fire bright.
- (3.) Firing lightly, and often, and spreading the fuel thinly over the whole surface of the grate.
- (4.) During firing by any system, avoiding the formation of hollow or burnt-out places in the fire, especially at the back end of the grate through which air may pass to the flues.
- (5.) The firing should on no account be in irregular and heavy charges.

APPLICATION OF AIR.

Admission of Air at the Bridge through a perforated plate. This is a common and on the whole the most successful of the methods for preventing smoke; and it has been in use since 1820, but care should be taken with hand firing that this air supply ceases as soon as the smoky gases from the newly fired coal cease to pass over the bridge. The automatic arrangements, fitted to cut off the air supply to the bridge, appear to work very satisfactorily, so long as they are kept in good order.

Admission of Air at the Door.—With coals containing much volatile matter, such as most of the coals used in Sheffield, an air supply at the front and over the top of the fire is necessary not only to burn the smoke, but to properly burn the gaseous products.

Necessity for Care with the Air Supply.—The importance of attention to this point cannot be too strongly urged, as an insufficient supply of air results in dense smoke; while excess of air is followed by loss of power in the boiler, and loss of economy of fuel.

It is no uncommon thing to find three or four times as much air passing through the flues as is necessary for the combustion of fuel, and this excess air is fulfilling no purpose whatever except to carry away heat up the chimney to waste.

Artificial Draught and Hard Firing.—Where an excuse is made for a smoky chimney that the boilers are "Hard Fired" the fact usually is, not that the actual weight of coal burnt on the grate is larger than in other cases where no smoke is made, but that the draught may be insufficient to burn without smoke the weight of coal thrown on the bars. This defect may easily be remedied by some *artificial method of increasing the draught*, as by a steam jet forced draught, such as

Meldrum's or other similar system, or by induced draught by a fan as carried out with so much success in the "Ellis and Eaves" system constructed by Messrs. John Brown and Co. In the latter system the heating of the air supplied has no doubt an important influence on smoke abatement. By thus increasing the draught the power of a boiler to generate steam might be doubled, and twice the weight of coal might be burnt on the grate of the so-called hard-fired boiler without fear of smoke.

Mechanical Stokers.—The *Coking Stoker* is in principle a perfect smoke preventer.

The *Sprinkling Stoker* emits more or less light smoke continuously where the draught is good. With a defective draught the sprinkling type of mechanical stoker may make much smoke. This may be reduced, however, by any means of improving the draught, as steam jets over the fire. Whatever advantage may be claimed for the mechanical stoker, experience with it in Sheffield shows that it must not be looked upon as invariably solving the smoke problem.

In the writer's opinion the success of the mechanical stoker depends not primarily on its being a smoke preventer, but a means of saving labour on a range of boilers where a mechanical system of coal conveying is also adopted.

All mechanical appliances sooner or later give trouble unless kept in good condition.

They all have their limitations, and none is uniformly successful under all conditions.

Boiler Firemen.—Whatever the conditions may be, or whatever the appliance used, the chief need in all cases is intelligence, skill, and close attention on the part of boiler firemen, and money paid to secure such service would often be found the least expensive means of preventing excessive smoke.

Much smoke is made in Sheffield through neglect, and through want of appreciation of the skill necessary to fire a boiler smokelessly. It is sometimes supposed that a man can attend to a boiler and perform several other duties at the same time; also that boiler firing is a very simple matter, and merely requires ability to shovel on coals; but there is a wide difference between the skill necessary to fire a boiler, and to fire a boiler smokelessly. It is not an easy matter to prevent smoke, in many cases it is a very difficult matter, and requires exceptional skill, and this fact has not yet been realized as generally

as it should be. The skill necessary for successful boiler firing is recognised in the large ocean mail steamers, where the boilers are under the charge and direction of the senior engineers, while the juniors are engaged on the engines, and not *vice versa* as might be supposed.

The coal bill is usually an important item of expenditure, but it is seldom realised how great are the possibilities of gain or loss to an employer, on a year's working, which may result from the skilful or unskilful performance of the boiler firemen. The margin of difference between the cost of skilled firing as against unskilled, for the same quantity of steam supplied, may easily amount to 30 per cent of the coal bill.

The Bye Laws.—It is no doubt fully realised by smoke abatement authorities, that the exigencies of ordinary factory work are not usually favourable to smoke abatement, but rather antagonistic to it, and for obvious reasons: it is troublesome, it is more or less costly, it demands closer attention and more constant watchfulness, and it calls for the enforcement of a stricter form of discipline, both in the working and management of steam boilers.

It is clear, therefore, as would be admitted even by the worst offenders, that if the smoke nuisance is to be effectively suppressed, and the health of the citizens safe-guarded, the most effective means is the rigid enforcement of the bye laws, as in this way only will the necessary effort be put forth, and the necessary carefulness and watchfulness maintained, which is so necessary if any real improvement is to be made.

- (3.) As to the question of smoke from the various metallurgical furnaces. This is a much more difficult question, but there are encouraging signs that the present form of furnace is likely to give way to a superior type, at least in some departments of such work. Thus there has recently been introduced what is known as the new form of Siemens' Gas Furnace, which has already been successfully applied on a large scale in England, Belgium, France, Spain and Italy. There are several at work in our own district, and I hear from reliable sources that the results obtained with it have fully realized the expectations formed of it.

It can be readily used for producing a reducing, oxidizing or neutral flame as required, together with complete absence of smoke.

It is hardly likely that manufacturers will be induced to pull out their existing furnaces and substitute the new Siemens' furnace, at a large initial cost, with the single object of preventing smoke; but a more powerful inducement will undoubtedly lead to such a change in the near future, if the economy effected by the new furnace is anything like what it is stated to be.

One Siemens' furnace usually replaces two ordinary coal fired furnaces, and the saving with one of such furnaces, heating twenty tons of iron piles per twelve hours, is given as follows: Saving by reduction in waste of iron per week, £30; saving in coal per week, £15; or a total saving per year of forty weeks of £1,800.

The approximate cost of such a furnace is £600, so that with such inducements to improve upon the present type of furnace, there is a reasonable prospect that a reduction in the amount of smoke made, from this source, may be hoped for in the near future.

Failing the introduction in all cases of the New Siemens' Furnace, Messrs. Meldrum and others are undertaking, under guarantee, to prevent the smoke from metallurgical furnaces by a method which they state in no way interferes prejudicially with the present mode of working.—Yours faithfully,

W. RIPPER.

THE MEANS AND METHODS OF PREVENTION OF SMOKE.

It must be generally admitted that the question of the possibility of preventing the emission of an appreciable quantity of black smoke from steam boiler furnaces, under ordinary circumstances, is practically settled beyond dispute. All the published reports on the subject agree upon this point, and the report issued by the Committee for Testing Smoke Preventing Appliances, after exhaustive experiments, states the following conclusion:—"A manufacturing district may be free from manufacturing smoke, at least from the steam boilers—with which alone the committee have concerned themselves—and as to the means by which it may be so freed, this Report contains ample information."

Mr. Fletcher's opinion on the point is too well known from his published writings to require repetition, and as to Mr. Ripper's opinion, based on wide experience, we find it clearly and unequivocally stated.

In considering, therefore, by what means the desired result may be best attained in this city, and what alterations of procedure (if any) the Health Committee should adopt in the future in regard to the

question, I think it will be advisable to consider: (1.) The question of the time during which the emission of dense smoke may be permissible. (2.) The method of observation to be employed. (3.) The relation of the Committee to the question of the provision of appliances by manufacturers to prevent smoke.

Time Limits
for Permissible
Black Smoke

1. Previous to 1892 ten minutes of dense smoke in an hour was allowed to be emitted from any manufacturing chimney, irrespective of the number of boiler furnaces attached to it, and each observation extended over a period of one hour's duration, as at present. Subsequently this limit was reduced to six minutes, and again afterwards, in conformity with the desire of the Sheffield Smoke Abatement Association the limits which are at present in force were adopted. These limits differentiated for the first time between various chimneys according to the number of furnaces attached, and it must be acknowledged that the justice and practicability of the suggestion at once commended itself to the Health Committee.

The limits thus proposed were that for—

1 boiler,	2 minutes	of black smoke	should be allowed.
2 „ 3	„ „	„ „	„ „
3 „ 4	„ „	„ „	„ „
4 and over,	6 „	„ „	„ „

And the result of the adoption of these standards produced a most beneficial improvement in the quantity of smoke emitted from many chimneys.

It has been frequently suggested that these limits might be still further reduced, and with the proviso that a certain amount of grace should be allowed for the lighting of furnaces when the work of the day commences, I am of opinion that no hardship would be inflicted by a reduction of the limits to the following—

1 boiler	...	...	...	...	...	1 minute.
2 „	...	...	...	...	...	2 „
3 „	...	...	...	...	...	3 „
4 or over	...	...	...	...	...	5 „

I feel confident that smoke from steam boiler furnaces under ordinary conditions of work could with care and attention be kept within these limits subject to the proviso I have mentioned. During the first hour of the day, when fires are being rekindled, the time might be extended to 10 minutes in the case of from 1 to 3 boilers and 15 minutes for more than this number.

As Mr. Ripper very truly mentions, and as was fully recognised by previous authorities, a special difficulty is occasioned by variable demand for steam power in certain trades, and when this exists the task of preventing the emission of smoke is increased very considerably. This must be apparent to anyone who has studied the

question, and it seems to me only fair that a relaxation of the above suggested limits should be made in the case of steam boiler furnaces used in connection with heavy rolling mills and in working steam hammers, and I would therefore recommend that in such circumstances the limits should be extended to double those suggested above.

While I advocate further restrictions being imposed on the amount of smoke emitted, based on the firm belief that no hardship will thereby be imposed on manufacturers, either in the way of expense or inconvenience, except such as results from an increased amount of care and attention having to be given to an important part of their business administration; yet it is only fair to state, in answer to those who delight in contrasting other towns with our own, to the latter's disadvantage, in regard to the regulations in force in such towns, that Sheffield by no means compares unfavourably with them in respect of the permissible limits of smoke emission, as will be seen from the following table.

The information was collected last year, and was kindly sent to me by Mr. Albert Taylor, Chief Sanitary Inspector of St. George's Vestry, London.

Limits in
other Towns.

DISTRICT.	Length of time the Chimneys Watched.	Maximum Allowance of Black Smoke.	REMARKS.
Bath	2 to 3 hours	5 min. in hour	
Blackburn	1 hour	7 " "	
Brighton	Varies	2 " "	
Bolton	$\frac{1}{2}$ hour	$2\frac{1}{2}$ " $\frac{1}{2}$ hour	
Birmingham	1 " "	15 " hour	
Birkenhead	Varies	4 " "	
Bury	1 hour	10 " "	
Croydon	Varies	10 " "	
Glasgow	1 hour	Not fixed.	{ Proceedings frequently taken for 2 or 3 minutes black smoke. Police take smoke observa- tions.
Huddersfield	1 " "	7 min. in hour	
Halifax	1 " "	5 " "	
Hull	1 " "	Not fixed.	{ Smoke Inspector supplied with half-plate snap shot camera.
Leeds	1 " "	5 min. in hour	
Liverpool.....	Varies	4 " "	Three Smoke Inspectors.
London County Council	" "	1 to 5 min. "	{ Five minutes allowed from light- ing of furnaces and one minute afterwards.
Manchester	$\frac{1}{2}$ hour	2 to 3 " $\frac{1}{2}$ hour	Four Smoke Inspectors.
Nottingham.....	10 minutes	3 to 5 " hour	{ Smoke observations are taken by the Police.
Norwich	1 hour	10 min. "	
Oldham	$\frac{1}{2}$ " "	4 " "	
St. Georges', Hanover Square	$\frac{1}{2}$ " "	$2\frac{1}{2}$ to 5 m. $\frac{1}{2}$ hr.	
Salford	1 " "	5 min. in hour	
St. Helens	1 " "	5 " "	
Sheffield	1 " "	2 to 6 min. "	{ Allowance varies with the number of boilers in use.

The above information is interesting as showing how variable are the limits imposed and times of observation employed in other towns, and

it must be confessed that Sheffield comes creditably out of the comparison, both in respect of the maximum limit imposed and as being the only town where a logical differentiation is made between the number of furnaces discharging smoke into a chimney and the period of time allowed.

Methods of
Observation
Inspectors.

2. In regard to the duration of observations, I do not recommend any change in the existing arrangements whereby each chimney is observed continuously for a period of not less than one hour at a time. Both Mr. Fletcher and Mr. Ripper concur in this. The former suggests another method of noting the results of observations which undoubtedly has much to commend it, as offering more reliable and complete information in regard to the behaviour of a chimney during the time it is under observation, and certainly for scientific accuracy it is as perfect a system as could be adopted. A difficulty in adopting it for practical purposes in connection with the control of smoke by a Corporation presents itself to my mind, and that is, that the law makes the offence under section 91 of the Public Health Act, the emission of black smoke, and I doubt whether it would permit of faint smoke being counted under any circumstances as an equivalent of black smoke, in proving an offence under the Act, even if faint smoke were emitted continuously from a chimney during the whole period of observation. If this view is correct, then much of the advantage of the system advocated by Mr. Fletcher is lost, although undoubtedly by its use a more exact record would be obtained. Under the circumstances I am of opinion that the present system of observation whereby any black smoke emitted is at once noted, together with the exact time of the emission and its duration, and the total for the hour then added up and recorded as the total emission for the hour, is the best, and gives sufficiently satisfactory results. In one direction, however, I have no hesitation in recommending the Committee to institute an improvement, and that is in increasing the present staff of smoke inspectors. It is only necessary to consider the immense extent of the area covered by the city, and the large number of chimneys, great and small, spread over this area, to make it apparent to every one that if a strict and efficient watch is to be exercised over the smoke nuisance in the city, the number of inspectors must be increased.

Increase in
Inspecting Staff.

At present one inspector has the supervision of the whole of Brightside and Attercliffe, so that, for example, while on duty in the neighbourhood of Neepsend Lane, the whole of Attercliffe is enjoying absolute freedom from supervision, and knowledge of the fact of his presence in a distant part of his district is not unfrequently

communicated by telephone to works in other parts, with the result that evidence of a want of care in stoking soon becomes apparent in these localities. The other inspector has the whole of the centre of the town, the Park district, Walkley, Heeley and Ecclesall to watch, and the inadequacy of the means of observation is exemplified when I mention that last year in response to urgent complaints of the nuisance caused by smoke in the Rivelin Valley, it was necessary to send him there upon several occasions to make observations, during which time the whole of the rest of the district, extending as far as Heeley, was free from any form of supervision. Both from the number of Works and from the extent of area covered by the town, I am of opinion that there should be at least four Smoke Inspectors constantly employed, if prevention of the nuisance is to be more strictly carried out. This increase in the staff should at least be made for a temporary period, say of two years, after which it is possible that a permanent improvement might have been effected, and for the future sufficient supervision be afforded, to ensure compliance with the regulations, by the present staff.

3. In regard to the question whether the Committee should suggest the means it is advisable to adopt to prevent smoke from steam boiler furnaces and the position of the Committee in regard to this question in relation to manufacturers, there can be no doubt that the attitude assumed by you in the past, in not recommending any special form of apparatus, is sound, and least open to objection on the part of manufacturers themselves.

That smoke can be almost wholly prevented must be taken as proved, and the means by which this result can be effected has been fully dealt with in published reports, which are available for any person who is interested in the question. The circumstances tending to cause undue smoke production vary in individual cases, and it is quite possible that what will act as an efficient smoke preventer in one case will prove ineffectual in another, and as the question is one wholly affecting the manufacturer, it is only right that he should himself endeavour to make out where the fault lies and provide the proper remedy. Unfortunately too many think that sufficient has been done, if, without seeking practical advice from an experienced engineer and without intelligent enquiry on their own part, an appliance is procured from the first patentee who happens to call upon them, extolling the infallibility of his invention and promising results which a little investigation would soon show to be exceedingly problematical. Large sums are annually wasted by manufacturers from this cause, and will, I fear, continue to be so wasted until the

various causes of smoke production in each individual case are fully realised and competent advice secured from a disinterested and practical engineer upon the causes of the smoke and the means of prevention best adapted to the circumstances of the case.

Too often, as I have already mentioned, the cause of the excessive emission of smoke is due to insufficient boiler space for the steam power required, and in such cases, while no doubt there are appliances which will tend to mitigate the nuisance produced, none will effectually cure it except the provision of boiler room equal to the demands of the power required.

Again, in many instances, money is spent on the provision of appliances where none are really required, provided care and attention is exercised in firing ; indeed, in my own experience several cases have occurred where, on an interest being shown in the question by the manufacturer, and the stoker warned that inattention to his duties would be followed by the punishment of dismissal, excellent results have at once ensued.

Even where good mechanical appliances have been provided the responsibility of master and man does not end, as is often supposed by both, since there is no appliance in the market which can be relied on to perform its functions efficiently for any length of time unless properly looked after and attended to. This is a frequent cause of transgression of the law, and manufacturers are apt to complain if called to account for permitting undue emission of smoke, where appliances have been provided, but which owing to carelessness have been allowed to get out of order or are not properly attended to. The remedy for faults due to defective firing or inefficient apparatus is to improve the class of men entrusted with the duty of supervising the firing of boilers. If the importance of the duty of preventing smoke is insisted upon by stricter enforcement of the law, and at the same time it is recognised how much depends upon the intelligence and skill of the person entrusted with this duty, manufacturers will insist upon a higher standard of efficiency among those whom they employ, and be glad to ensure a satisfactory result as regards smoke production, by a slight increase of wages to the more educated workman.

The various means and appliances which have been proved by experience to act efficiently in assisting the prevention of smoke, are mentioned in the Reports of Mr. Fletcher and Mr. Ripper, and also in the Report of the Committee for Testing Smoke-preventing Appliances, and I can only again advise anyone who proposes to supply himself

with an apparatus, to carefully consider the opinions expressed in them, and above all things to remember that the cause of the smoke may depend on many conditions, so that while one form of apparatus may be a success, another may be unsuitable, whereas in all, constant care and intelligent treatment is an indispensable requirement.

I have prepared a list of the boilers which are provided with some form of smoke-preventing appliance, and find that out of 1,116 boilers 579 are supplied with one or other of the following—

Sprinkling Stokers	...	...	...	...	45
Coking „	...	...	..	...	13
Forced Draught	...	...	...	...	82
Hollow Bridges ...	..	...	...	...	254
Hollow Bars ..	...	...	...	...	24
Oates' Apparatus ...	...	...	...	...	81
Steam Jets ...	...	...	...	...	13
Double Doors ...	...	...	...	...	23
Rocking and Patent Bars	...	..	...	...	26
Doors in Dead Plate	...	...	...	...	14
Other Patents ...	...	...	...	...	5

All these may under favourable circumstances prove of valuable assistance in preventing the emission of an undue amount of smoke. Some of them tend to reduce to a minimum the personal factor in smoke production by automatic mechanical arrangements, while others afford valuable assistance to the stoker when used with skill and care. While it must not be forgotten that in most instances where the boiler room is not insufficient, careful and skilful stoking is capable of preventing the emission of undue quantities of smoke, yet it must be acknowledged that any appliance, especially if it be automatic, which assists the more perfect combustion of the fuel, is an advantage and assistance, and will tend to eliminate the result of carelessness or inexperience in firing on the part of the stoker.

It is doubtful whether the provision of any form of apparatus produces any material saving to the manufacturer, except perhaps in a few instances by permitting the use of a cheaper class of fuel. So far as my experience goes the apparatus which has produced the best results generally, after adequate trial, are coking stokers and Oates' apparatus, the latter admitting air automatically, for a given time both at the door and bridge after firing.

In concluding this subject I would only again impress on manufacturers, whose chimneys can be proved to emit excessive quantities of smoke, the necessity of endeavouring to arrive at a correct knowledge of the cause in each particular instance, if need be, by calling in

the assistance of a competent engineer, before adopting any appliance for remedying the defect.

METALLURGICAL FURNACES.

Metallurgical
Furnaces chief
cause of the nuisance.

In a town such as Sheffield, the smoke emitted by the various forms of furnace used in working metal is really the practical difficulty which stands in the way of effecting a marked purification of the atmosphere, and rendering it comparable with that of other towns. There are a very large number of furnaces of all descriptions, located all over the city, but chiefly in the districts of Attercliffe and Brightside, daily emitting dense volumes of the blackest smoke for periods not of minutes, but of hours, and this at such a level that it quickly envelopes the neighbouring streets in a dense cloud. The great nuisance resulting would be more bearable if all this smoke were produced in a locality where there was no residential property, but unfortunately this is not so, since in the midst of densely populated neighbourhoods, and near the centre of the town, furnaces are to be found which practically deprive those living near at hand of the enjoyment of such ordinary necessities of life, as ventilation of their houses and a respirable atmosphere. This state of things has no doubt to some extent resulted from the growth of the town, the vacant land which surrounded the works at the time of their erection having been required for dwelling-houses, in order to meet the convenience and demands of the workmen employed in the rapidly increasing trade of the town.

While, however, the smoke thus produced especially affects those living in such close proximity to it, it also affects those living in other districts of the city, and is the chief cause of the bad reputation Sheffield has acquired in respect of the impurity of its atmosphere.

The problem of effecting a means by which such smoke may be materially diminished, is therefore one demanding the most earnest consideration of the Corporation and ratepayers. As a result of my enquiries on the subject, I think one fact must be taken for granted, namely, that there are no means at present known whereby the smoke can be satisfactorily dealt with under the existing processes in use in connection with such furnaces.

Means may hereafter be discovered, whereby without interfering with processes to which the Sheffield workman pins his faith, and which have undoubtedly made the name of Sheffield known all over the world, the smoke, after being produced, may be so treated as to remove all cause of complaint, so far as visible black smoke is concerned, and such means may be found in a process of washing the smoke, so as to remove all unburnt carbon from it, and even deal with the resulting product as a commercial success. But

at present no such satisfactory method has been devised, and from certain experiments which have been carried out by Professor Ripper, I am inclined to doubt the possibility of effectively washing smoke of its visible constituents.

Use of Gas in
Furnaces.

The method of dealing with the smoke therefore seems to depend on an alteration in the processes of manufacture employed, and as is well known, the substitution of gas for coal as a fuel, has for many years been tried, and met with great success, so far as the smoke problem is concerned.

For over thirty years gas has been used for reheating furnaces in Sheffield by at least one large firm, while at present there are several of the largest works in the city where the use of gas has almost supplanted coal in most of their furnaces.

In America the use of gas in large works, of a nature similar to those in Sheffield is, I am informed, almost universal, and the erection of furnaces employing coal would not be entertained.

From the enquiries I have been able to make from those who are thoroughly conversant with the subject and have practical experience in the use of gas furnaces, there can be little doubt that gas is perfectly applicable to certain forms of furnaces, and can be so utilized without causing any material alteration in the process or mode of working, and with practically no objectionable production of smoke.

The furnaces I refer to are (1) those employed in connection with mills for rolling rods or bars of any size, and for rolling plates; (2), melting furnaces.

There appears to be an obstacle to using gas in connection with the rolling of thin sheets, from the difficulty of regulating the heat so as not to produce "scaling," but this difficulty could no doubt be overcome, and certainly the subject deserves careful enquiry, and is worthy of the institution of experiments as to the best form of furnace and the precautions necessary to meet the objection.

It is astonishing how contradictory the opinions of practical men are in regard to the use of gas in furnaces. One gentleman with an experience of them, extending over many years, states that he intends to substitute coal for his gas furnaces again, as he does not find them satisfactory owing to their requiring great attention on the part of workmen in using them, and because he is unable to do his heavy work economically, with the result that it has to be sent out. Another manufacturer, whose gas furnaces are employed for the lighter work in connection with his rolling mill, states that they work most satisfactorily, and he intends to substitute this form of furnace whenever opportunity occurs. One of the largest firms in the City say that they could not do without gas in the heavy

work of their rolling mills, and that both on the score of economy and quickness of work gas is preferable to coal. In going round the works I noticed some ordinary heating furnaces emitting the usual dense volumes of smoke, and on asking the reason why gas was not used, I was told that it was simply on account of their not having room in the vicinity for laying down the necessary gas-producing plant

While I must admit a considerable amount of diffidence in expressing an opinion on a question involving so much technicality, and on which there are so many persons whose training and experience entitles them to speak with authority, yet I cannot help being impressed with the belief, notwithstanding all the arguments that can be used against it, that in the great majority of furnaces in Sheffield gas is applicable, and that any objections to its use can be overcome by further research and careful experiment.

I have had the opportunity of seeing plans of furnaces for heating and annealing purposes by means of gas, which I am informed are worked with complete success in America, and where this form of furnace has been made applicable to the heating of thin sheets with a perfectly satisfactory result.

If this is so, then the question of the possibility of using gas successfully in all forms of rolling mill furnaces is settled, and if generally introduced here, the abolition of the smoke nuisance would be practically accomplished.

The objections which may be urged against the use of gas furnaces are—

- (a.) Increased cost, unless there is work for the furnaces both day and night. If the furnaces are only worked in the day time, then economical working is very difficult, because the furnaces have to be kept hot all night, which means the burning of coal and wages for a man at the producer. Gas furnaces cannot be allowed to cool down, as it takes several hours to get them into working order again.
- (b.) Cost of erection of furnaces and greater cost of repairs, as compared with coal furnaces.
- (c.) Extra space required for gas-producing plant.
- (d.) Difficulty of workmen in adapting themselves to changes, however slight, in the processes to which they have been accustomed, and liability of work being spoilt in consequence.

The objections in regard to the cost of altering existing furnaces so as to adapt them for the use of gas, and the space required for a gas producing plant, might offer in many cases a great difficulty to the general adoption of gas for the purpose of preventing smoke, and any arbitrary requirement in this respect would be both unjust and impracticable.

If, however, it could be demonstrated clearly that advantages would result from the use of gas, and its use proved to be attended with no increase of cost or material disadvantage, a great advance towards the solution of the problem of smoke abatement and purification of the atmosphere would result.

I am, Gentlemen,

Your obedient servant,

HARVEY LITTLEJOHN,

Medical Officer of Health.

APPENDIX I.

Letter from Mr. Wakefield. Report of Select Committee, 1819.

“ Manchester, July 6th, 1819.

“ Sir,—I beg leave to state to the Committee the principal objections that have been made to the burning of smoke, in order to show you the prejudices I have had to combat. It was said by the first practical gentleman that burning the smoke was a loss of 10 per cent. on the most improved plan, as well as difficult to execute, and injurious to the pans by concentrating the heat; and, when an engine was overloaded or the pan too small, that it could not be otherwise than make a heavy smoke; so that the idea of burning smoke was given up and treated with contempt. In 1790 and 1791 I had the superintendence of Mr. Drinkwater's mill, who was a magistrate, and wished to do everything in his power to prevent his engine being a nuisance, and I turned my attention particularly to it; but although we succeeded then in making less smoke, we burnt more coals. Since that time I became a water spinner in the country, and had not so much occasion for the use of steam; but on my return to Manchester, I found there had been no improvement made, and that the nuisance had become insufferable, which caused me to turn my attention particularly to it. Many persons were threatened with indictments to make them raise their chimnies, which answers no purpose, only carrying the smoke higher, so as to clear its own premises, but falls upon the next neighbour; besides, the lofty chimnies being dangerous, some have fallen, and persons been killed by them. On a reference to my statement, it will appear I have succeeded in removing all these objections.—I am, Sir, your most obedient humble servant,

“ M. A. Taylor, Esq., M.P.”

“ JOHN WAKEFIELD.”

APPENDIX II.

Letter from Mr. Coombs. Report of Select Committee, 1819.

“ 66, High Holborn, London, July 2, 1819.

“ Sir,—In submitting my plans to the consideration of the honourable Committee, I beg leave to accompany them with a few remarks, which, although not so clear as I could wish, may still tend to elucidate the operations of the apparatus, and of exciting some ingenious artist to correct the existing evils, such as the immense waste of fuel, the inconsistent plan of erecting as also of feeding the fire of steam and other boilers, the obviation of which inconvenience has employed much of my time for upwards of ten years back; and, although I have succeeded in some points, yet there remains much to be done; and so convinced am I of its practicability, that I have looked with the daily expectation of some engineer producing a plan that would embrace completion. Steam engines are now brought to so high perfection that there seems nothing scarcely that cannot be performed by them, and I am of opinion they can be made their own servants, to supply their own fuel, and also to consume their smoke, on different plans; and I would remark a powerful drawback, namely, the door in front for feeding the fire, the removal of which I strongly recommend, well knowing its great mischief—every time the door is opened to supply the fire, thousands of gallons of cold air rush in, striking against the bottoms and sides of the boilers, cooling the flues, and most completely counteracting our grand object, of retaining heat, may I say, equal in effect almost to water. The usual method of supplying the boiler with fire, the door is opened every five minutes to admit four shovels of coals; by this method, out of twelve hours the door is opened three hours, exposing the boiler and flues, which not only impair and damp the fire, but assists much to force up the virtue of the coals unconsumed. Within the bills of mortality, how many thousands of chimnies are at this moment emitting into the atmosphere their black and immense volumes, consisting of the strength and virtue of some hundreds of chaldrons of coals. May not this rouse the thinking mind to exert its energies to an application of this smoke, which is no other than an impure gaseous state of coal? The perfection of gas, and its usefulness, which is nightly before our eyes, convinces me that the smoke of steam and other boilers may be transmuted into fuel, and to a great extent of saving. Steam boilers require a strong heat and power to raise the steam to a certain force at first, then to maintain that force, continuing a solid and steady heat without so strong draft, or, in other words, without the extraordinary waste and consumption of coals. With my drawings and model I will more fully explain it. Brewers' coppers I have found much more difficult, as they must not only have a strong boiling heat, but also power to damp their fire with facility; this sudden change they require twice a day. With the power of

moving the body of coal from the boiler, I consider we may, and I am emboldened to say, from late experience and observation, it can be accomplished; by igniting smoke we convert it into fuel. To convey an accurate description with my pen I find it difficult, but by a verbal explanation, I doubt not to make it evident the great advantage resulting in forcing the smoke through red-hot cylinders, pipes, or flues for ignition, and also in feeding the fire with hoppers and wheels, or perpendicular, or in an oblique direction. That I may be more fully understood, I have given a section of a coke oven, the process of which, has years back convinced me that boilers may be heated on the same principle, and with an extensive saving of time and fuel. Coals, like a corn-field on fire, will communicate its heat and flame from one particle to another, as the currency of air drives it. The arrangement of air into all fires I consider of the utmost consequence, as I am confident, that with care, even our atmospheric air may be considered as fuel. In my specification 1813, I claim the shape of a boiler, standing on an iron pillar at the back; also, on a plate of iron: for small boilers, it answers; but it is the brewers' coppers that have baffled my efforts till within these three months. I am prepared for many objections to my drawings and plans, but I wish to observe that I am as willing to assist as be assisted: and—I remain, Sir, your humble and obedient servant,

"M. A. Taylor, Esq., M.P.

"BENJ. MERRIMAN COOMBS."

APPENDIX III.

Extract from Report of Sir Thos. de la Beche and Dr. Lyon Playfair, 1846.

"Although the smoke arising in many towns from the consumption of coal must be regarded as a nuisance, the consideration of that arising from a multitude of private fires, collectively producing a considerable volume of smoke in large cities, such as London, should be carefully separated from investigations respecting that evolved from the chimnies of steam engines, breweries, and other works generally. Due caution is also required so to classify the latter, that while on the one hand those fires and furnaces from which a discharge of smoke can be prevented should be brought within the provisions of legislative enactments, the progress of important branches of our national industry should not, on the other, be impeded.

The general principles upon which the combustion, or rather the prevention of smoke, may be effected are now well known, and admitted to be applicable in practice. Smoke consists of vapours produced by the partial combustion or distillation of coal, carrying up small particles of the fuel in mechanical suspension, and depositing, by the combustion of one of their constituents, carbonaceous matter in a fine state of division. The mode of preventing this smoke is to admit a sufficient quantity of air to effect the combustion of the carbonaceous matter when the vapours are of a sufficiently elevated temperature to unite entirely with the oxygen of the air. If the temperature be not sufficiently elevated, the hydrogen of the vapours alone is consumed, and the carbon is separated in the fine state of division referred to. The gases produced by the complete combustion of fuel are colourless and invisible, and therefore do not come under the definition of the term smoke.

As the prevention of smoke implies the complete combustion of fuel, the result, as an abstract statement, always is, that more heat is generated, and a saving of fuel effected, when it is so consumed as to prevent the emission of smoke; but although this theoretical conclusion is undoubtedly correct, the practical results are not always consonant with this statement.

In consuming smoke in the usual way a quantity of cold air is introduced into the fire, and as this must be heated up to the temperature of the surrounding fuel, the loss of the latter may be equal to, or even greater than, the saving of the fuel from the combustion of the products of distillation. This often results in the careless use of furnaces constructed on the principle of smoke prevention, and thus leads to the contradictory statements given by those who have used such furnaces. But in all carefully conducted experiments the saving of fuel has been considerable, and the reason of this will be at once perceived, when it is considered that in addition to the combustion of the products of distillation there is a large amount of fuel saved by the combustion of a gas called carbonic oxide, formed by the proper product of combustion, carbonic acid, taking up in its passage through the incandescent fuel another portion of carbon, which escapes useless as regards the production of heat, unless burned by the air introduced at the bridge of the furnace, for the purpose of consuming the products of distillation.

From these considerations and from experiments conducted under our inspection, with a view to determine this point to our satisfaction, we arrive at the conclusion that although from careless management of fires there is often no saving, and that

indeed there is frequently a loss of heat in the prevention of smoke, still that with careful management the prevention of smoke is in many cases attended with, and may in most cases be made to produce, an economy of fuel.

It may be unnecessary to remind your Lordship that the cause of the emission of smoke in manufactories may be classed under three different heads, the relative importance of which involves very different considerations in any attempt to legislate for its prevention. These are—

1. The want of proper construction and adjustment between the fireplaces and the boilers, and the disproportionate size of the latter to the amount of work which they are expected to perform.
2. The deficiency of draught, and improper construction of the flues leading to a chimney of inadequate height or capacity.
3. The carelessness of stoking and management by those intrusted with the charge of the fireplaces and boilers.

These differences in the causes of smoke have already induced the Legislature to proceed cautiously in the local Acts for its suppression. A fine inflicted and levied summarily is quite applicable, when the emission of smoke is due to the carelessness of those intrusted with the management of the furnaces, and may with justice be levied on the master, who is responsible to the public that his servants act in such manner as to prevent his establishment being a public nuisance. A fine thus summarily levied, when the cause of the nuisance is unconnected with carelessness of management, and depends on bad structural arrangements, becomes oppressive in cost of alterations by acting as a fine infinitely greater than the Legislature contemplated as a punishment for the offence."

APPENDIX IV.

Conclusions of Report of the General Board of Health, 1855.

1. "That the emission of smoke is the effect and may be taken as the proof of imperfect combustion, and is therefore always attended with waste of fuel.
2. That the fuel wasted is not only the visible smoke, which is unburnt carbon, but generally a far larger portion in the form of gas, both common coal gas and that called carbonic oxide, which is only half-burnt carbon, and which, therefore, has not produced the heat which it would have generated if it had been perfectly consumed.
3. That the chief impediment to the prevention of smoke in manufactures is the insufficient boiler surface in proportion to the steam required; a deficiency which causes waste in two ways; first because much of the heat produced escapes up the chimney uselessly, and next because this deficiency has to be made up by overfiring, whence imperfect combustion and consequent waste of fuel.
4. The employers of furnaces labour under great difficulty as to the best and most economical use of fuel, because ordinary makers of furnaces seem to be guided in their construction by little better than empirical rules, instead of acting upon well-established scientific principles or the results of accurate experiments.
5. That notwithstanding this great difficulty many persons have succeeded in entirely preventing the escape of visible smoke, except while first lighting their furnaces, and many others have reduced the time during which smoke is emitted to a small fraction of its former amount.
6. That experience has fully proved that there is no truth in the common allegation that if smoke be prevented, there must be increased difficulty in getting up and maintaining steam.
7. That successful modes of preventing smoke, if there be proper boiler surface, may be adopted without the infringement of any patent right, the methods in question not having been patented or the patents having expired.
8. That notwithstanding the great and obvious advantages of perfecting the combustion of fuel, and the certainty that the cost of doing so will be amply repaid by the saving effected, such is the indisposition of practical men to depart from the beaten track, that nothing but the force of law is likely to ensure the care and attention necessary to protect the public from a grievous nuisance, the manufacturers themselves from heavy unnecessary expense, and the national resources from grievous waste of fuel to the amount of millions a year.
9. That though the absolute and immediate prohibition of smoke could not be enforced without compelling most of the owners of furnaces to incur very heavy expenses, its reduction to a very small amount may be effected with comparative ease, and with very great benefit both to themselves and others; while it cannot be

denied, that any who produce more smoke than others who use fuel for the same purposes, do produce more than is practically necessary.

10. That the enforcement of smoke regulations can be most easily and quickly effected by the appointment of constables to keep a regular and constant watch upon all chimneys liable to emit much smoke; and that the prevention of smoke will be more quickly and certainly effected by constant supervision and immediate information of any breach of the regulations, than by heavy penalties irregularly imposed.

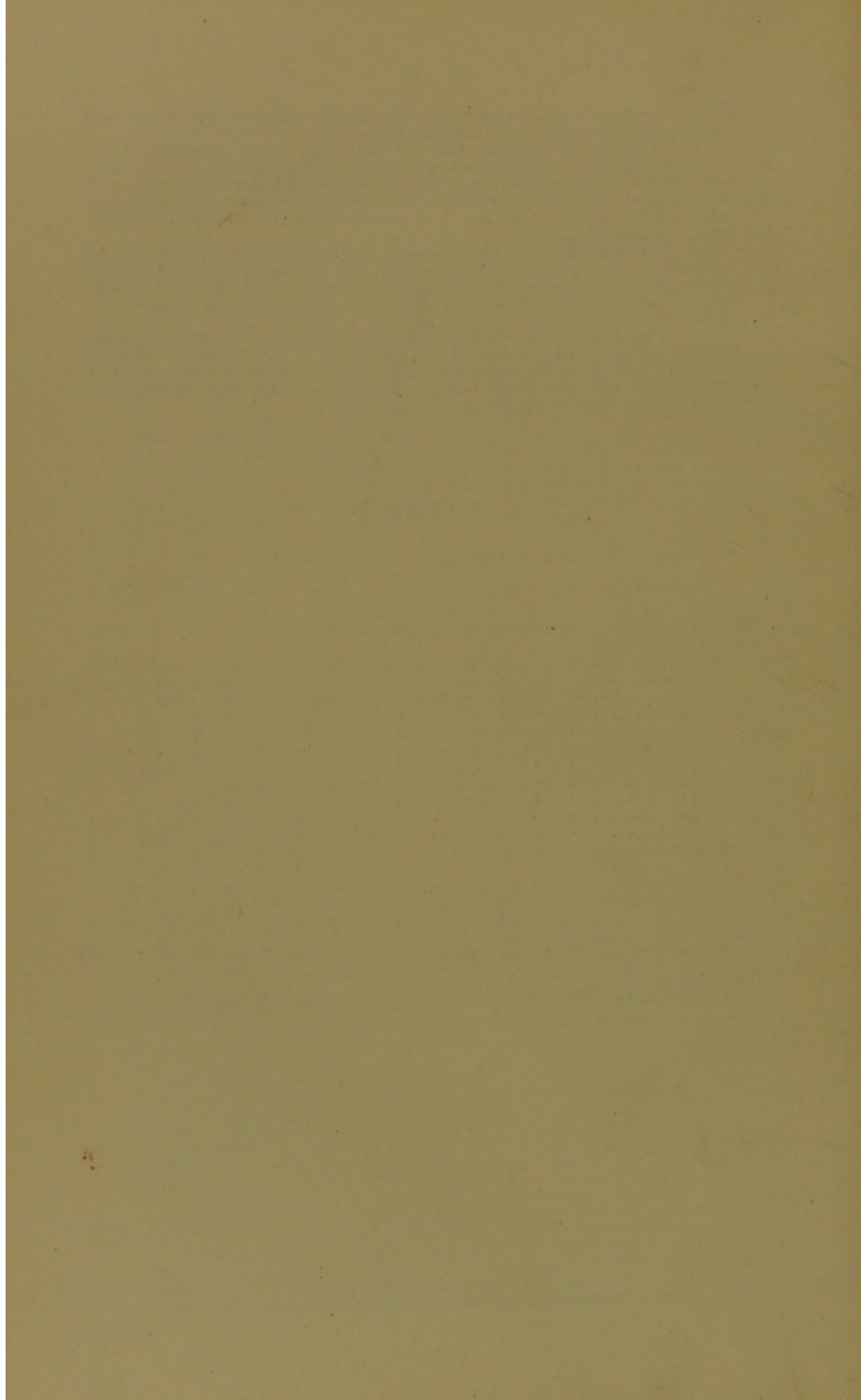
11. That great facility in the prevention of smoke would be afforded by the publication of the specifications and descriptions of patented and other inventions for the prevention of smoke, by which those interested could be informed what they could and could not do in this matter without infringing upon any patent right.

12. That great facility would also be afforded by the appointment of officers specially qualified, and *not connected with any patentee or manufacturer of boilers or furnaces*, to superintend the police officers employed to suppress the nuisance of smoke, and to advise owners of furnaces how best to comply with the provisions of the law, and to report upon cases of its infringement."

APPENDIX V.

(MR. FLETCHER'S REPORT. SHEET A.)

Station No.	Date														
Chimney	1	2	3	4	5	6	7	8	9	10	11	12	13	14	&c.
Time of Observation.															
A.M.															
5.0.....	—	—	2	—	1	—	—	—	3	—	1	3	2	—	1
5.2.....	—	—	3	—	1	1	—	—	2	—	1	3	1	—	2
5.4.....	—	—	3	—	1	2	—	—	1	—	1	3	1	—	1
5.6.....	1	—	3	—	—	1	—	1	—	—	1	3	1	—	1
5.8.....	1	—	2	—	—	2	—	1	—	1	—	3	2	—	1
5.10.....	1	1	1	—	—	1	—	1	—	1	—	2	2	—	2
5.12.....	2	—	—	—	1	2	—	1	—	—	1	2	1	—	2
5.14.....	1	1	—	—	1	3	—	—	1	—	1	1	1	—	1
5.16.....	1	—	1	—	1	1	—	—	2	1	1	1	1	—	1
5.18.....	—	1	2	—	—	1	—	—	3	1	1	1	2	—	1
.....	—	1	3	—	—	—	—	—	3	—	—	3	1	—	2
.....	—	—	3	—	—	—	—	—	2	—	—	3	1	—	1
5.30.....	—	—	—	—	—	—	—	—	1	—	—	3	1	—	1
	7	4	23	0	6	14	0	4	18	4	8	31	17	0	17
Minutes per hour.....	28	16	92	0	24	56	0	16	72	16	32	124	68	0	68 $\frac{2}{3}$
Dense Smoke—															
Minutes per hour	9 $\frac{1}{8}$	5 $\frac{1}{8}$	30 $\frac{3}{8}$	0	8	18 $\frac{3}{8}$	0	5 $\frac{1}{8}$	24	5 $\frac{1}{8}$	10 $\frac{3}{8}$	41 $\frac{1}{8}$	22 $\frac{3}{8}$	0	22







SOME
TEXT
FALLS
INTO GUTTER