Report / Committee on Air Pollution.

COMMITTEE ON AIR POLLUTION

REPORT

Presented to Parliament by the Minister of Housing and Local Government, the Secretary of State for Scotland and the Minister of Fuel and Power by Command of Her Majesty
November 1954

LONDON
HER MAJESTY'S STATIONERY OFFICE
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(Assistant Secretary, Ministry of Housing and Local Government).

Secretary

Miss R. CAVE,
(Ministry of Housing and Local Government).

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* (Mr. F. W. CHARLES and Mr. P. CHANTLER were appointed on 25th February, 1954).

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APPENDICES

COMMITTEE ON AIR POLLUTION

REPORT

To:

The Rt. Hon. Duncan Sandys, M.P.,
Minister of Housing and Local Government.

The Rt. Hon. James Stuart, M.P.,
Secretary of State for Scotland.

The Rt. Hon. Geoffrey Lloyd, M.P.,
Minister of Fuel and Power.

1. We were appointed on 21st July, 1953, with the following terms of reference:—

> to examine the nature, causes and effects of air pollution and the efficacy of present preventive measures; to consider what further preventive measures are practicable; and to make recommendations.

2. We started our inquiry by taking stock of the facts already known about air pollution—its nature, causes and effects and the methods of prevention in use, and in November, 1953, we presented an Interim Report which contained a short factual summary of the position as it appeared to us at the time. The Report made some recommendations as to the immediate steps that might be taken to avert the worst consequences of air pollution under extreme conditions such as the London fog of December, 1952. We would repeat these recommendations since the need for them is still present, and we reproduce them in Appendix I. But we would emphasise again that these are no more than short-term palliatives until more definite methods of prevention can take effect.

3. The Interim Report showed the extent of the problem with which we have to deal. Air pollution, as we indicated, is caused by smoke, gases, grit and dust from domestic and industrial chimneys, locomotives and ships, exhaust gases from motor vehicles, and the solid and gaseous pollutants from chemical works and industrial processes. We have, during the year, been examining all these aspects of the problem and the related questions such as the cost of pollution, the economics of prevention, the pattern of domestic heating, the availability and prices of different fuels and the effectiveness of the law and its administration. We have naturally given close consideration to individual episodes such as the London "smog" in December, 1952, but our inquiry has in the main been directed to the wider general problem of air pollution wherever and in whatever form it occurs. We have visited a number of cities in the Midlands, the North of England, Scotland and Wales, to obtain first-hand knowledge of local conditions. We have held many meetings with representatives of local authorities, representatives of industry, and the many interested organisations, and we have received a wealth of written material on the various aspects of our inquiry. We took little formal evidence; rather taking the view that all interests were in agreement as to the objective and that therefore it was a matter for joint discussion to find the means. The names of the persons and organisations from whom we received evidence or information are listed in Appendix XIII and we wish to record our sense of indebtedness to them all for the valuable assistance they have given us.

4. We set up six Sub-Committees and divided the work of the Committee among them, and certain individual members of the Committee undertook detailed studies of particular matters relating to the general problem. We have held 59 meetings as a full Committee, and 74 meetings have been held by the Sub-Committees, a total of 133 meetings.

5. We now have the honour to submit our final Report. In it we have endeavoured to present the salient features of the problem as a whole and to state our main conclusions and recommendations directly and without excessive detail. Where necessary, however, the technical and other considerations on which our conclusions are based have been included as appendices to the Report.

6. In presenting this Report we wish to state our emphatic belief that air pollution on the scale with which we are familiar in this country today is a social and economic evil which should no longer be tolerated, and that it needs to be combated with the same conviction and energy as were applied one hundred years ago in securing pure water. We are convinced that given the will it can be prevented. To do this will require a national effort and will entail costs and sacrifices ; the recommendations made in this Report will involve expenditure by the Government, local authorities, industry and householders alike. But we are confident that our proposals, if carried out, will secure happier and more healthy living conditions for millions of people, and that on all counts the cost of the cure will be far less than the national loss in allowing the evil to continue.

7. We are satisfied that the most serious immediate problem to be tackled is visible pollution by smoke, grit and dust, and we have been able to make definite recommendations in regard to these. We must emphasise that the problem is not one which can be solved overnight. Real improvement can be secured only by a continuous programme urgently and insistently carried out over a number of years. The objective of our recommendations is that by the end of ten to fifteen years the total smoke in all heavily populated areas would be reduced by something of the order of 80 per cent. This would mean a degree of freedom from air pollution which many parts of the country have not known for more than a century. With regard to gaseous pollution, there is not yet the knowledge to deal effectively with the whole problem ; but we have made a number of recommendations for preventive action and have indicated the directions in which ultimate solutions may be found.

8. It is basic to all our recommendations that at the outset it should be made the declared national policy to secure clean air, and that a statement to this effect should find expression in the new legislation—the " Clean Air Act "—which we are recommending.

9. We wish to pay a special tribute to all the Assessors, to our Secretary, and to the various Secretaries of the Sub-Committees. This is more than the formality which it perhaps on occasion may be, because we doubt if any Committee has made a heavier demand on those who have served it. Without the intense work of all, the Committee could not have made the wide and detailed survey on which its conclusions and recommendations are based.

(Signed) HUGH BEAVER (*Chairman*).
ROGER DUNCALFE (*Deputy Chairman*).
A. D. BOYD.
J. L. BURN.
F. W. CHARLES.
S. R. DENNISON.
T. FERGUSON.
G. E. FOXWELL.
R. LESSING.
GORDON NONHEBEL.
C. J. REGAN.
O. G. SUTTON.

ROSE CAVE,
(*Secretary*).
10th November, 1954.

THE NATURE AND EFFECTS OF AIR POLLUTION

10. Our Interim Report*, published in December, 1953, described in some detail the nature and amounts of air pollution present in this country. To make this Report self-contained we briefly re-capitulate:—

(i) the most serious problem is the pollution which arises from the combustion of fuels (coal, oil and their products);

(ii) the effects are most severe, and the need for prevention is most urgent, in the "black areas" which were indicated broadly in the Interim Report. These are the urban areas which are liable both to heavy pollution and to natural fog;

(iii) a distinction can be drawn between visible pollution by smoke, grit and dust, and pollution by invisible gases, the most important of which are the oxides of sulphur;

(iv) more than half of all the *smoke* comes from industrial sources and railways, but for each ton of coal burnt domestic chimneys produce twice as much smoke as industry and discharge it at a lower level;

(v) nearly all the *grit and dust* comes from industrial sources, including power stations and railways;

(vi) *sulphur dioxide* is discharged wherever coal, coke or oil is burnt, whether in industrial or domestic premises;

(vii) the following table in which the figures given in the Interim Report have been revised and brought up-to-date, shows the main uses of fuel and estimates of pollutants discharged from such uses in Great Britain in 1953.

Main Supplies and Uses of Fuels and Estimates of Pollutants Discharged in 1953

Class of Consumer	Fuel Supplied	Fuel Burned			Pollutants Discharged		
		Solid	Liquid	Coke Oven Gas (Unpurified)	Smoke	Grit and Dust (c)	Sulphur Dioxide
	Million tons			Million Cubic Feet	Million tons		
Coal							
Domestic	36·8	36·8			0·9	0·1	0·9
Electricity Works	36·7	36·7			small	0·3	1·0
Railways	13·8	13·8			0·3	0·1	0·4
Industrial and miscellaneous (a)	64·6	64·6		73,976	0·8	0·3	1·8
Coke ovens (b)	25·9			128,040	small	small	0·1
Gas Works (b)	27·2	6·2(d)			small	small	0·2
	205·0						
Coke (Excluding consumption in Gas Works and Blast Furnaces)		14·7			nil	small	0·4
Oil							
Diesel and gas oil	3·0		3·0			nil	0·1
Fuel oil	5·3		5·3			nil	0·3
Creosote-pitch mixture	0·7		0·7			nil	small
	9·0						
Total		172·8	9·0	202,016	2·0	0·8	5·2

(a) Includes general industry, collieries, patent fuel works, non-industrial establishments, waterworks, and the Service Departments.
(b) Although over the whole country the smoke and grit discharged from gas works and coke ovens is small, the pollution from certain types of plant and particularly from older coke oven plants can have a serious local concentration.
(c) This column does not include grit and dust emissions, estimated as about 0·5 million tons, from industrial processes other than steam raising.
(d) This is coke.

* Cmd. 9011.

11. Our Interim Report dwelt particularly on the ill effects of air pollution on human health, as well as referring to the widespread material damage caused by the corrosion of buildings, metals and other materials in polluted atmospheres, not merely on isolated occasions such as the severe London fog of December, 1952, but as a result of the general and continuous incidence of pollution over large parts of the country. We have since made a closer study of the effects of air pollution generally on human life and health.

The Effects on Health

12. Whilst scientific evidence about the effects of air pollution on human health is incomplete, enough is known to make it abundantly clear that it is injurious to both physical and mental health. It fosters disease and can cause death.

13. The effects of the London fog of December, 1952, which resulted in the deaths of some 4,000 people, have been the subject of a recently published report by an expert committee appointed by the Minister of Health†. Our Report deals rather with the consequences of the continuing air pollution that persists year in and year out over wide areas of the country. There is a clear association between pollution and the incidence of bronchitis and other respiratory diseases. Statistics show that every year the death rate from bronchitis in England and Wales is much higher than in other European countries for which reliable figures are available. The following table shows comparative death rates from bronchitis for England and Wales and the Scandinavian countries:

Death rates from Bronchitis per 100,000

		Males	*Females*
Denmark	1951	2·2	1·9
Norway	1951	5·5	5·8
Sweden	1951	5·0	4·0
England and Wales	1951	107·9	62·7
	1952	83·8	42·0
	1953	91·9	47·6

Not all of the excess can necessarily be attributed to air pollution since other factors, for example, climate or housing conditions, play a part, but in general it is the industrial towns liable to heavy pollution that have the highest death rates.

14. The death rates from pneumonia and bronchitis in 1952 in this country show a definite and consistent difference between the large centres of population and the rural areas, as is shown in the following tables:

† (Reports on Public Health and Medical Subjects No. 95 H.M. Stationery Office 1954).

ENGLAND AND WALES

Death rates per 100,000 *of the population*

Standardised to sex and age distribution.

Cause of death	Urban areas with a Population of			Rural Areas
	100,000 and over	50,000 to 100,000	Under 50,000	
Pneumonia	47·90	39·22	35·75	31·55
Bronchitis	61·56	53·82	48·77	36·94
Other respiratory diseases (excluding influenza)	11·19	9·71	10·60	9·66
TOTAL	120·65	102·75	95·12	78·15

Percentage of deaths from all causes due to respiratory diseases (excluding influenza)

	Urban areas with a Population of			Rural Areas
	100,000 and over	50,000 to 100,000	Under 50,000	
Males	12·12	10·62	10·15	8·98
Females	8·19	7·57	6·75	6·44
TOTAL	10·23	9·13	8·50	7·78

SCOTLAND

Death rates per 100,000 *of the population*

Cause of death	Counties of Cities	Large Burghs	Small Burghs	Landward Districts
Pneumonia	46	35	30	26
Bronchitis	54	42	27	29
Other respiratory disease (excluding influenza)	19	20	17	14
TOTAL	119	97	74	69

In the heavily polluted central Clydeside conurbation in particular, the death rate from bronchitis is commonly much higher than in the rest of Scotland. In 1952 in the Clydeside area 11·7 per cent. of all male deaths and 9 per cent. of all female deaths were due to respiratory disease whereas the corresponding figures in the rest of Scotland were 7·5 per cent. and 5·6 per cent.

15. Air pollution is clearly most harmful because of its action on the respiratory system, but it is also damaging because it obscures natural light and thus reduces resistance to infection and retards recovery from illness. In evidence submitted to the Royal Commission on the Distribution of the Industrial Population in 1938, the Registrar General listed as one of the four factors most important in increasing urban death rates "the production of smoke from factories and houses which reduces the effective sunlight". The psychological effects of reduced light and sunshine may be no less serious than the physical effects.

16. The comparative death rates for urban and rural areas generally suggest that pollution of the atmosphere may be a factor in the production of cancer of the lung.

17. There is an urgent need of more precise knowledge regarding the effect of polluted air as the cause of disease and death and we consider that measures should be taken to ensure that consultants, and in particular pathologists, and interested general practitioners, should, in selected areas have full opportunity and facilities to investigate in careful detail cases of illness or death the probable cause of which is air pollution. We are impressed, too, by the need to explore the relationship between the physical and chemical nature of the constituents of polluted air and morbidity and mortality. There should be systematic investigation of the varying incidence of respiratory disease in urban and rural areas.

18. We know that intensive researches on the subject are now being undertaken both in this country and in the United States. The Medical Research Council have informed us of their programme of research which we welcome and regard as a matter of the greatest urgency. But a great deal of work remains to be done on the precise scientific determination of the ill effects of the several elements in air pollution and their inter-relationships. This is not purely a medical or a pathological matter, and it is important that medical, chemical and physical research on this subject should be closely co-ordinated. But action to reduce pollution by smoke, grit and dust and sulphur oxides need not and must not be held up while further medical research is done. There can be no doubt that the effect of air pollution on health is wholly bad, whether measured positively in relation to growth, well being and joy of living, or more negatively in terms of death, disease and the economic loss which goes with incapacity to work.

The Economic Cost

19. Our Interim Report quoted some previous estimates of the total cost of air pollution amounting to £100–£150 million per annum. All estimates are necessarily somewhat conjectural owing to the lack of adequate data and the great diversity of the possible items of damage or loss. Many of the items are hardly measurable in terms of money, and for those that are, little or no precise information can be obtained. One can but make reasoned estimates of the broad orders of magnitude, taking account only of the specific items which can be given something of a definitive monetary value.

20. The economic effects of pollution can be considered under two heads ; direct costs and loss of efficiency.

The direct costs include laundry and domestic cleaning ; the cleaning, painting and repair of buildings ; the corrosion of metals, which entails the cost not only of replacements but also of providing protective coverings etc. ; damage to goods ; additional lighting and extra hospital and medical services, etc.

The loss of efficiency includes for example, the effects on agriculture of damage to soil, crops and animals, interference with transport, and reduced human efficiency due to illness.

21. We have made inquiries of many different sources about the costs falling under each of these heads. After examining all the evidence we have been able to obtain we feel justified in stating that air pollution is at present costing the nation about £250 million a year in terms only of losses that can be given a monetary value. The way in which this estimate is arrived at is explained in Appendix II.

22. This does not include the value of the fuel that is lost through incomplete combustion, one of the main causes of smoke. This probably amounts to between £25 million and £50 million a year, and represents a waste of coal (possibly as much as 10 million tons) which the nation cannot afford, and may be still less able to afford in the future. Nor as we have said do they include those costs that cannot be measured in terms of money, though they may be immense, for instance, the loss of happiness and health.

23. Enough has been said to prove that air pollution as it occurs in this country to-day is a social and economic evil of the first magnitude. It not only does untold harm to human health and happiness ; it is also a prodigal waste of material resources. Expenditure on curing it would be a fraction of the savings which would result from the cure. The case for preventive action is overwhelming. We are convinced by all the evidence we have heard and from the thought we have given to the matter that effective prevention is possible. We have been greatly impressed during the course of our inquiry by the strength of informed opinion on both these points, and by the growing public demand for action.

INDUSTRIAL SMOKE

24. All the evidence we have heard has confirmed the validity of the statement made in our Interim Report that, with a few exceptions, no industrial chimney need normally emit more than a light haze of smoke if the combustion arrangements are adequate and are properly operated. This applies equally to commercial and other non-industrial premises, and, of course, to domestic chimneys, which, unlike industrial chimneys, seldom in fact produce dark smoke.

25. Our first recommendation is that, subject to some necessary exceptions, the emission of dark smoke as defined in paragraph 95 from any chimney should be prohibited by law throughout the country.

26. The exceptions we have in mind are twofold. Firstly, the emission of dark smoke from even the most efficient boiler and steam-raising plant must be regarded as unavoidable for occasional short periods when fires are being lit, or raked, or during soot-blowing, or in case of mechanical breakdown. Secondly, exceptions must be made for those industrial processes in which according to present knowledge the prevention of dark smoke entails special technical difficulties. The legislative provisions we propose are described in detail in paragraphs 96, 99-101.

27. Apart from these exceptions we are satisfied that industrial furnaces can avoid emitting dark smoke. Repair and maintenance, constant supervision and encouragement of the fireman to do his best, are highly important for the prevention of smoke no less than for the efficient use of fuel. It is a function of management to ensure that the conditons for smokelessness are provided, understood and observed by the boiler-house staff. Overloading of boilers cannot be accepted as an excuse for making smoke. Although the coal is often blamed we are satisfied that coal quality by itself is rarely the cause of excessive smoke. Extensive modernisation and improvement of plants will be necessary however and this will take a few years to accomplish. In particular the 40,000 or so hand-fired boilers now in use will need additional equipment, for preference mechanical stokers, or, if that is impracticable, they should be fitted with smoke-eliminating devices of proved efficiency such as smoke-eliminator doors of the type designed by the Fuel Research Station. With mechanical stokers, firing is continuous so that there is little difficulty in maintaining the right rates of supply of primary and secondary air, to avoid excessive smoke and achieve a high efficiency in the use of fuel.

28. The necessary improvements will require an initial capital outlay, but the whole cost will normally be recouped by the consequent savings in fuel. Again we would stress that excessive smoke is almost invariably a sign of wasted fuel, and expenditure on smoke-reducing equipment is therefore always likely to be a profitable investment.

29. Under the Government Loan Scheme administered by the Ministry of Fuel and Power capital is available on favourable terms for approved fuel-saving projects in industry. The Ministry receive technical advice from the National Industrial Fuel Efficiency Service on the engineering aspects of projects. We recommend that the scope of the loan scheme should be extended forthwith to include projects directed specifically to secure the reduction of air pollution, and we would urge industry to make the maximum use of the facilities provided. We would welcome any modifications to the scheme which would extend its scope or make its terms more attractive.

30. It has been represented to us that an effective incentive would be to allow the capital cost of new plant and equipment installed to save fuel and to prevent smoke, to be charged against revenue for tax purposes in the year in which the expenditure is incurred. Manufacturers installing new plant and equipment are already entitled to tax allowances, i.e. either 20 per cent. investment allowance and 100 per cent. depreciation allowance spread over the life of the asset; or, alternatively, 20 per cent. initial allowance and 80 per cent. depreciation allowance spread over the life

of the asset. To allow the whole cost as a charge against revenue in the year in which incurred would mean a smaller relief in total than the former, but the relief would all come in the first year. It has been urged that this would give a material impulse to conversion by smaller firms and we submit this for consideration.

31. The management and operation of industrial boilers and furnaces require a high degree of skill from all those concerned with the process if they are to be operated efficiently and smokelessly. A lot of unnecessary smoke is often produced, particularly in smaller works, because the boilers are operated by untrained men with inadequate supervision. It is of paramount importance in the interest of both smoke abatement and fuel economy that stoking should be recognised throughout industry as an operation requiring skill and that firemen should be properly trained. We look forward to the time when every boiler plant and furnace will be tended by fully trained and competent firemen.

32. Training courses for firemen and boiler attendants are now available at many technical colleges and institutions throughout the country. We urge managements to encourage their employees to take such courses. There should also be provision for a limited certificate of competence to be related to one or more specified kinds of appliance and for granting it on the evidence of a practical and oral test alone. This will ensure that a fireman could be granted a certificate of competence on the actual boiler he handles. We hope that the National Industrial Fuel Efficiency Service will extend their activities, especially in regard to the smaller firms, by developing to the maximum extent their plan for practical training of firemen on the job. This training scheme, if widely used, could yield rapid results.

33. There should be suitable financial reward for trained and efficient firemen. This has been secured in some works by recognition of the skill of efficient firemen by appropriate rates of pay, or by means of incentive schemes based on the actual conditions in each works and related to proficiency in smoke prevention and fuel economy. Evidence has been put before us that such incentives have been repaid by savings in fuel. But whether incentives are used or not the good fireman should receive the remuneration which his skill deserves.

34. Some form of smoke indicator is a useful check on the amount of smoke emitted. Recording smoke meters make it possible to keep a continuous record and are useful both to firemen and managements. They are essential for incentives schemes. More information about measuring smoke density is given in Appendix V. The provision of smoke alarms should become established practice for all industrial boiler plants and furnaces; this is already the case in some industrial towns in the United States of America.

35. It is desirable that there should as soon as possible be authoritative standards for smoke control and also for smoke indicators, recorders and alarms. We recommend that the following documents should be prepared and issued by the British Standards Institution:—

(1) Codes of practice indicating the extent to which smoke can be reduced by good practice and the means of securing such reductions.

(2) One or more specifications for smoke indicators, including a simple indicator and recording meter and an alarm system, together with guidance on their installation and use.

GRIT AND DUST

36. Grit and dust are emitted from furnaces, whether or not there is visible smoke, and from many other industrial processes. The methods of control are different from those required for the prevention of smoke. To some extent the escape of grit and dust from boiler plant can be reduced by the use of suitably prepared fuels and by careful attention to firing, but their discharge from chimneys or at low level from dusty processes can be effectively arrested only by the use of special plant provided for the purpose. Different appliances are needed for the various types of duty, and they vary in efficiency and cost. Thus, whereas well-designed mechanical arrestors, which are relatively cheap, are suitable for coarse grits from many types of industrial boiler plants, costly electrostatic precipitators, sometimes preceded by mechanical arrestors, are necessary with pulverized fuel boilers ; and for many industrial processes involving fine dusts it is necessary to use other equipment such as fabric filters. Even so, it is not possible to prevent all emissions of fine dust, and with small plants it would not be realistic to expect 100 per cent. collection of grit. The important factors are the weight of the dust discharged, the size of the particles, and whether the chimney is of sufficient height to disperse the residual dust adequately. (See Appendix VI.)

37. It is, in fact, difficult to lay down maximum tolerable limits for grit and dust emissions and they must be related to the size of the plant. Nevertheless, we consider it essential that the most up-to-date and efficient grit and dust arrestors should be used with all furnaces which burn pulverised fuels, or which burn solid fuel in any form in large quantities. Our proposals for legislation to secure this are contained in paragraph 98. This equipment should qualify for the financial assistance which we have already indicated in paragraph 29 for equipment installed to reduce air pollution.

Power Stations

38. Although much thought and money have been applied to the prevention of pollution and to increased efficiency in burning coal, power stations remain potential sources of serious pollution by grit and dust because of the great quantities of coal used, much of which is pulverised. Furnaces fired with pulverised fuel inevitably produce large quantities of grit and dust. No plant at present known will prevent all emission of dust, and the most efficient method now in general use, electrostatic precipitation, may even when in perfect working order allow 2 per cent. of the dust to escape. There are large installations from which, even under such conditions the escape of dust may amount to 10 tons daily. The problem in regard to power stations is accentuated by the enormous size of modern power stations. The need for these must be accepted but that must not disguise the fact that they are a concentrated source of heavy pollution. Not only their equipment but also their siting are therefore of major importance.

39. Electrostatic precipitators are expensive, and for a large boiler plant may add as much as 10 per cent. to the cost of a complete boiler unit. There is, therefore, scope for different and less dusty methods of combustion. We understand that new methods which result in a much smaller discharge of dust are in the course of development, and if successful these will in time greatly mitigate the nuisance.

40. For over 20 years every statutory consent for the construction of a new power station has included a condition that the most efficient and up-to-date method of arresting grit shall be used. Many of the complaints are directed at the older boiler plants which are equipped only with

mechanical grit arrestors. The latter were designed satisfactorily for the coal available when the stations were brought into operation, but during the last 15 years the ash and dust content of coal has increased so that many of these arrestors are now overloaded. Further, many old plants have low chimneys which are inadequate for the dispersion of the solid matter which escapes the arrestor plant. The use of these old stations is diminishing as new plant is brought into operation, and we appreciate that it would be uneconomic to spend large sums of money modernising old power stations whose future life is strictly limited. Nevertheless we think that there should be a definite date, say 1964, after which no power station should be allowed to operate with obsolete and inadequate grit and dust-arresting plant or unduly low chimneys except in emergency conditions. The important question of chimney heights is dealt with in detail in Appendix VI.

41. We are proposing elsewhere that power stations, like certain other industrial processes which present special technical problems, should in future be placed under the supervision of the Alkali Inspectorate.

Measurement of Grit and Dust

42. The measurement of grit emissions presents difficulty. Deposit gauges on the ground do not necessarily show the quantities discharged from a particular source and accurate measurements can be obtained only by taking samples of the flue gases. A standard method of sampling has already been published (B.S. 893) but it is lengthy and complicated in practice; we think it would be of advantage to works managements and local authorities if a simpler standard method could be devised. We recommend that this work should be undertaken by the British Standards Institution.

POLLUTION FROM SPECIAL PROCESSES

43. The special problems of pollution from the heavy chemical and allied industries are governed by the Alkali etc. Works Regulation Act, 1906, and the Alkali etc. Works Regulation (Scotland) Act, 1951, as extended by subsequent legislation. The industries concerned are those for the manufacture of acids, smelting of sulphide ores, the coal-carbonisation by-products industry (tar distillation, ammonia recovery, sulphur removal, and benzole extraction), refining and processing of petroleum and its products, the heavy chemical industry generally, certain metallurgical operations, and the manufacture of cement.

44. The Acts are administered by the Alkali Inspectorate of the Ministry of Housing and Local Government and the Department of Health for Scotland. Their effect is that the best practicable means must be used to render emission inoffensive and harmless. The expression "the best practicable means" covers both the right type of plant and its use and maintenance. For certain processes upper limits are specified by the Acts for the concentration of acidity in the effluent gases which may be discharged to the air. Wherever it is technically possible complete elimination is required. Before any process which is registrable under the Act can come into operation it must be certified by the Chief Alkali Inspector as being equipped with the latest and best practicable means for reducing emissions to a minimum. The Inspectors are qualified technical officers and they have wide powers of entry, testing and inspection. They are empowered to take legal proceedings for enforcement, but their practice is to rely principally on advice and persuasion and legal action is seldom necessary.

45. The different processes concerned and the methods of control in use are described in detail in the Chief Inspectors' Reports, which are published annually. We have heard no serious criticism, and a great deal of praise, of the system of control in force under the Alkali Acts and of the results achieved. We are satisfied that this system, under which processes are registered, and supervision and control follow, exercised as it is by an experienced technical inspectorate, constitutes the means best calculated to apply a continuing challenge to, and exert effective supervision and control over, those industrial processes which present special technical difficulties in the prevention of dark smoke, grit and dust. We therefore propose that all these processes be scheduled and brought under the Alkali Inspectors, and that the Alkali Inspectorate be expanded to the necessary extent. The processes we have in mind and the legislative provisions required are described in more detail in paragraphs 99-101.

Cement works

46. We know that there have been widespread complaints about the emission of dust from cement works, which are already registered under the Alkali Acts. The problem is most serious in the Thames-side area where the works on both sides of the river between Dartford and Gravesend are responsible for some two-fifths of the 11 million tons of cement produced annually in this country. Since cement works were scheduled under the Alkali Act in 1935 every new kiln installed at the Thames-side works has been fitted, at considerable cost, with electrical precipitators to deal with the dust laden gases. But even with precipitators working at full efficiency it is problematical whether dust emission from cement manufacture can be kept below a rate equivalent to 0·5 per cent. of the cement made.

47. The dust arrestment problem at cement works is more difficult than that at power stations by reason of the fact that the kiln gases contain some 40 per cent. of water vapour. There are therefore hazards of condensation on the precipitators with a consequent liability to corrosion and electrical failure. The admitted difficulties are receiving the close attention of the Alkali Inspectors and the industry working together. The problem at Thames-side is one of extreme difficulty by reason of the huge output in an area of only eight square miles, but we would urge that their efforts should not be relaxed until improved techniques have reduced the dust deposition from the cement works to a negligible minimum.

SULPHUR POLLUTION

48. One of the most deleterious products of the combustion of fuels is sulphur, present in the form of its oxides, mainly sulphur dioxide. Sulphur dioxide is discharged into the atmosphere with the chimney gases wherever fuel in the form of coal, coke, fuel oil or unpurified gases is burnt. The degree of efficiency of combustion does not affect the quantity of sulphur dioxide evolved. A relatively small proportion of the sulphur contained in solid fuels is retained in the ashes, but the bulk goes into the atmosphere. Coal and coke commonly contain between 1 per cent. and 2 per cent. of sulphur, and the position is likely to get worse since the average sulphur content of coals mined in Britain is steadily rising. Fuel oil frequently contains between 3 per cent. and 4 per cent. of sulphur.

49. The fuels used annually in Great Britain contain some 3½ million tons of sulphur and, allowing for what is retained in the ashes and the amounts recovered in gas works and elsewhere, the total quantity of sulphur dioxide discharged to the air amounts to about 5¼ million tons a year. Every

industrial and domestic installation which burns fuel other than town gas, purified coke oven gas or coke in blast furnaces, sends into the atmosphere its quota, great or small, of this invisible but harmful gas.

50. The obvious initial step in reducing the pollution of the atmosphere by sulphur oxides is to remove as much sulphur as possible at the pits by cleaning the coal. The National Coal Board now cleans much of the coal and is pressing forward its coal preparation programme. There is, however, a limit to what can be done in this way and we must conclude that, whilst it is important to reduce the sulphur content of coal as much as possible by cleaning before combustion or carbonization, in the present state of our knowledge a large proportion of the sulphur cannot be removed by these means (see Appendix VIII). It is technically possible to remove most of the sulphur from fuel oil, but the cost is too great at present for the oil industry to undertake this as a normal commercial operation.

51. It would be satisfactory if some material could be added to the coal before combustion that would retain the sulphur in the ashes. No practical success has attended efforts to do this so far, but we would like to see further research carried out in this direction.

52. A method which has received much attention is the washing of sulphur dioxide from the flue gases on their way from the furnace to the chimney. We referred to this in some detail in our Interim Report. In the present state of knowledge, this method is only practicable in very large installations, and it is now being used only at the Battersea and Bankside power stations in London. At the coal-fired station at Battersea with plant constructed before the war, about 80 per cent. of the sulphur dioxide is removed. At the oil-fired station at Bankside with equipment of later design, more than 95 per cent. of the sulphur dioxide is removed. With new plant, at present capital and operating costs, at a coal-fired station the overall cost would be equivalent to an addition of about 8s. for each ton of coal burnt in the boilers, or an addition of about 0·06d. a unit of electricity generated. Both the Battersea and Bankside processes require vast quantities of water and the effluent is discharged into the river as a nearly saturated solution of calcium sulphate. It would not be possible to use the system to any greater extent on the Thames. In the process that was for some years used at Fulham Power Station the gas was washed with a re-circulating suspension of calcium sulphate to which chalk was added and impure calcium sulphate was produced as a thick sludge. The process did not discharge an effluent to the river. The reports of the Chief Alkali Inspector in 1937 and 1938 stated that the plant was operating very efficiently and that over 97 per cent. of the sulphur dioxide was removed. The cost of operation (at present prices) is of the order of 10s. a ton of coal burnt. But in both the Battersea and Fulham processes technical difficulties, particularly in regard to corrosion and erosion, are not yet solved. The Fulham plant was stopped early in the war and was never re-instated.

53. A promising and substantially cheaper process which produces sulphate of ammonia as the end product is now on the point of large-scale trials at a power station by the British Electricity Authority. We understand that this process has been under consideration for a number of years, and we are not impressed by the speed with which these matters have been pursued. We feel that the method promises good results and we think there should be less hesitation about putting it into practical operation, recognising that some of the difficulties, particularly corrosion problems, can only be overcome in operation. It appears likely to be less costly than other methods of gas-washing, but it will probably add something to the costs of generating electricity.

54. The standard practice in modern power stations at present is to discharge the gases unwashed through tall chimneys 300 feet or more high. It is claimed that the hot gases have a buoyancy which carries them high into the atmosphere, where they are diluted and dispersed sufficiently to render them relatively innocuous by the time any portion diffuses to ground level. It has been strongly urged as an objection to gas-washing that it lowers the temperature of the flue gases and thereby reduces their buoyancy. The unwashed gas contains more sulphur dioxide but, being hot, it tends to disperse widely. A washed gas contains much less sulphur dioxide but, being cool, it reaches ground level more quickly ; occasionally part of the steamy cloud of flue gas is carried down by wind eddies.

55. Nevertheless, we have reached the conclusion that gas washing is desirable provided that the washing process removes not less than 90 per cent. of the sulphur dioxide in the flue gases. A lower efficiency than this would not suffice, but if 90 per cent. or more of the sulphur dioxide is removed it is most unlikely that pollution in the immediate vicinity would be aggravated by cooling the gas, while it is certain that over a much wider area it would be virtually eliminated. In our view the cost of gas-washing, even if it amounts to ·06d. to ·07d. a unit of electricity supplied may well be justified by the advantages of a cleaner atmosphere and the human and material benefits which would follow, until research produces more efficient and less expensive methods. Sulphur dioxide is one of the most harmful of all the polluting agents. The heaviest concentrations are produced by very large fuel burning installations and it is only at such installations that the removal of sulphur dioxide is practicable at present. We therefore consider that the most efficient methods of removing sulphur dioxide from flue gases should be adopted at power stations in future, except when they are so sited as to avoid polluting densely populated areas. Gas-washing should not, however, be taken as a justification for lowering the height of chimneys.

56. Although much attention has been devoted to removing sulphur dioxide from power station gases, it must not be overlooked that complete success would still leave more than three-quarters of the sulphur problem unsolved. In general industry the scale of operations is so much less than in the electricity industry that no system of gas washing likely to operate at a reasonable cost is yet in sight. No known methods exist whereby the greater part of the sulphur from industrial and domestic chimneys can be prevented from being poured into the atmosphere in the form of corrosive gases. The increasing use of town gas, a fuel virtually sulphur-free, will assist in reducing sulphur pollution, and the use of electricity will have the same effect when the sulphur problem at power stations has been solved. There will still remain many uses of fuel, such as steam-raising, for which the more expensive refined sources of energy will be too costly. There is thus no present prospect of substantially reducing the emission of sulphur oxide from general industry or domestic fires. This is an important issue which requires further attention and it is one of the matters which we recommend for intensive research.

57. We would point out that sulphur is an important raw material for industry, and that world supplies of sulphur for the future are by no means sure. There are possibilities (to put it no higher) that significant amounts of sulphur and saleable sulphur compounds could be recovered from coal-cleaning plants, from coke oven gas, from oil refinery gases, from producer gas and from the flue gases of very large fuel-burning installations. It would seem to us that expenditure on the removal of sulphur from the atmosphere, which would at the same time yield sulphur and saleable sulphur compounds from indigenous raw material might well be a profitable national investment, and that Government assistance towards the development of processes would be worth considering.

RAILWAY SMOKE

58. Railway locomotives are responsible for over one-seventh of all the smoke discharged to the atmosphere. Most of this smoke is produced by shunting engines and stationary locomotives and it therefore tends to occur most frequently in those urban areas which are already liable to serious air pollution. We have heard many complaints from local authorities and the public about the harmful and objectionable effects of the excessive smoke and grit which occurs in the vicinity of railway stations, engine sheds and marshalling yards.

59. There can be no doubt that the only complete answer is the replacement of coal-fired locomotives by electric, diesel or other smokeless methods of traction. The British Transport Commission have informed us that their current plans for the modernisation of the railways include schemes for the electrification of a number of lines, some of which are to be put in hand in the near future. We think that the factor of pollution should be taken into account in considering future schemes, and that the programme of electrification should be accelerated and extended.

60. The only present alternative to electrification, other than the straightforward conversion to oil firing of existing steam locomotives, is to replace coal fired engines by diesels or gas turbines. Some diesel engines are already in use for light-weight passenger trains, and five prototype main line diesel locomotives are, we understand, also in experimental operation. The Commission envisage a gradual extension of these services. Some progress has also been made in introducing diesel shunting locomotives. We are told that 250 of these are already in service and that 800 are expected to be in use by the end of 1957. This will represent 30 per cent. of the total number of shunting locomotives in use. The British Transport Commission inform us that a further five-year programme of replacement is now in preparation. From our point of view this rate of progress is too slow and we recommend that the change-over to diesel engines should be accelerated on the widest possible scale. We consider that there should be no coal-fired locomotives used for shunting, either on the railways or at industrial works, in any black area after 1960.

61. We have made inquiries into the possibility of substituting diesel or electric for steam traction while trains are entering and leaving the black areas, but we understand that the operating difficulties involved are such as to make this impracticable. Changing locomotives at the outskirts of the black areas would, we are told, necessitate alterations of the permanent way and the provision of sidings and additional accommodation for locomotives; it would also require modifications in signalling, more staff and additional stops. The process of changing over would involve delay and would slow up traffic on the busiest routes. We must accept these arguments, but all this cannot relieve the railways of responsibility for operating without causing nuisance.

62. Pending the extended use of alternative methods of traction we believe that further steps could and should be taken in the short term to reduce smoke from steam locomotives. We recommend that the British Transport Commission should give urgent attention to methods of reducing smoke from coal-fired locomotives, particularly during shunting operations and lighting the fires. We would draw special attention to the use of over-fire jets, which we understand are now used with good results in the U.S.A. This work should not, however, impede the extension of electrification and diesels, the progress of which should be kept under constant and critical review.

63. The Acts* at present in force for the control of smoke from railways have evidently proved ineffective, and we are satisfied that the law requires revision. The legislative provisions we propose are outlined later in this Report.

MOTOR VEHICLE EXHAUSTS

64. Pollution of the atmosphere by motor vehicle exhausts has increased with the growth of motor transport. It has attracted special attention being a fairly recent development as compared with the long-standing problem of smoke from chimneys. The great increase in the number of diesel-engined vehicles in recent years has been particularly significant. The contribution of exhaust gases to the total volume of air pollution is still relatively small, but it can reach considerable proportions locally in areas of heavy traffic congestion when the movement of air is restricted.

65. The exhaust gases include carbon monoxide, some sulphur dioxide and other gases including oxides of nitrogen, hydrocarbons and aldehydes. Diesel engines may also produce large quantities of dark oily smoke. There is at present no known method of preventing the emission of sulphur dioxide or carbon monoxide from vehicle exhausts. The amount of sulphur dioxide from this source is negligible as compared with the total quantity discharged into the atmosphere from other sources. More research is required to determine whether the carbon monoxide from vehicle exhausts reaches harmful concentrations in dense traffic areas. There are other gases about whose effects still less is known and at our suggestion the Fuel Research Station are now making a study of the extent of pollution by these exhaust gases in London streets under different weather conditions.

66. Smoke from diesel engine exhausts can be a serious nuisance. It is discharged at a low level and may even at times endanger traffic by reducing the field of vision. The dirt it deposits on windows, lamp posts and other objects in the street is objectionable and difficult to remove. Diesel smoke is unnecessary. All the evidence we have heard, including that from some of the largest bus and coach undertakings, agrees that diesel engines, if they are properly maintained, properly serviced and properly driven, need not emit smoke except possibly for a short burst when starting. More attention must be given therefore to the proper maintenance and driving of diesel engine vehicles and the necessary servicing facilities must be provided. It would be useful if means could be found whereby a driver could be made aware that he is emitting smoke. We would not agree that even at starting such smoke should be tolerated, but to prevent it will require research into diesel engine design.

67. The present law on the subject is explicit, and in our view adequate. The Motor Vehicles (Construction and Use) Regulations, 1951, made under the Road Traffic Act, 1930, require every motor vehicle to be maintained in such condition, and to be so used, as to prevent the emission of smoke or visible vapour the emission of which could be avoided by taking any reasonable steps or by the exercise of reasonable care. We cannot find, however, that the law is in fact enforced. Enforcement is at present the responsibility of the police and we can well understand that they have much else to do. There, however, is the law, and we would press that it should be enforced in future. It is a matter in which the local authorities should be able to assist. Owners of vehicles should clearly realise that they are liable to prosecution if their vehicles emit smoke unnecessarily.

* The Railways Clauses Consolidation Act, 1845, Section 114; and The Regulation of Railways Act, 1868, Section 19.

DOMESTIC SMOKE

68. We have made it clear that much can be done to reduce industrial smoke. But nearly half of all the smoke in the air comes from domestic chimneys. The proportion is greater in areas where houses predominate. Further, most of the domestic smoke is produced during the winter months when foggy conditions are most likely to occur. Although the smoke from domestic chimneys is less dense than that from industrial chimneys, it is discharged at a low level and its harmful effects are thereby accentuated. No cure can, therefore, be found for the heavy smoke pollution of our cities and towns unless the domestic chimney is dealt with. In our view there would be little justification for requiring industry and commerce to take all possible measures to prevent smoke, often at considerable cost, if the problem of domestic smoke were not also tackled.

69. The extension of smokeless zones is an admirable and effective method of securing smokelessness and we advocate its use to the maximum extent where conditions permit. Its scope is limited, however, since complete smokelessness is not practicable in areas which include industry as well as houses. We contemplate therefore a second type of area—a " smoke control area "—which would be on a much larger scale and in which concurrently with the measures we propose to reduce industrial smoke, domestic users would be required to use only smokeless fuels, bituminous coal containing not more than 20 per cent. of volatile matter (and in consequence substantially smokeless) or manufactured fuels having similar smokeless qualities. We recommend the progressive extension of smokeless zones and smoke control areas throughout the black areas under the legislative provisions outlined in paragraph 109. In addition we recommend local authorities to make their new housing estates smokeless by requiring the occupiers, as a condition of tenancy, to use only smokeless fuels in the appliances with which they are provided. We have inspected a large municipal estate where this method has been used with evidently satisfactory results.

70. The development of smokeless zones and smoke control areas will, of course, entail radical changes in the present pattern of domestic fuel use. The problem of domestic smoke is fundamentally different from that of industrial smoke in that bituminous coal can usually be burnt with little smoke in suitable industrial plant, whereas in most of the appliances at present used for domestic heating, it cannot. Smoke can be reduced by the careful use of well-designed closed stoves and of some of the latest improved open fires, but at the present time there is no prospect of developing an open fire, or a stove which could take the place of the open fire, capable of burning bituminous coal smokelessly. At the same time it seems clear that in many parts of this country open fires are likely to remain the usual means of heating houses for many years to come. Any real cure for domestic smoke must therefore mean replacing house coal by smokeless fuels, in which we include electricity and gas.

71. One possible means of replacing house coal by a smokeless heating service would be by district heating schemes in which groups of houses would have their rooms warmed and hot water supplied from a central source. Such schemes, however, though both technically efficient and smokeless, are only practicable in special conditions, and in the absence of any simple heat meter, generally uneconomic. We must, therefore, seek the replacement of house coal by direct use of smokeless fuels in individual houses.

72. In the black areas it is estimated that some 19 million tons a year of bituminous coal are now used for domestic purposes, and we have reviewed in detail the possible sources of smokeless fuels which would be required

to replace this coal. We anticipate an increasing contribution from the continued expansion in the use of gas and electricity, especially for cooking purposes. We consider that their use in place of house coal should be encouraged by the removal of the present purchase tax of 50 per cent. on gas and electric room and water heaters. Both gas and electricity will, however, probably remain more expensive than solid fuel for continuous room heating and this must limit the extent to which they will replace coal. Oil is used, though on a relatively small scale, for domestic heating services. We expect this use to increase but oil is unlikely to be used to a large extent for heating houses in this country. We must conclude that for as long as we can foresee the main substitute for house coal must be solid smokeless fuel.

73. The available solid smokeless fuels are natural smokeless coal, manufactured fuels such as "Phurnacite" and low temperature cokes ("Coalite" and "Rexco"), coke from coke ovens and gas works coke. The National Coal Board anticipate some increase in the supply of their natural smokeless coals and manufactured fuels, and the independent low temperature coke manufacturers are already expanding their capacity. Some extra coke might be available and suitable for domestic use from the coke ovens. Certain other measures could be taken to provide the necessary increased supplies of coke suitable for domestic use without, we believe, making impossible demands on the national resources of coking coal. There are quite considerable quantities of solid smokeless fuels, including coke, that could be made suitable for domestic purposes but which are now being used in plants that could burn bituminous coal or oil with little or no smoke. Here is obvious opportunity for replacing such coke and releasing it. Increased coke production at gas works must, however, be the main source of increased coke supply; coking coals and gas coals can be blended satisfactorily with considerable amounts of non-coking coals for the manufacture of coke, and the gas industry could extend the range of coals carbonized. From figures given us by the National Coal Board it appears that something approaching half of the coals which are of broadly carbonizable types are not being carbonized. We are aware that these types of coal are in considerable demand, and that, as the National Coal Board have pointed out to us, not all of this coal is available or suitable for carbonization. But much of it is used for purposes for which it could be displaced by oil or non-carbonizable coal and we consider that the provision of smokeless fuel should be given priority. Replacement by smokeless fuel will release carbonizable coal now used as house coal and, as we have already made clear, we expect gas and electricity to fill part of the gap. We have no doubt that by combinations of all these measures, the house coal now used in black areas can in time be replaced by some form of smokeless fuel. It is true that implementation of these measures will involve problems of various kinds, the final solution of which must in some cases be materially affected by national fuel policy. But it is worth remembering that carbonization offers a substantial reduction in total coal requirements as compared with burning raw coal in older types of open fires.

74. We anticipate that the increasing use of oil will be of considerable assistance in releasing solid smokeless fuel and carbonizable coal. Coke at present used by commercial concerns and public authorities for central heating could, by substitution with oil, be released for domestic use in the black areas. We understand that over 2½ million tons of coke a year are at present being used by Government Departments and other public authorities and it would be open to the Government, if they thought fit, to give a substantial lead in the change-over to oil in this field.

75. The release of coke must clearly be co-ordinated with the demand which will arise as smokeless zones and smoke control areas are created. It would have been satisfactory to us to be able to show exactly how these operations could be planned over a definite period, and we have given a great deal of thought to the matter. One of our members in particular has made a special study of the main question of coke supplies, and his views and conclusions are reproduced in Appendix XI. But even with all the assistance we have received we do not feel able to prescribe the exact pattern of future supplies. We are not in a position, and it is not our task, to review the fuel policy of the nation nor the policies and objectives of the nationalised industries concerned. They have given us much valuable assistance, but although we have common ground in the efficient and economical use of fuels, our objectives and theirs do not necessarily coincide.

76. After studying all the available information we have come to the firm conclusion that by making full use of all the sources of supply indicated above the replacement of house coal throughout the black areas by coke and other smokeless means of heating is practicable. Whilst we should not care to predict to what extent the solution will ultimately depend on coke, we are entirely satisfied that from the sources we have indicated enough coke could be found to permit the creation of smokeless zones and smoke control areas as fast as the administrative action and the replacement of appliances would permit during the next five years at least. The complete programme will take much longer—some ten to fifteen years. By then there may well be new methods of smokeless heating or new sources of supply of smokeless fuels and it is possible that methods will have been developed of burning coal sufficiently smokelessly in domestic appliances, all of which may play a part in the final solution.

77. Our conclusion is, therefore, that there are fully adequate means for making an immediate and substantial start, with the assurance, in our opinion, that the basic supplies of coke can be made available. The responsibility for future progress must in our view, rest fairly and squarely on those who direct the fuel policy of the country. Our recommendation is that clean air should be the declared national policy and that such should be recognised both by the Government and by the nationalised fuel industries as an essential element in fuel policy in the future. As a Committee we feel that it is sufficient to look five years ahead leaving the detailed pattern of fuel usage to evolve.

78. Seeing that initially we look to coke as the main solution, we must make clear that when we speak of coke we mean a high quality free-burning fuel that will be completely satisfactory to the domestic consumer when used in modern appliances. We have seen areas where such coke is provided and used with full satisfaction. A great deal of the coke now produced, however, is not of this quality and measures must be taken to provide an improved fuel by care both in the production of extra coke and in the preparation of existing supplies now sold elsewhere that are transferred to domestic users in the black areas. We recommend that the British Standards Institution should prepare specifications of quality and methods of testing coke to be used in domestic appliances; and that the Gas Boards and other producers of coke should supply to these standards.

79. We realise that there may be some difficulty at first in getting people to accept coke in place of house coal, their traditional fuel, but we feel sure that this difficulty can be overcome by improved and consistent quality coupled with vigorous and convincing presentation of the value and desirability of coke supplemented by a good information and consumer service.

The householder should be made to realise that coke is cleaner than raw coal both for himself and for his neighbours and that when burnt in modern appliances it provides an equally pleasant source of room heating and is a more efficient, labour-saving and economical fuel. Coke is not, as some people say, "coal with the goodness taken out"; it is "coal with the smoke taken out of it". If properly used it gives more heat weight for weight than coal. We are confident that the domestic consumer will ultimately recognise the advantages of a supply of this high grade fuel and its convenience, coupled with the major advantage of freedom from smoke and dirt. We believe that these advantages will be sufficient to outweigh any moderate increase in coke prices, should such in the event prove necessary.

80. It is frequently asserted that coke is a more expensive fuel than house coal for domestic heating purposes. The information available to us points to quite the contrary conclusion. Coke is usually sold at no higher price than that of an average grade of house coal, and it is so much more efficient when used with reasonable skill in suitable appliances that the cost of a "useful" therm* from coke is appreciably less than from house coal. To provide a superior coke of standard quality suitable for general domestic use may involve some increase in cost but not so as to make coke a more expensive domestic fuel than house coal in terms of cost of a useful therm. Appendix X gives our estimates of the relative cost to the consumer for room heating by the various domestic fuels, taking prices as they are in the main black areas at the present time. The Table shows that this advantage would not be eliminated even if there were a rise in the price of coke of as much as £1 a ton, with ordinary coal prices remaining the same. We conclude that the present and prospective cost of coke to the consumer is not by itself an obstacle to its wider use.

81. We have heard that coke is sometimes regarded with some suspicion, because it is alleged that when used in stoves or open fires it is liable to cause carbon monoxide poisoning. We consider that there are no grounds for apprehension provided proper appliances are used, and they are properly installed, because coke produces no more carbon monoxide than raw coal.

82. A more serious difficulty is that coke—even the improved product which we envisage—cannot be burnt satisfactorily on the majority of open fires now in use. The provision of suitable smokeless fuels is therefore only one part of the solution; the other is the provision of suitable appliances. This must in fact be the first step, since the improved appliances are a requisite for burning coke satisfactorily. In the interim period before a zone becomes officially smokeless or "smoke controlled", coal can be burnt on these appliances more efficiently than on appliances of the older type. The appliances required are described more fully in Appendix IX. If all the households in the black areas were ultimately to be supplied with smokeless fuels in the solid form, then appliances would be required over 15 years or so for some 7 million households. But we envisage conversion proceeding mainly through a programme of expanding smokeless zones and smoke control areas, so that in the years immediately ahead only a portion of this 7 million is concerned.

83. It is already the practice of local authorities at the instance of central Government to install improved appliances capable of burning coke efficiently in the new houses they build. We recommend that private builders should be required to follow the same practice.

* The term "useful therm" refers to the heat delivered to the consumer's room, water or for whatever purpose it is required. Essentially, it may be defined as therms of heat in fuel delivered adjusted for efficiency in use.

84. We think it desirable that the design and performance of the recommended appliances should be kept under constant review so that the standard can be progressively raised. We suggest that the British Standards Institution should consider laying down specifications and methods of testing, and that there should be means whereby the public can recognise appliances which comply with the approved standards. We recommend also that wherever practicable all such appliances for burning solid smokeless fuel be fitted with easy means of ignition (e.g. gas ignition) as a condition of approval for installation in smokeless zones and smoke control areas. In existing houses, the replacement of older appliances could be stimulated by publicity and by an extension of hire purchase facilities for the improved appliances.

85. Both in smokeless zones and in smoke control areas, however, house owners will be obliged to install the necessary appliances, where they are at present lacking, in which to burn smokeless fuels. In most houses one or more open fires, with or without back boilers, and in some others old-fashioned cooking ranges, would have to be replaced by appliances using one or other of the smokeless fuels. We think it right that the duty of effecting the necessary replacements should be laid on the owner of the premises, but that he should be entitled to assistance towards the cost involved. We think this would be justified both in order to facilitate the extension of smokeless zones and smoke control areas and because the benefits to be gained from smokeless fires would be shared by the community. We recommend that a substantial contribution should be made from public funds towards the cost of installing approved types of appliances in houses in these areas. We suggest that the contribution should be defrayed partly by the local authority and partly by the Exchequer. We think it would be reasonable for the latter to bear 50 per cent. of the total cost and that the local authority should decide in each case how much of the balance they should contribute and how much should be borne by the owner. It should, however, be a condition of the Exchequer payment that some contribution should be made by the local authority.

86. In the majority of cases the total cost of conversion should not exceed £10 a house; for converting a single open fire it might be less; but in some cases, which may be relatively few, it must be recognised that the cost would be considerably more than £10. We have made it clear that we cannot define the pattern that the conversion to "smokelessness" will follow over the whole period. What we are immediately concerned with is the first five years, during which provision for coke-burning appliances must in our view be planned forthwith. We recommend therefore that provision should be made in the first instance for an Exchequer grant not exceeding £15 million, which would suffice for the first five years.

87. We believe that it is only by positive measures of the kind we have outlined, combining compulsion to stop producing smoke with financial help in providing the means to do so, that a real advance can be made towards abolishing smoke from domestic chimneys.

LEGISLATION

88. In the preceding pages we have expressed our views about the urgent need to reduce air pollution and how that reduction could be effected. It is now necessary to consider what legislative provisions would be needed to implement our proposals. It became clear to us at an early stage of our inquiry that the present law for the control of smoke and other visible pollutants needed considerable revision and strengthening. We have heard

much evidence about the limitations of the smoke abatement provisions of the Public Health Act, 1936, and the corresponding provisions which apply in Scotland and London, and of the many difficulties which local authorities encounter in administering the law. It is indeed apparent from the conditions which prevail to-day that the law has failed to achieve its purpose, notwithstanding that it has been in operation for many years and that considerable progress has been achieved in the technique of smoke prevention.

Defects of the Present Law

89. The statutory provisions for the control of smoke were described briefly in our Interim Report. We have heard a number of serious criticisms of the provisions of both the English and the Scottish Acts. The Public Health Act, 1936 contains no provisions for regulating domestic smoke; smoke from the chimneys of private houses is expressly excluded. There is no provision in the Acts for the creation of smokeless zones; local authorities have obtained the necessary powers hitherto only by promoting local Bills. The Acts do not directly prohibit smoke, and the procedure for enforcement is circuitous. It is a defence, except in proceedings in respect of "black smoke", for the person responsible to show that the best practicable means have been taken to prevent the emission of smoke. The term "black smoke" is not defined in the Act and is difficult of proof in a court of law; in fact it is doubtful whether smoke is ever black in the strict sense of the word when it leaves a chimney. Under the general law it is also necessary, when proceedings are being taken in respect of the emission of smoke from a chimney, to show that the smoke constitutes a nuisance. This is a matter of considerable difficulty in built-up areas where smoke is being discharged from a number of different chimneys simultaneously.

90. Local authorities may, under Section 104 of the 1936 Act, and subject to confirmation by the Minister of Housing and Local Government, make byelaws regulating the emission of smoke "of such colour, density, or content as may be prescribed by the byelaws". Many authorities have made such byelaws, which possess the advantage that infringements may be prosecuted without proof of nuisance. No byelaw has yet been made so as to apply to anything but black smoke, and if it were, the defence of "best practicable means" would still be available. At present these byelaws are undoubtedly a useful addition to the general law, and it has been suggested that they could be used to greater effect in future, especially if they could be extended to cover smoke other than black smoke. We take the view, however, that the first objective should be to strengthen the general law for the control of smoke, grit and dust, and that, if this can be achieved, it should not be necessary to rely on local byelaws.

91. Criticism has also been levelled at the protection given to various processes by Section 109 of the Act. This provides that the smoke abatement provisions of the Act shall not extend to a mine so as to interfere with its efficient working, or to a number of metallurgical processes so as to interfere with or obstruct any of those processes. Although the Minister has power by order to vary the classes of processes to which the section applies and to impose conditions, no such order has yet been made and the effect of the provision appears to have been to confer virtual exemption upon a large section of industry. The Scottish public legislation applying to burghs contains provisions exempting similar industrial processes, but the Secretary of State is not empowered to vary the specified classes of processes.

Proposals for amending Legislation

92. In our view it should be accepted without further proof that dark smoke is a nuisance and an evil. In so far as such smoke is known to be preventable, as it is to a very large extent today, the law should prohibit it directly. It should not be necessary to enquire whether or not the best practicable means of prevention are being used ; this is relevant only to those processes in which it is known that smoke prevention presents serious practical difficulties. In these cases there should be a continuing challenge and effective machinery for ensuring that the best practicable means of prevention are used, and that progress is made in the development of improved methods. We think these broad principles should form the basis of fresh legislation—a new "Clean Air Act", which would replace all the existing statutory provisions relating to smoke pollution and would be nation-wide in effect. Our proposals for this purpose are set out below.

Prohibition of dark smoke

93. We are satisfied, as we have said earlier, that with few exceptions no industrial chimney need normally emit more than a light haze of smoke if the combustion arrangements are adequate and are properly operated. We recommend therefore that subject to the necessary exceptions, new legislation should prohibit the emission of dark smoke, as described below, from any chimney. This could be achieved at once in the case of all those premises where the boilers and furnaces are already capable of burning fuel without discharging excessive smoke, if operated with proper care. There are nevertheless a large number of premises which are not at present equipped with efficient plant. For these, a reasonable time must be allowed for the necessary modifications and improvements. We suggest therefore that the operation of any new legislation should be deferred for a period of three years from the publication of this Report, which would allow time for any necessary re-equipment in the great majority of cases. There might still be instances in which it would be impracticable to complete the improvements before the legislation came into force. We recommend that as a temporary measure it should be competent for the local authority on the application of the owner or occupier of any premises, if satisfied that for adequate reasons it had not been possible to equip the premises to prevent the emission of dark smoke and that steps would be taken to effect the necessary improvements, to grant a temporary exemption certificate. Such a certificate would be valid for not more than one year at a time ; it would be renewable at the discretion of the local authority and would be admissible as a defence in proceedings, provided that the existing equipment were properly maintained and used. Power to give such certificates should cease entirely after seven years from the passing of the Act.

The provisions indicated in this paragraph should not apply to certain processes for which special arrangements are proposed in paragraphs 99–101.

94. By "smoke" we mean suspended particles or droplets of carbonaceous matter, grit and dust arising from the combustion of fuel. We refer primarily to smoke discharged from chimneys, and we think this should include smoke from ships and boats. We do not think the provisions we propose need apply to smoke from other sources, for example from road-making processes or garden bonfires ; these should remain subject to the nuisance provisions of the Public Health Acts.

95. By "dark smoke" we mean smoke of density equivalent to, or greater than, shade 2 on the Ringelmann Chart, which is reproduced in Appendix V. We think that this would be generally recognised as dark smoke in the

ordinary meaning of the term, and that there should seldom be difficulty in practice in deciding whether or not smoke from a chimney is dark in this sense. The Ringelmann Chart is widely used in America and is well known in this country. We have examined the possibility of measuring the density of smoke emitted from chimneys by means of instruments, but none of the methods so far devised can be relied on to give infallible results. We think it better to rely on ordinary methods of proof, by means of visual and other evidence, and do not suggest that the term " dark smoke " should be strictly defined by reference to a precise scientific test. The density of smoke passing through a chimney flue can, however, be observed and measured accurately by means of an automatic smoke-recording instrument of the kind mentioned in Appendix V. Where a defendant in proceedings can show that a reliable instrument of this type is in use, it should be open to him to produce its records in his defence, as evidence both of the density of the smoke emitted and the duration of the discharge.

96. As we have said it will be necessary to make allowance for short discharges of dark smoke which are unavoidable at certain times, for example during soot-blowing and raking of fires. We think it would be proper to permit a total upper limit of six minutes of dark smoke in any period of four hours but that no single burst of dark smoke should last more than three minutes. In addition, we recommend that it should be a defence in any proceedings for the defendant to prove that the emission of dark smoke was solely due either to lighting up of the furnace from cold and that reasonable care and efficiency had been exercised, or to temporary mechanical failure which could not have been foreseen. We recommend that the Minister of Housing and Local Government and the Secretary of State for Scotland should have power to make regulations to prescribe or to amend the permissible limits for temporary emissions of the kind referred to in this paragraph.

97. The foregoing indicates the extent to which the emission of smoke should in our view, be prohibited by law under penalty, but in many cases we believe that it is usually possible, given good practice, to obtain a higher degree of smoke control. We have recommended earlier in this Report that codes of practice or similar documents should be published for this purpose. Such a publication would be of assistance to managements and to local authorities in maintaining a high standard of smoke control and in securing compliance with the law.

Grit and Dust

98. Special provision is needed to regulate the emission of grit and dust from chimneys, independently of dark smoke.

We recommend that, subject to the exceptions indicated below:—

(1) the owners and occupiers of all industrial or trade premises in which furnaces are fired by solid fuel should be under a statutory duty to take all reasonably practicable steps to prevent the emission of grit or dust therefrom.

(2) every new industrial installation which is designed to burn pulverized fuel, or solid fuel in any other form at a maximum rate of 10 tons an hour or more, should be provided with effective grit-arresting plant, to the satisfaction of the local authority, who should not withhold approval without the consent of the Minister of Housing and Local Government or the Secretary of State for Scotland.

(3) in the case of any such installation, new or existing, it should be the duty of the owner or occupier of the premises if so required by the local authority to make regular measurements of grit emission, and to inform the local authority of the results, in such manner as the Minister or the Secretary of State may prescribe.

The "Scheduled Processes"

99. The provisions outlined above for the prohibition of dark smoke and in relation to grit and dust, should not apply to certain industrial processes in which it is known that prevention presents special technical difficulties. These will include some of the processes at present specified in Section 109 (1) of the Public Health Act, 1936, and certain others. The problems which arise in these cases are primarily technical and are common to similar processes carried out in different parts of the country. We propose that they should be subject to supervision by a central technical inspectorate, and not by the staffs of local authorities. We recommend that this work be entrusted to the Alkali Inspectorate of the Ministry of Housing and Local Government and the Department of Health for Scotland, and that the provisions of the Alkali &c. Works Regulation Act, 1906, should be extended for this purpose. The effect we envisage is that every works carrying on a "scheduled process" would be required to register annually, and would be subject to inspection by the Alkali Inspectors, whose duty it would be to ensure that the best practicable means of control were used at all times.

100. We propose that the scheduled processes should be designated by Act of Parliament or by a statutory order made thereunder, and that the appropriate Minister should have power, after consultation with the interests concerned, to extend or curtail the list, either in respect of processes generally or in respect of individual works by subsequent orders. We suggest that the initial list should include:—

(i) Metallurgical works as defined in Section 109 (1) of the Public Health Act, 1936, in so far as they present special difficulties in regard to the prevention of air pollution;

(ii) Power Stations: works where solid or liquid fuel is burned for the purpose of generating electricity for distribution to the general public or for purposes of public transport;

(iii) Gas Works: works for the manufacture of coal gas, water gas, carburetted water gas or oil gas for distribution to the general public;

(iv) Coke Works: works, not being gas works as defined above, in which the carbonisation of coal is carried out;

(v) Ceramic Works: works for the manufacture of pottery, blue bricks or tiles in kilns intermittently heated by the combustion of oil or coal;

(vi) Lime Works: works in which carbonates of calcium or magnesium are burned through the agency of coal.

101. We consider it desirable that the list should be reviewed by the Ministers annually so as to ensure that further processes are covered when necessary and that existing processes are dropped from the list and made subject to the ordinary law as soon as the special problems of these processes are solved. We would emphasise the need for vigorous and continuous action to secure the development of satisfactory preventive measures in all these cases.

Colliery spoilbanks

102. The Alkali Inspectors have been directly concerned for many years with the control of smoke and fumes from colliery spoilbanks. Although nuisances from this source may be dealt with under Part III of the Public Health Act, 1936, the Public Health (Coal Mine Refuse) Act, 1939, requires the local authority to obtain the consent of the Minister of Housing and Local Government before taking legal proceedings. The provisions in force in Scotland are similar. We think the present method of collaboration between the local authority and Alkali Inspectorate should continue, but we recommend that

pollution from colliery spoilbanks should be removed from the nuisance provisions of the Public Health Act and that the Act of 1939 (and the corresponding Scottish Act) should be replaced by a provision which would require persons depositing coal mine refuse to use the best practicable means for effectively preventing spontaneous heating and the discharge of fumes. Local authorities should, as at present, obtain the Minister's consent before taking proceedings for enforcement.

Control of new industrial installations

103. We have considered the desirability of adopting a general provision on the lines of the clause which appears in a number of local Acts which makes it an offence to install an industrial furnace unless it is so far as practicable capable of being operated continuously without emitting smoke. The clause provides also that a person proposing to install a furnace may seek the local authority's approval to the installation in advance. It has been suggested to us that there would be advantages in a general provision on these lines, and further, that it should be made obligatory to submit plans of the installation to the local authority for approval.

104. We agree that such a provision to regulate the design of new furnaces would be valuable as a means of securing that new plant is designed not only to avoid making dark smoke, but also to secure the best possible standard of smoke reduction. We think that voluntary provision for obtaining the local authority's approval would be of assistance to managements who require advice, and would help to promote confidence as between local authorities and industry. We do not consider that the submission of plans should be compulsory.

105. We recommend therefore that a provision on the lines of the present local Act clause should be included in general legislation, so that it could be adopted by local authorities who so wished.

106. Special attention should be given both by the local authorities and the developers to the height of new chimneys in order to secure adequate dispersal of the dust and sulphur oxides in the chimney gases. Appendix VI gives a summary of present technical knowledge on the subject.

Railway Smoke

107. Smoke from railway locomotives is at present governed by the Railway Clauses Consolidation Act, 1845 (Section 114) and the Regulation of Railways Act, 1868 (Section 19). These provide in effect that every railway steam locomotive shall be constructed so as to consume its own smoke, and that an offence is committed if any locomotive fails to do so, so far as practicable, through the default of the British Transport Commission or its servants. Hitherto no particular body appears to have been charged with the duty of enforcing these provisions and it seems that they have been largely disregarded.

108. We recommend that the existing provisions should be repealed by new legislation and replaced by a provision under which it would be an offence for any railway locomotive to emit dark smoke as defined in paragraph 95 above, or to emit any smoke or grit in such quantities as to cause a nuisance, except upon proof that all practicable steps were taken to prevent it. This should apply also to works locomotives. Responsibility for enforcing the law should be placed upon the local authorities.

Domestic Smoke

109. The provisions we propose for the prevention of dark smoke, though applicable to domestic as well as industrial chimneys, will by themselves

have little effect in reducing domestic smoke. Domestic chimneys seldom emit dark smoke; it is the cumulative effect of light smoke from a large number of low chimneys that matters. In order to implement the measures we have proposed, we recommend that legislative provision should be made as follows:—

(i) Local authorities generally should have power, by means of orders requiring confirmation by the Minister of Housing and Local Government or the Secretary of State for Scotland after such local enquiry as may be proper to establish—

(*a*) smokeless zones as provided for in recent local Acts;

(*b*) smoke control areas in which the domestic consumption of coal containing more than 20 per cent. of volatile matter would be prohibited.

(ii) Statutory authority would be required for the financial contributions which we propose should be made by the Exchequer and by local authorities towards the cost of converting domestic appliances in smokeless zones and in smoke control areas.

(iii) The installation of appliances of improved types for the main domestic space and water-heating services should be compulsory in the case of new premises.

Enforcement

110. We recommend that the responsibility for enforcing the law for the prevention of smoke, grit and dust, except in the case of the "scheduled processes", should be placed as a statutory duty upon the local authorities.

111. While the foregoing proposals for amending legislation are designed to strengthen the law and to facilitate its enforcement, we would emphasise our view that advice and co-operation are better methods of securing compliance with the law than prosecutions. For this reason we suggest that if it should seem necessary to take legal proceedings, local authorities should make it their practice to warn the potential offender in advance and advise him of the preventive measures they consider necessary. Legal action should follow promptly, however, if satisfactory steps are not taken.

112. The maximum penalty for smoke offences at present is £50 (£5 in Scotland) or £5 a day for continuing offences. Even £50 seems inadequate today, and we recommend that the penalties for offences under any new legislation should be increased appropriately. We would refer in this connection to the scale of penalties imposed by the Rivers (Prevention of Pollution) Act, 1951, which provides a maximum fine of £200 on conviction on indictment for a first offence, and imprisonment for six months and/or a fine of £500 for subsequent offences.

ADMINISTRATION

113. We have said that the main responsibility for administering the statutory provisions for the control of air pollution should continue to rest with the local authorities. We have considered, but discarded, suggestions that more satisfactory results would be achieved if the duty were placed upon some other body, e.g. a national board, regional boards, or county councils. Although it is true that air pollution knows no boundaries, its origins are local, and with certain exceptions we consider that prevention can best be enforced by the local authorities on the spot. We have seen ample proof of the anxiety of many local authorities and their officers to tackle the problem of air pollution in their areas. But the task will be a

formidable one, and it will be accomplished only if they are prepared and willing to accept the challenge. Our recommendations, if accepted, will place a heavy responsibility on the local authorities and progress towards cleaner air will depend very largely upon their efforts. We think this is right.

114. We regard it as imperative that the responsible authorities should employ adequate smoke control staffs with the necessary technical knowledge and experience, not only for the detection and prosecution of offences, but also for giving advice and assistance where needed about methods of prevention. At present smoke abatement is usually the responsibility of the local authorities' Sanitary Inspectors. It is one of many duties they discharge, and in most areas it represents only a very minor part of the Inspectors' activities. A recent Report on the Recruitment, Training and Qualification of Sanitary Inspectors* showed that only 1·3 per cent. of the total time of all Sanitary Inspectors was spent on smoke abatement duties. Out of a total of some 4,500 Inspectors, less than 100 spent more than 5 per cent. of their time, and only 16 more than half of their time, on this work. This causes us much concern. It is clearly an inadequate foundation for the task that lies ahead. Many more qualified inspectors will be needed.

115. We endorse the recommendations made in the same Report in regard to the need for Inspectors with higher standards of training in air pollution matters, and particularly the need for practical training.

116. We recommend that the responsible local authorities should be required to submit and publish annual reports to the Minister of Housing and Local Government and the Secretary of State for Scotland on the action taken and the progress made in regard to air pollution in their areas.

117. The problems of the large urban and industrial centres call for concerted action by all the local authorities concerned and we stress the importance of joint action or other arrangements to secure effective co-ordination. This is especially true of the Greater London area, and for this area we recommend that the local authorities, while retaining the responsibility for administering the law, should establish a Joint Committee which would be able to view the problem of London as a whole, including the control of smoke from shipping, co-ordinate the measurement of air pollution, and plan and supervise the creation and extension of smokeless zones and smoke control areas so as to cover the whole area. We suggest that the Committee should receive the annual reports of the constituent authorities, and should itself make an annual progress report to the Minister of Housing and Local Government.

118. We attach particular importance to the recommendation made in paragraph 99 that the control of pollution from certain industrial processes should be in the charge of the Alkali Inspectors of the Ministry of Housing and Local Government and the Department of Health for Scotland. This will necessitate a large expansion of the present Inspectorate. The Alkali Inspectors are already frequently called in by local authorities to advise in regard to works not registered under the Alkali Act, and a larger number of Inspectors working within smaller districts would make for closer collaboration with the authorities. The local authority inspectors and the central inspectorate should be regarded not as separate entities but as a partnership working together for the solution of a common problem which is of national as well as local concern.

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* Ministry of Health: Report of the Working Party on the Recruitment, Training and Qualification of Sanitary Inspectors. H.M.S.O. 1953.

119. For purposes of central administration, air pollution is a matter with which several Government Departments are concerned—the Ministry of Housing and Local Government, the Ministry of Fuel and Power, the Ministry of Health, the Department of Health for Scotland, and to a less extent, others. The Government organisations primarily responsible for research are the Department of Scientific and Industrial Research, the Medical Research Council, and the Agricultural Research Council. Each Department is concerned with particular aspects of the problem, which cannot be divorced from its other responsibilities. We are not suggesting any change in present departmental organisation or responsibilities. The proposals made in this Report will, however, if adopted, be only the beginning of a heavy task which will occupy many years and will call for a combined effort by many different interests. There is the preparation and supervision of the programme of conversion to smokelessness with the synchronising of fuel markets and fuel production, and the production and installation of suitable appliances. There is the watching and adjustment of the changing pattern of fuel user. There is continuous propaganda and education to be carried on. We are impressed by the large amount of vital research and development work to be done and we elaborate this in Appendix III. We therefore recommend that a " Clean Air Council " should be appointed to co-ordinate all aspects of the work in future, to encourage research and development and to review the progress made in implementing any new legislation. It should submit an annual report to Parliament. The form of this body we must leave to be decided by Ministers ; but that it is urgent and essential we have no doubt.

120. In this Report we have of course addressed our recommendations to the Ministers who appointed us. We have stated our view that it is the local authorities who should be given the means and who should accept the main responsibility for the attack on air pollution. But we would like to stress once more that neither the Government nor local authorities are likely to achieve any real measure of success unless all interests co-operate and unless public opinion, individual and corporate, clearly demands and will support the action that is required.

SUMMARY OF RECOMMENDATIONS

121. **Recommendations entailing legislation**

(1) Subject to certain exceptions the emission of dark smoke from any chimney should be prohibited by law. (Para. 93.)

(2) The use of efficient grit and dust arresting plant should be obligatory in new industrial installations which burn pulverised fuel, or solid fuel in any form at a maximum rate of 10 tons an hour or more. It should be the duty of the owner or occupier of premises on which any such installation, new or existing, is situated, to take measurements of grit emission and to inform the local authority of the results if so required. In other industrial installations fired by solid fuel, all reasonably practicable steps should be taken to prevent the emission of grit and dust. (Para. 98.)

(3) In the case of certain industrial processes in which the prevention of dark smoke, grit or harmful gasses presents special technical difficulties, responsibility for ensuring that the best practicable means of prevention are used at all times should be vested in the Alkali Inspectorate, and the provisions of the Alkali Acts should be extended accordingly. (Paras. 99-100.)

(4) The provisions now in force under a number of local Acts for regulating the design of new industrial furnaces should be included in general legislation. (Para. 105.)

(5) The law for the control of smoke from railways, and of pollution from colliery spoilbanks, should be brought up to date and strengthened. Responsibility for enforcement should rest with the local authorities. (Paras. 102, 108.)

(6) Local Authorities should have power under general legislation by means of Orders requiring confirmation by the appropriate Ministers to establish (1) smokeless zones in which the emission of smoke from chimneys would be entirely prohibited ; and (2) smoke control areas in which the use of bituminous coal for domestic purposes would be restricted. (Para. 109.)

(7) Financial assistance should be provided by local authorities and by the Exchequer towards the costs incurred by house owners in converting appliances in smokeless zones and smoke control areas. (Para.109.)

(8) Domestic heating appliances installed in all new premises should be of approved types. (Para. 109.)

(9) The present purchase tax of 50 per cent. on gas and electric room and water heaters should be removed. (Para. 72.)

(10) Except for the processes referred to in (3) above, responsibility for enforcing the law for the prevention of smoke and grit should be placed as a statutory duty on the local authorities. (Para. 110.)

(11) Local Authorities should be required to submit annual reports on their progress in smoke abatement to the appropriate Minister. (Para. 116.)

(12) Penalties for smoke offences should be increased. (Para. 112.)

122. **Other Recommendations**

(1) The following documents should be prepared and issued by the British Standards Institution:—

(*a*) codes of practice indicating the extent to which smoke can be reduced with good practice, and the means of securing such reductions. (Para. 35.)

(*b*) Standard specifications for smoke indicators, recorders and alarms. (Para. 35.)

(2) The British Standards Institution should also consider devising simpler standard methods of sampling flue gases to determine grit emissions. (Para. 42.)

(3) Stoking should be recognised as an operation requiring skill and firemen should be properly trained and remunerated. (Paras. 31-33.)

(4) The Government Loan Scheme for approved fuel-saving equipment in industry should be extended to include equipment installed for the purpose of reducing air pollution. (Para. 29.)

(5) Consideration should be given to allowing the whole of the capital cost of new plant and equipment installed to save fuel and to prevent smoke to be charged against revenue for tax purposes in the year in which the expenditure is incurred. (Para. 30.)

(6) The most efficient practicable methods of removing sulphur from flue gases should be adopted at all new power stations in or near populated areas. (Para. 55.)

(7) The factor of pollution should be taken into account when future schemes for the electrification of the railways are being considered and the programme of electrification should be accelerated and extended. The changeover from steam to diesel shunting locomotives should be accelerated. (Paras. 59, 60.)

(8) The present law for the control of pollution by motor vehicles should be more rigorously enforced. (Para. 67.)

(9) The prevention of domestic smoke will require the replacement of bituminous coal now used in domestic premises in the "black areas" by smokeless fuels, and also the provision of new appliances, fitted with easy means of ignition, in which such fuels can be burnt satisfactorily. This should be secured by the progressive extension of smokeless zones and smoke control areas as increased supplies of smokeless fuels are made available. (Paras. 68-84.)

(10) The British Standards Institution should prepare specifications and methods of testing for coke for household use and for domestic solid fuel appliances. (Paras. 78, 84.)

(11) Clean air should be the declared national policy and it should be recognised both by the Government and the nationalised fuel industries as an essential element in fuel policy in the future. (Para. 77.)

(12) Local authorities should employ adequate smoke-control staffs with the proper training and technical qualifications. (Para. 114.)

(13) Arrangements should be made to secure effective co-ordination as between local authorities in the black areas and especially in Greater London. (Para. 117.)

(14) Development and research work on the many technical problems now outstanding should be undertaken or accelerated. (Paras. 18, 119. APPENDIX III.)

(15) A "Clean Air Council" should be established to co-ordinate and encourage research work and to review the progress made in implementing any new legislation. (Para. 119.)

APPENDIX I

The Recommendations for Immediate Action which were made in our Interim Report are reproduced below:

"Recommendations for Immediate Action

15. As a matter of immediate concern, we have given consideration to what precautions might be taken to avoid during the coming winters the worst effects of "smog". No measures that will materially change the present position can be put into effect at short notice. But it is possible to procure some reduction of the amount of smoke that is discharged into the atmosphere. That is a matter for everyone who uses or controls the use of fuels. It is a matter in regard to which everyone has both a duty and an opportunity.

(1) The Authorities

(*a*) Arrangements should be made as soon as possible for the Meteorological Office to issue a warning by appropriate channels, and in particular the B.B.C. of areas of normally high pollution in which serious fog is expected to obtain for at least 24 hours.

(*b*) Every effort should be made without delay (1) to provide adequate supplies of smokeless fuels to domestic consumers in London and other densely populated areas liable to bad fog during the winter; and (2) to inform such domestic consumers when such supplies are available so that they may, at least, lay in a small stock for use when fog is developing.

(*c*) The appropriate authorities should, by whatever means are most suitable, bring to the notice of the public resident in areas liable to "smog" the fact that the largest single producer of smoke is the domestic consumer, and that it is to the personal advantage of everyone to co-operate in taking all practicable steps to reduce the amount of smoke discharged into the atmosphere.

(*d*) Steps should be taken to secure fuller and more frequent measurements of pollution, especially during severe "smogs", in order to determine the peak concentrations reached. This will greatly assist our further investigation. Local authorities can do most valuable service in this respect.

(2) Industry

Smoke control measures in industry, shops, offices, hotels, etc., should be brought up to peak efficiency at the beginning of the winter and their performance checked at frequent intervals throughout the winter. Special efforts should be made, even when equipment is old fashioned or inefficient, to prevent heavy smoke emission when stoking. Much of the smoke from factory furnaces whatever their nature can be prevented, and industrial management should accept at all times and particularly under foggy conditions, the responsibility of ensuring that no substantial amount of smoke is emitted.

Managers of industrial plants, public utility undertakings, and establishments, such as hospitals, institutions, offices and laundries, should institute a special continuous check to ensure that dark smoke is not emitted from their chimneys either by night or by day, and particularly during the early morning before daybreak. This check can best be made by the installation of a simple smoke density indicator. There are several proprietary instruments on the market, but even a simple home-made device is helpful. Sketches of two types that can be made up by most small works for a few pounds are given in Appendices II and III.

(3) The Householder

Householders in large towns who are dependent on solid fuel and who normally burn coal should, before each winter, lay in a stock of, say, 1 cwt., of coke or other smokeless fuel for use during periods of persistent fog. A mixture of coke and coal will burn reasonably well and will greatly reduce smoke.

(4) Instructions to the general public when persistent fog is forecast

Householders who can use only coal should take special care not to make more smoke than can be helped; fires should not be banked at night.

Householders who can use smokeless fuels should confine themselves to those fuels during periods of persistent fog. A mixture of coal and coke as already mentioned will effect some improvement.

Rubbish should not be burned, nor bonfires lit, while the fog lasts.

The general public should refrain from bringing motor cars into densely populated centres during a serious fog warning. In serious fog drivers of all motor vehicles should switch off engines whenever traffic is stationary, even temporarily.

Factories, commercial buildings, hotels, institutions, etc., should immediately put into effect action to watch and control all stoking of furnaces, and to prevent smoke.

Steps for mitigating the effects of "smog"

Less "smog" will find its way indoors, and rooms will be kept warmer, if draughts can be prevented.

Elderly people and those suffering from chronic chest and heart conditions, would be well advised to keep indoors and to rest as much as they can if the fog is very thick. Those who must go out will find that a closely-fitting simple gauze mask, or a woollen scarf wrapped round the mouth and nose, will give some relief, by filtering out some at least of the solid contents of the "smog".

16. The fullest co-operation of all sections of the public on the lines here indicated is essential.

17. It is emphasised that the measures proposed in this section are no more than palliatives to be put into force during the next few winters pending the results of permanent and satisfactory measures."

APPENDIX II

THE ECONOMIC COST OF AIR POLLUTION

Memorandum by the Economic Sub-Committee

Earlier Studies

1. There have been few previous attempts in this country to estimate the cost of air pollution on either a national or local scale; more data are available in the United States, and these are useful for comparative purposes.

The following are the main estimates which we have considered:—

(*a*) the Pittsburgh survey of 1913; this estimated the total cost for the City to be $9,944,740, i.e. about $20 per head per annum (or about £4 at the 1912 rate of exchange);

(*b*) a survey made in 1919 by the Air Pollution Advisory Board of the Manchester Corporation: this gave the total cost as at least £750,000 for the City, amounting to roughly £1 per head per annum.

(*c*) in 1925 Shaw and Owens ("The Smoke Problem of Great Cities") suggested that the cost of pollution varied directly with the amount of sootfall. By applying the Pittsburgh estimates of 1912 on this basis, they suggested figures for 1924 of £1 4s. 0d. per head of population for London and £1 10s. 0d. per head of population for Manchester. This method is unlikely to give satisfactory results. Even if it were valid, the figures given by Shaw and Owens neglect the fall in the value of money between 1912 and 1924, and should be increased by some 75 per cent. on this account.

(*d*) in 1939 the Medical Officer of Health in Liverpool estimated the cost for that city at £2·5 million, between £2 and £3 per head of population. This was regarded as being on the low side, and it did not attempt to be completely comprehensive. Allowing for the change in the value of money, it would now represent between £5 and £8 per head of population.

(*e*) the National Smoke Abatement Society in 1939 sponsored an inquiry based on a comparison between costs in smoky districts and "normal" costs in clean districts. Unfortunately the inquiry had to be suspended owing to the War.

(*f*) the estimate made by the Heating and Ventilation Reconstruction Committee of the Building Research Board in their Report on the Heating and Ventilating of Buildings published in 1945 (the Egerton Report). This gave an overall figure of £45 million, apparently for Great Britain, or £1 per head of the total population. This total estimated cost of £45 million is divided in three ways:

(i) between domestic heating and industry (including railways)—one half for each;

(ii) according to the suggested source of the damage—£21 million for smoke, £20 million for sulphur dioxide and £4 million for unburnt fuel;

(iii) according to the nature of the damage: £26·2 million for what are called "tangible items", i.e. cleaning, laundry, damage to buildings, and unburnt fuel, all of which are roughly measured, and the balance of £18·8 million for "intangible items" which include "increased corrosion of metals, loss of daylight, damage to crops and health of man and beast and dislocation of transport services," with no attempt to assign definite figures to these individual headings.

Allowing for the fall in the value of money since 1945, the present figure would be of the order of £80 million a year.

(*g*) a recent estimate by "The Times" Special Correspondent writing in April, 1953 gives a figure of £150 million a year.

(*h*) two recent estimates for Greater New York and Chicago give figures of $16 and $20 per head of population respectively. At current rates of exchange, these are equivalent to about £5 15s. 0d. and £7 per head per annum.

(*i*) the 1952 Report of the Bureau of Smoke Prevention of the City of Pittsburgh estimates the annual saving within the city limits resulting from the elimination of smoke (which has largely been achieved in that city) at a total of $27 million, or $41 (about £14 10s. 0d.) per head of population. The estimate is built up from the savings made under various heads by certain classes of building (e.g. stores and large buildings, smaller stores, etc.), but the savings for manufacturing plants are given as a total (of $4 million) and not classified in detail. Omitting the manufacturing plants, the results can be summarised as follows:—

	$	*Percentage of total*
Cleaning, painting, depreciation of buildings	12,138,000	52·8
Laundry (household and personal)	6,700,000	29·1
Lighting	3,475,000	15·1
Damage to merchandise, storage for protection ...	195,000	0·8
Injury to plants and shrubs	500,000	2·2
Total	$23,008,000	100

2. There is thus a wide range between the various estimates. In the United States, the lowest estimate is for New York, as $16 per head of population, and the highest is for Pittsburgh at $41 per head of population. At current rates of exchange, these are equivalent to about £5 15s. 0d. and £14 10s. 0d. respectively. In this context, however, the official exchange rates may be misleading, and a rate more favourable to sterling should be adopted. For the United Kingdom, the Egerton estimate gives a figure (at present prices) of about £1 10s. 0d. per head of total population, whereas the Special Correspondent of "The Times" gives one of £3 per head. These U.K. figures would, of course, have to be considerably increased, at least doubled, to give the cost per head in a heavily polluted atmosphere. Apart from the inevitably hazardous nature of any estimate, those which have been quoted are not always comparable in that their scope differs. Most of the estimates are less comprehensive than that which we have attempted to make: even the highest, for Pittsburgh, omits some important items. It is possible, therefore, that a figure approaching that for Pittsburgh might be nearer the truth for this country than earlier estimates would suggest, even though Pittsburgh was more heavily polluted than the average of our "black" areas and the exchange rate overstates the sterling equivalent of costs measured in dollars.

Basis of our estimates

3. It cannot be too strongly emphasised that even the best estimate of the cost of pollution cannot be more than a reasoned guess. Adequate data do not exist. Although we have tried to collect more evidence than has hitherto been available, we have had only limited success, and the information we have obtained can do little more than suggest broad orders of magnitude. Further investigation in this field is possible, but even the most elaborate enquiries could not be expected to yield results of a high degree of accuracy. The type of investigation which would be interesting would be a comparative study of expenditure on certain specific items in selected polluted and non-polluted areas. This would, however, be of limited value; it could not achieve finality even in its own field, while many items of costs are not susceptible to this type of investigation. In many cases, the gain in accuracy would be insufficient compensation for the labour involved.

4. Even if there were adequate data, there would still be certain problems of definition, the particular treatment of which would affect the estimates. We deal with those which are relevant to our estimates in the following paragraphs.

5. We exclude from our estimates all the costs involved in the **prevention** of smoke and other forms of pollution. These are not properly to be regarded as costs caused by pollution, and there is the important consideration that they are incurred by the consumer of the fuel and not imposed on the rest of the community in an indiscriminate fashion. They can, of course, be considerable.

6. Our estimate is confined to those items which it is possible to measure, however roughly, in terms of money. We therefore have not attempted to include the effects on health (except in so far as reduced working efficiency is concerned), the possible higher death rate, the loss of amenity and a whole series of social consequences. Nor have we attempted to put a price on the unpaid labour of housewives whose work is substantially increased in smoky areas; but we have included an estimate for the corresponding costs outside the home, where the work is carried out by paid employees. A border-line item which we have excluded is the effect of heavy pollution on land values, including both urban values and those in the countryside affected by movement of population away from polluted areas.

7. Earlier investigations have rarely stated clearly what is meant by "cost". On a strict definition, the term should be confined to actual expenditure which has to be undertaken to repair the damage caused by pollution. We refer to this as **direct cost.** It includes the items normally covered in earlier investigations, such as laundry, domestic cleaning, painting and repair of buildings, damage to wholesalers' and retailers' stocks, replacement of household goods, replacement of corroded metals, additional lighting, extra medical services, etc. Even this

type of cost, however, belies its apparent simplicity. The owners of property in polluted areas do not necessarily observe the standards of maintenance which could exist without pollution; housewives in smoky towns may accept lower standards of cleanliness. There will thus be a cost of pollution which is not reflected in actual expenditure, and even if we could measure expenditure accurately (which we cannot) we should not have a true estimate.

8. In addition to the direct costs imposed by pollution, there is a considerable **loss of efficiency.** Pollution affects human health and thereby reduces economic effectiveness. The acidity of soil is increased, crops are retarded in growth, and animals suffer in health not only directly but also from poor quality grazing. There may also be important effects on transport. It is impossible to measure this loss of efficiency, but we suggest a broad order of magnitude.

9. The Egerton Report included loss of fuel through imperfect combustion in its estimate, assessing it at £4·4 million a year (1945 prices). This figure was arrived at by estimating that the unburnt smoke from domestic fires was equivalent to 1·29 million tons of coal, at a cost of £2 12s. 0d. per ton, with a further 1·11 million tons from other sources, at a cost of £1 per ton. We consider that this estimate is far too low. In our Interim Report we suggested that between 5 and 10 million tons of coal are lost every year through inefficient use. The Egerton Committee appears to have taken the pit-head cost of coal as the measure of the loss, but this is misleading. Transport which has to be used to carry the coal from the pit to the domestic grate, so that it can then be wasted, is just as much a loss to the community as the cost of mining the coal itself, and the price to the consumer is therefore the true measure of the loss. On this basis, we put the loss at not less than £25 million, and possibly as high as £50 million, a year. This, however, cannot logically be regarded as a direct cost of air pollution, nor does it necessarily follow that methods of combustion which produce little smoke will always be more economical of fuel than those which produce much.

10. In assessing the **direct costs,** the method which we have in the main followed is to attempt to estimate the proportion of either the total national expenditure, or estimated expenditure per head, on each specific item which can be attributed to air pollution. Such specific evidence as we have obtained has been mainly directed towards giving some indication of the relative amount and frequency of expenditure in polluted as compared with non-polluted areas, and thereby providing a factor which could be applied to the national expenditure. The "black" areas delineated in our Interim Report contain one-half of the total population of the country, and we have assumed that this proportion of one-half can be applied to other items, e.g., the painting and decoration of buildings. This might involve some degree of under-estimate of cost, as the proportion of buildings in "black" areas is probably greater than one-half of the national total. There is also some under-estimate involved in the fact that the "clean" areas which are taken as the standard are by no means free from pollution; the costs in these areas might be considerable, but they are entirely excluded from our estimate. On the other hand, the fact that lower standards are often accepted in polluted areas means that on our method there will be some over-estimate of the proportion of expenditure (but not of "cost") attributable to pollution.

11. We have not found it possible to distinguish the costs imposed on the community by different forms of pollution. We can see no justification for the basis adopted by the Egerton Report, that "most of the tangible effects . . . are due to smoke, and most of the intangible effects are due to sulphur oxide", and consider that the data at our disposal do not justify an attempt to make separate estimates. It is probable, however, that the character of the data, and our method of estimation, take fuller account of the damage caused by grit and smoke than that caused by other pollutants.

Direct costs

12. We have attempted to estimate the direct costs under certain specific heads, and the results are given in the following paragraphs. As already stated, in the

absence of valid data, we have on occasion to fall back on guesswork; but whenever there is any doubt about any item, we have taken the lowest figure which seems reasonable. In total, therefore, our estimate is likely to underestimate the costs imposed by pollution.

13. *Laundry and household goods.*—The principal earlier estimates are:—

Pittsburgh, 1912: laundry, dry cleaning and renewal of curtains constituted 25 per cent. of the total, at $5 per head (£1 at 1912 rates of exchange).

Manchester, 1918: the Air Pollution Advisory Board conducted an inquiry into the costs of materials and fuel for households for family washing in Manchester and Harrogate. The average cost in Manchester was 40 per cent. higher than in Harrogate (25·62d. per week as against 18·24d.) and amounted to £1 12s. 0d. for a family and 7s. 6d. for each person per year. This calculation excludes the labour of the housewife; there was no investigation into the costs of laundry not done at home.

The Egerton Report, 1945: this used the earlier inquiries, which were stated to be confirmed by the Ministry of Labour inquiry into household budgets of 1938, which showed that agricultural households spent on the average sixpence a week less on laundry and soap and cleaning materials than industrial households. The total figure was given as £13·8 million.

Pittsburgh, 1952: the figure for laundry bills is $10 per head per year, equivalent to £3 10s. 0d. at present rates of exchange. This item still constitutes 25 per cent. of the total cost of pollution.

The Electrical Association for Women conducted an inquiry in October–December, 1953, and made the results available to us. For the families investigated it was found that the weight of the average weekly wash per head in industrial areas was 6 lb. as against 4¾ lb. in rural areas; the cost of materials was 2d. per head higher in industrial than in rural families, and there was a significant difference in the housewives' time. The results probably understate the difference in the cost of materials. The investigation showed some striking differences in the frequency with which curtains had to be washed.

14. We make our estimate under two heads of (i) laundry not done at home and (ii) washing done at home:—

(i) The evidence suggests that in a polluted area the cost of laundry can reasonably be put at 50 per cent. above that in a non-polluted area. With one-half of the population in black areas, therefore, one-fifth of the national expenditure on laundry results from pollution. The total expenditure has been estimated at about £75 million a year, of which £15 million can be attributed to pollution.

(ii) Over one-half of the families in this country rarely use laundries, and most of the rest do some home laundry. For a family doing all washing at home, the extra cost in a polluted area can be put at 15s. 0d. per head per annum, which is probably too low a figure. With at least 12½ million persons in this category in black areas, the additional cost is about £10 million a year.

The total under this head is therefore put at £25 million a year, or £1 per head of population in the black areas.

15. *Buildings.*—The two main items which we can estimate under this head are the cost of painting and decorating and of cleaning. An estimate of the damage caused by corrosion and decay must be speculative.

16. The Egerton Report gave estimates of £5·6 million for cleaning and decorating of houses and shops and £2·4 million for damage to buildings; the latter figure is stated to be the estimate made by Sir Frank Baines in evidence submitted to the Fulham Power Station inquiry in 1930. These figures are certainly far below the truth. The 1952 figures for Pittsburgh give £6 10s. 0s. per head of population under this head, as against the Egerton figure (at present prices) of below £1 per head of population in polluted areas.

17. For painting and decorating, evidence from local authorities suggests that houses in polluted areas require painting almost twice as frequently as those in

clean areas. A large industrial city in Yorkshire stated that on an estate of prefabricated bungalows on the outskirts of the city, external painting was necessary once every five years; similar bungalows near the city centre needed painting every three years. Other large local authorities estimate that pollution adds about £4 per annum to the cost of decorating a house. A large firm owning over 200 stores in various parts of the country informed us that in clean areas painting will last five years, but that in industrial towns repainting is necessary after three years. A calculation on these data assumes that local authorities, private owners of houses and business firms maintain these standards of cleanliness, which is by no means the case. Some over-estimate here will, however, be amply offset by under-estimate in other directions.

18. With some 7 million houses in black areas, the cost of additional painting and decorating at £3 per house per annum (to take a lower figure than that given by local authorities) comes to £21 million per annum. It is estimated that there are some 500,000 shops and warehouses in Great Britain; if half are in black areas and need to be painted every four instead of every six years, at a cost of, say £250 each, the cost of pollution under this head is about £5 million a year. This is probably an under-estimate. It assumes that the additional cost of painting in polluted areas averages about £20 per shop per annum. In Pittsburgh, the annual saving is estimated at about £1,800 for large buildings and at about £180 for smaller stores and buildings. Evidence for this country suggests a figure of several hundred pounds a year for a medium-sized building. An estimate for other business premises and public buildings is still more speculative, but we suggest the same figure as for shops, i.e. £5 million a year. The total therefore becomes about £30 million a year, or £1 4s. 0d. per head of population in the polluted areas; the corresponding figure for Pittsburgh is £6 10s. 0d.

19. That this is not too high is suggested by another calculation. It has been estimated that the total expenditure on painting in the country is £150 million a year. The evidence suggests that the annual cost of painting buildings in polluted areas is at least one-half as great again as that in non-polluted areas; on the basis that one-half of the buildings are in polluted areas, this would give a figure of £30 million a year (i.e. one-fifth of the total). To the extent that the acceptance of lower standards in the black areas is not offset by additional costs in the non-polluted areas (which we have entirely neglected), this figure will be an over-estimate of the expenditure under this head: but it will be an under-estimate of the cost of damage.

20. For cleaning of stone and brickwork, the firm owning multiple stores already mentioned informed us that in polluted areas stone fronts require cleaning twice as frequently as in non-polluted areas, where cleaning is necessary only once in every 7 to 10 years. This firm spends £15,000 a year on this item. We obtained estimates from some of the principal firms specialising in the cleaning of buildings of the increased cost of this work caused by air pollution. The total figure they provided amounts to £200,000 a year, but this represents only part of the total expenditure caused by pollution. Moreover, it is under this head that there is probably the greatest neglect of high standards of cleanliness; it is a matter of common observation that in industrial towns buildings are left to become coated in grime because the owners do not consider that it is worth while to have them cleaned. Expenditure in this direction is probably insignificant compared with that on painting, but it nevertheless must amount to over a million pounds a year.

21. The cost of routine cleaning of shops, offices and other buildings must be an appreciable item. The Pittsburgh estimate gives £300,000 a year under this head, as the cost of additional labour. A retail distribution firm in this country gives a figure of £200 a year for cleaning of lighting fittings alone at one of their large branches (this same branch has to have its stone facing cleaned once a quarter). One of the joint-stock banks informed us that in dirty areas paint-work has to be washed down every second year or so, as against every fourth or fifth year in clean areas. The cost of cleaning materials has been stated to be two and one-half times as great in dirty as in clean areas. Only the broadest guess at this item can be hazarded, but we consider that £10 million a year would not be excessive.

22. Depreciation of buildings must be a considerable item. The estimate of £2·4 million a year made by Sir Frank Baines and quoted by the Egerton Committee was in fact an average derived from a total of between £55 and £60 million estimated to have been the excess cost of making good the damage caused by pollution over the previous quarter of a century. Subsequently, Sir Frank Baines stated that he was convinced that the actual damage was probably far in excess of this amount. Damage of this kind is gradual, and it is often neglected until a stage is reached when restoration becomes imperative. We have been unable to obtain any additional evidence which would make a firm estimate possible, but we consider that £5 million a year to be a minimum figure.

23. *Corrosion of Metals.*—The rate of corrosion of many metals is increased by atmospheric pollution. Consequently, more frequent replacements are needed, protective coverings have to be provided, a bigger allowance has to be made for the effects of corrosion when designing structures with consequent higher capital cost, and more expensive materials have to be used. Since each metal is affected in a different way or to a different degree and since there is a wide range in the extent of air pollution it is most difficult to estimate what the cost of such corrosion amounts to. The Egerton Report, in fact, classes this as an "intangible item". It has been estimated that the cost of atmospheric corrosion in the U.S.A. is as much as $2,000 million a year (£700 million). It seems certain that the figure for this country must be high; one estimate gives £200 million a year as the cost of repair and prevention of corrosion of iron and steel. Not all of this, of course, is attributable to atmospheric pollution: the metal would still rust in clean air. It is, however, undoubted that corrosion is considerably accelerated by the presence of pollutants, especially sulphur dioxide. One investigation suggests that about one-third of the annual replacements of steel rails is required because of pollution; other evidence gives replacement of constructional steel at a rate of about 0·5 per cent. per annum of existing structures as the consequence of pollution. Replacement involves, of course, not only the cost of the metal but also the costs of construction, which may well be the larger item.

24. We have obtained specific evidence from the Transmission Department of the British Electricity Authority, who estimate that air pollution is costing them £834,000 a year. This is not entirely on account of corrosion, as it includes certain items such as cleaning and washing of insulators, but it is mainly made up of replacement costs, increased protective coverings, and of costs of more substantial design and more expensive materials. This is striking evidence of the importance of this item. In the absence of further specific evidence, we can do no more than hazard a guess at the total amount, and accordingly suggest £25 million a year. Although this may appear to be high, it is far below comparable estimates for the United States, and may be an underestimate.

25. *Damage to goods.*—There is abundant evidence to show that atmospheric pollution causes direct damage to leather, textiles and other materials, and thereby shortens their useful life. An indirect item is the shortening of the life of textiles by more frequent laundering. It is impossible to obtain precise data, but certain orders of magnitude indicate that this must be an item of some importance. The total consumers' expenditure on clothing and household textiles is not far short of £1,000 million a year. If the effect of air pollution is to reduce the life of textiles by one-tenth, on the assumption that one-half of the use of textiles is in polluted areas, then the cost will be of the order of £50 million a year.

26. A direct effect which has been estimated in other studies is the loss resulting from damage to goods in shops. The Pittsburgh enquiry of 1952, for example, gave figures of $1·65 million for damage to merchandise in 1,000 wholesale and retail stores. A striking example is that given by the multiple-store firm in this country, which informed us that after the "smog" of December, 1952, they had to reduce prices of damaged goods by a total of £90,000; there

is also a continuous loss under this head at their shops in all polluted areas. A loss of £10 for each shop in polluted areas would give a total figure of £2·5 million a year, and this would appear to be below the true figure; it is less than 0·25 per cent. of total sales of clothing and textiles.

27. *Lighting.*—Most enquiries have included the cost involved in the greater use of artificial light. The Pittsburgh enquiry of 1913 assessed it at $1·50 per head of population; that for 1952 gives $5 per head. We have been unable to make any estimate for this country. It is impossible to distinguish between the effect of meteorological conditions and that of air pollution. Moreover, the peak demand for electricity occurs in mid-winter, when the beginning and end of the working day occur during natural twilight, and when variations in natural light are of minor significance. A large proportion of any additional demand caused by pollution would probably be from industrial and commercial users, and we have had evidence that these classes of consumers are not greatly influenced. In general, conditions for the use of electricity in this country are not comparable with those in the United States, and it is not possible to apply the Pittsburgh experience here. We therefore omit this item as not likely to be of great importance in this country.

28. *Medical Services.*—It is impossible to make even an approximate guess at the cost of additional medical attention involved by air pollution. Statistics of morbidity are not in a form which would enable any valid deductions to be made, though they do suggest that air pollution is a significant factor in increasing the incidence of certain diseases. Net annual expenditure on the National Health service within the United Kingdom is now approaching £500 million a year. It is impossible to say what proportion of this total represents expenditure on treatment of illness caused, or exacerbated by, air pollution, and we therefore cannot put any figure on this item. Nevertheless, we believe that it is probably substantial.

29. To summarise those items of direct cost on which we have been able to put a figure, however hazardous, we have the following:—

	£ millions per annum
Laundry	25
Painting and decorating	30
Cleaning and depreciation of buildings other than houses	20
Corrosion of metals	25
Damage to textiles and other goods	52·5
	152·5

We do not think that these figures are excessive, but rather that they are underestimates. As we have had to omit certain items, such as the cost of the medical services, we would conclude that the direct costs of air pollution are of the order of at least £150 million a year.

Loss of efficiency

30. In this field only a rough guess at possible orders of magnitude is possible. For one item, agriculture, we have been informed that the loss from direct damage to crops and soil is of the order of £10 million a year. We have obtained some evidence of the effect of heavy "smog" on transport, but there are insuperable and inherent difficulties in its interpretation; loss takes the form of delay and congestion, which cannot be measured in terms of money, while natural fog is perhaps more important than the occasional severe "smog" which causes the most serious dislocation. It is also impossible to assess the loss caused by the reduced efficiency of the worker, although it is clear that it must be significant. A reduction of 1 per cent. in working efficiency in manufacturing industry (caused, among other reasons, by loss of time, ill-health, and a general reduction of working pace) would mean a loss of about £55 million a year. In other sectors of the economy, including transport, it would involve a loss of some £60 million a year. Specific evidence on this point is entirely lacking, but a reduction in

efficiency of 1 per cent. is not incompatible with such indications as we have been able to obtain. It is, in fact, not unreasonable to believe that the loss of efficiency resulting from pollution might be as great as the direct costs which it imposes on the community; to avoid any danger of over-estimate, however, we suggest a figure of £100 million a year.

Conclusion

31. On the estimates we have given, we consider that air pollution is costing as much as £250 million a year in direct costs and loss of efficiency. This total is equivalent to £10 per head of population in the black areas, and to £5 per head of population throughout Great Britain. It excludes a loss of between £25 and £50 million a year from the imperfect combustion of coal which itself causes much of the pollution. Our estimate may seem high, but it is less than most of the estimates for the U.S.A. The most recent figure for Pittsburgh is £14 10s. 0d. a year for each inhabitant. Although Pittsburgh was more heavily polluted than the average black area in this country, and although the exchange rate may overstate the sterling costs, the Pittsburgh estimate excludes several items of direct cost and almost the whole of the loss of efficiency which we have included in the estimate for this country. It may well be that our estimate errs on the low rather than on the high side.

APPENDIX III

RESEARCH AND DEVELOPMENT

1. A large volume of technical knowledge is already available about the nature and sources of air pollution, its effects and methods of prevention. We would mention some of the research work already undertaken or in progress, before turning to the outstanding problems which we think call for further investigation.

The Measurement of Pollution

2. The system of measurements of air pollution carried out under the guidance of the Atmospheric Pollution Research Committee of the Fuel Research Board of the Department of Scientific and Industrial Research was referred to in our Interim Report,* and the methods in general use are described in Appendix VII. An adequate system of measurement on standard lines is essential both as a basis for preventive action and as a means of assessing the results achieved.

3. Standardised methods are in use for the measurement of deposited solid matter, sulphur dioxide and smoke. New instruments now being adapted or developed include an automatic electric-conductivity method of determining very small concentrations of sulphur dioxide, an integrating photo-electric device to determine the effects of air pollution in reducing the intensity of sunlight, and methods for the determination of various solid, liquid and gaseous impurities in addition to those now regularly measured. Several new instruments developed abroad for measuring deposited solid matter, smoke and sulphur dioxide are being tested under conditions in this country.

4. In addition to the general scheme of measurements, an intensive survey was carried out over a period of three years at Leicester; this showed, among other things, that a considerable proportion of the smoke in the town had been carried by the wind from sources fifty miles or more away. Special surveys of the distribution of sulphur dioxide are being made in five London areas and one rural area all adjacent to large power stations.

Motor Vehicle Exhausts

5. It is known that petrol-driven vehicles discharge large volumes of carbon monoxide, and that the exhaust gases of diesel-engined vehicles may contain appreciable amounts of hydrocarbons, aldehydes and oxides of nitrogen and

Note: Since the Interim Report was written, the number of bodies co-operating in the scheme of measurements has increased from 160 to 199, and the number of instruments in regular use from 1,350 to 1,482.

sulphur, but little is known about the distribution of these gases in the atmosphere. The Fuel Research Station has recently undertaken a survey of the carbon monoxide concentrations occurring under various conditions in streets in the London area, and this survey is to be extended to include other constituents of the exhaust gases.

The Effects of Pollution

6. A large amount of research on the relationship between air pollution and health is being undertaken by the Medical Research Council and other medical organisations and individuals. The Medical Research Council have informed us that their current research programme includes:—

(1) Studies on the composition of smog and the development of new methods of analysis.

(2) Studies of the effect of exposing animals and humans to the various constituents of "smog".

(3) Studies of morbidity and mortality data in relation to meteorological and pollution records.

(4) Studies of the aetiology and natural history of respiratory disease in areas of contrasting pollution.

(5) A survey of hospital patients, with and without respiratory disease, to investigate the relative rôles of various social and environmental factors including exposure to atmospheric pollution.

7. The material effects of air pollution have also been under investigation for many years, notably by the British Iron and Steel Research Association, the Building Research Station, and the Ministry of Agriculture and Fisheries.

The Reduction of Pollution

8. Most of the technical problems involved in the smokeless combustion of coal in industry have been solved and practical methods and equipment for this purpose are to a large extent available. Effective methods of grit arrestment are known; the need is to see that they are more widely used. The removal of the finer particles of dust still present difficulty.

9. Technical methods of reducing smoke from coal-fired railway locomotives are also known; again it is a matter of their practical application.

10. The prevention of pollution by sulphur dioxide present problems of great difficulty, and the methods of flue gas washing so far developed are applicable only to very large sources such as power stations. There are many other possible lines of research or technological advance which might reduce the emission of sulphur compounds into the atmosphere on a more general scale.

11. The emission of acid and other noxious fumes from chemical works and allied processes is under the control of the Alkali Inspectorate and a large volume of technical knowledge has been built up in this field. Experimental work carried out in co-operation with the manufacturers has done much towards developing effective methods of control, and the standards attained in this country are higher than in most other industrial countries.

12. Despite all the work that has been done, however, it is apparent that there are still many problems to be resolved, and that further research and development work is required on a scale commensurate with the importance and urgency of the whole problem of air pollution. We became aware at an earlier stage of our inquiry of the need for more intensive measurements of air pollution under "smog" conditions and for further knowledge about the various problems associated with pollution by sulphur compounds. In March, 1954, we accordingly submitted an interim recommendation that the necessary work should be put in hand. In addition, we have mentioned earlier in this Report a number of other matters which call for investigation. For convenience we summarise below all the outstanding problems as we see them, and we recommend that the necessary research and development work on them be undertaken without delay.

MATTERS ON WHICH FURTHER RESEARCH OR DEVELOPMENT WORK IS REQUIRED

13.—(1) More frequent and intensified measurements of pollution in the London area and in three or four other specified areas which are susceptible to severe "smog".

(2) The development of automatic recording instruments for measuring pollution by smoke, sulphur compounds, carbon monoxide, and other pollutants.

(3) The intensification of research directed towards the possibilities of—

(*a*) reduction of the amount of sulphur in fuel before use;

(*b*) prevention of the release of the sulphur in the fuel into chimney gases;

(*c*) removal of sulphur from the chimney gases before discharge into the air; and

(*d*) providing more information on the dispersion of sulphur compounds in flue gases after discharge from chimneys of various heights and in all atmospheric conditions, and the ultimate fate of the sulphur compounds.

(4) The physiological effects of air pollution on health, particularly in relation to respiratory diseases, with the objects of identifying the substances responsible, determining their limiting concentrations, and developing preventive, protective and remedial methods. In particular, the effects of combinations of sulphur dioxide and smoke should be studied.

(5) The effects on the dispersal of pollution of chimney height, chimney design, and the position of chimneys in relation to surrounding buildings, hills, etc.

(6) The development of cheaper and more efficient dust arresting equipment for both large and small plants, particularly for dealing with the finest particles of dust.

(7) The development of techniques and instruments for monitoring grit and dust emissions.

(8) The development of improved techniques for the prevention of pollution from the special processes for which the Alkali Inspectorate is responsible, including the "scheduled processes" referred to in paragraphs 99-100.

(9) The prevention of harmful emissions from motor vehicle exhausts, particularly of diesel engines, by the development of improved designs of engine and fuel induction, and of catalytic and other devices for effecting the more complete oxidation of the gases after leaving the engine; and the development of monitoring devices.

(10) The prevention of combustion in colliery spoilbanks, and the controlled disposal of colliery wastes, in order to prevent such combustion.

(11) The production of solid smokeless fuels from other types of coal than those now used in gas and coke manufacture.

(12) The development of more efficient and economical domestic appliances, including if possible appliances capable of burning bituminous coal without smoke, and better methods of installation.

APPENDIX IV

PERFORMANCE OF GRIT AND DUST ARRESTING PLANT

Memorandum by the Industrial Sub-Committee

1. Factory managements and plant manufacturers are frequently led astray in their consideration of grit and dust arresting plant by expressing performance in terms of percentage efficiency of material caught. Thus plants of 94 per cent. and 96 per cent. dust removal efficiency appear at first sight to have substantially the same efficiencies whereas actually the dust escape from the former is 1½ times that from the latter. When assessing the discharge of

dust and grit from the chimney, it is advisable to consider all the following together:—

(*a*) The percentage escape relative to the inlet quantity of suspended matter.

(*b*) The total weight of escape in, for example, lbs./day.

(*c*) The concentration of solid matter in the effluent gases in grains per cubic foot of lbs. per million cubic feet—

$$1 \text{ grain/ft}^3 = 143 \text{ lbs/million ft}^3.$$

Since a ton of coal of 10 per cent. ash and 5 per cent. moisture gives about 450,000 ft³ of flue gas when burnt with 50 per cent. excess air (giving 12 per cent. CO_2), a dust emission of 1 grain/ft³ arising from combustion of coal is equivalent to about 64 lbs. dust per ton of coal burnt.

(*d*) The size grading of the escaping dust. Particles greater than 200 B.S. sieve size (0·076 millimetre) are distinctly gritty and would, for example, cause eye irritation. Particles having a size equivalent in free falling speed to solid particles of ash less than 20 microns in diameter are so fine that they are suspended almost indefinitely in natural air currents and hence behave as a gas*.

2. The method of sampling flue gases for dust given in British Standard 893 is lengthy and cumbersome. We are satisfied, however, that a simple sampling procedure with easily used equipment has been provisionally developed† which will enable sufficiently accurate measurements to be made to determine whether excessive grit or dust are being emitted from a chimney and, as already stated, we have recommended that the British Standards Institution prepare a specification and operation code for a simpler type of equipment.

APPENDIX V

MEASUREMENT OF SMOKE

RINGELMANN CHART AND SMOKE DENSITY

Ringelmann Method for External Observation

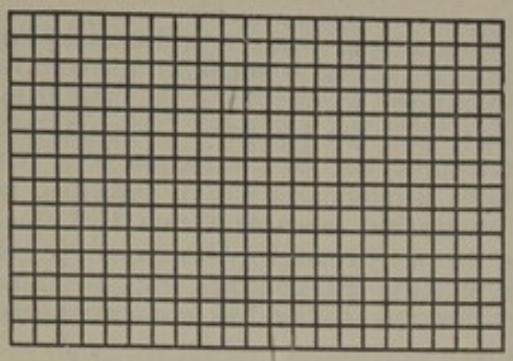
Memorandum by the Industrial-Sub-Committee

1. For observation from a distance of the density of smoke issuing from a chimney it has been the practice of smoke inspectors, particularly in the U.S.A., to use the well-known shade chart devised over 50 years ago by Professor Ringelmann of France. The estimation of the density of smoke by this method is made by comparing the shade of the smoke against shade cards held some 50 feet from the observer and preferably in line with the chimney.

2. The shade cards consist of grills of black lines. Charts with grills 4 inches square are published by Charles Griffin and Co. Ltd., London. A reduced reproduction is given below.

* Report by a Committee appointed by the Electricity Commissioners on the measures taken to obviate the emission of gritty particles, etc., from power stations; H.M.S.O. 1932.

† Trans. Inst. Chem. Eng., Vol. 29, 1, 1951.



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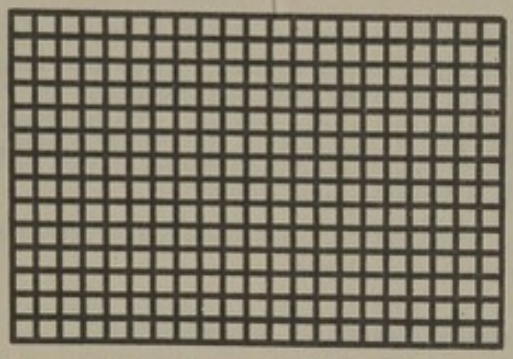

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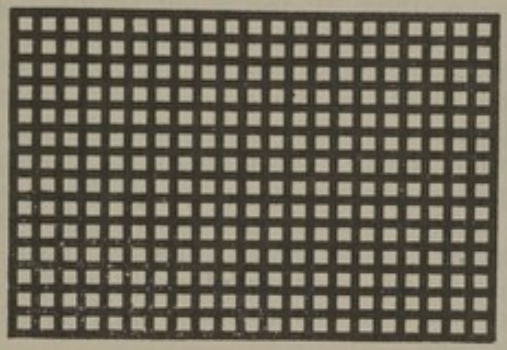
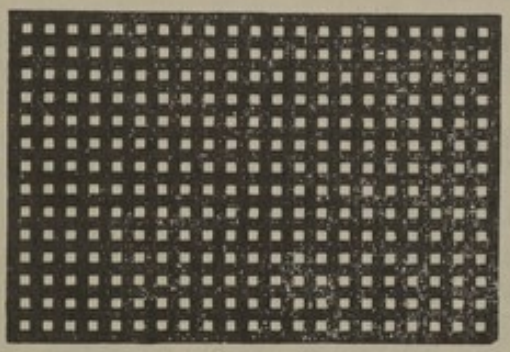


3.



4.

Source. Productivity Report on the Conservation of Fuel, Heat and Energy, published by the British Productivity Council, September, 1953.

3. The charts are described as follows:—

RINGELMANN CHART

Number	*Description*	*Approx. per cent. black on shade card*
0	No smoke	0
1	Light grey	20
2	Darker grey	40
3	Very dark grey	60
4	Black	80
5	Dense black	100

4. With the original Ringelmann chart it is necessary to have an observer and an attendant to hold the chart. This is wasteful in manpower and draws unnecessary attention to the operation. Moreover, it is difficult in heavily built-up areas to place the chart in line with the chimney. Various attempts are being made to overcome these disadvantages. One example is a photographically reduced chart, known as the Micro Ringelmann Chart, described in the Journal POWER, December, 1953, and obtainable from McGraw Hill Publishing Co., Inc., New York. The tests made on our behalf by two smoke inspectors indicate that the reduced chart is easier to use. Preliminary tests by the Fuel Research Station indicate that the micro-chart is rather less consistent than the large chart, but further tests will be made.

5. The shade of a smoke as viewed when it issues from the chimney arises from both transmitted and reflected light. Hence the brightness and uniformity of the sky, the wind velocity and also the diameter of the chimney can affect the accuracy of observation to some extent. Tests made on our behalf have, however, indicated that independent readings by two trained observers in general agree to better than half a Ringelmann shade.

6. There is scope for research on improved methods of observation less subject to the disadvantages enumerated above.

Plant instruments for measurement of smoke density

7. The only objective method of continuous measurement and recording of smoke density, that is, the only method which is not subject to human errors of observation and which is not dependent on external ambient conditions is one in which measurement is made of the amount of light obscured by the smoke when a beam of light is shone through the smoke in a flue. Instruments are now on the market for measuring and recording smoke density in this way and can be fitted with alarms which operate when the smoke is above a pre-set density. They are simple and easily installed instruments; for installation two 4 inch diameter holes are needed opposite each other in the walls of the flue. The only routine servicing required is cleaning every shift of the two observation windows in the walls of the flue. In addition the instruments require periodical adjustment and recalibration.

8. These instruments measure directly the percentage obscuration of the light passing through the smoke in the flue. In order to obtain readings of light and dark smoke on a sensitive part of the instrument, and for convenience in standardising, the length of light path through smoke should be about 3 feet. Corrections can be made mathematically for different lengths of light path.

If S_y is percentage obscuration in y ft.

and S_x is percentage obscuration in x ft.

$$\log \frac{(\ 100\ )}{100-S_x} = \frac{x}{y} \log \frac{(\ 100\ )}{100-S_y} \qquad (1)$$

9. Most of the instruments for the measurement of smoke density by light obscuration in a flue have on them a scale, the steps of which are in Ringelmann shades. It should be noted, however, that although there is a fairly good correlation between the obscuration by smoke of a beam of light passing through one particular chimney and the corresponding Ringelmann number of the smoke leaving the chimney, this does not hold for all chimneys. The scale given on the instrument therefore has only a relative value. Correlations made for us at one factory with water tube boilers during a period of two days when there were widely varying conditions of daylight showed that there is a reasonably close correlation between Ringelmann numbers obtained by external observation and percentage obscuration readings by an instrument over the range 1 to 4 Ringelmann shade. At this particular plant No. 2 Ringelmann shade corresponded to 50 per cent. obscuration of a light path of 2 feet 6 inches. Further tests are required to confirm whether this correlation holds with smoke produced from other classes of plant.

10. It was found in tests carried out in conditions described in Fuel Research Station Technical Paper No. 53 that the optical density d per foot of smoke varies directly as the weight of particles per cubic foot of one kind of industrial smoke (except for very thick smoke). Optical density is related to percentage obscuration S over 1 foot by the equation:—

$$d = \log \left(\frac{100}{100-S} \right) \qquad (2)$$

It would therefore seem better to give a scale on smoke density instruments in terms of optical density per foot for measuring undue density in flues.

APPENDIX VI

THE INFLUENCE OF CHIMNEY DESIGN AND HEIGHT ON THE DISPERSION OF FLUE GASES FROM INDUSTRIAL CHIMNEYS

Memorandum by the Industrial Sub-Committee

Introduction

The original function of high chimneys was to create draught for the furnaces. With the introduction of mechanically created draught early in the century, many factories were equipped with only short chimneys and as a consequence smoke dispersal was not good. More recently, however, there has been a trend towards use of high chimneys in order to improve dispersion by discharge into the higher levels of the air.

We have found that the information on chimney design and height and the effect of chimney height on probable conditions on the ground to the lee of the chimney is widely scattered and in general inaccessible to industrial engineers. We have therefore felt it necessary to go into the subject in some detail in this appendix. The following is a summary of the best informed opinion at present, but further investigation may cause these opinions to be revised.

1. Down-draught

When a wind blows across a building or a hill a down-draught is created on the lee side. (1) It is important that chimneys should discharge their smoke high enough for it to escape these down-draughts if possible.

A rule used successfully for about 20 years by the Electricity Industry is that the height of a chimney shall be at least 2½ times the height of the highest adjacent building. When the chimney is sited in hilly country or among buildings which make it impracticable to apply the "2½ times" rule, wind tunnel tests on models may be necessary to determine where to site the chimney and how high to make it to avoid down-draughts. Pending further research on the subject, a good working rule for low buildings is to make the chimney not less than 120 feet high—though discretion must of course be exercised for small installations.

2. Down-wash

Down-wash is the drawing downward of chimney smoke by the system of stationary vortices or eddies that form in the lee of a chimney when a wind is blowing. If the velocity of emission of the smoke is not great enough to overcome down-wash some of the smoke will be drawn by these eddies down into the down-draughts of the buildings beneath.

The down-draught will then carry the smoke to the ground. Experiments have shown that down-wash will not occur if the velocity of emission is sufficiently high. It is clear to us that further research on the design of chimney mouths is required.

Reference (2) gives a graph showing for a given wind speed the minimum velocity of emission for avoiding down-wash.

3. Chimney height and dispersal of smoke and gases

At whatever height smoke is discharged, gravity will eventually bring the larger particles of dust and soot to the ground. Moreover, because of the natural turbulence and mixing of the atmosphere, a proportion of the finer particles and gases in the smoke will reach the ground, although their motion is unaffected by gravity. The higher the point of discharge the greater will be the dilution of the gases and dust by the time they reach the ground.

When there are no effects due to down-draught, the concentration at ground level of cold gas emitted from a tall stack increases with increasing distance from the stack up to a distance which depends upon the height of the stack, and then decreases again. The maximum concentration has been deduced theoretically by Sutton (3). His formula can be written in the form:—

$$Y_{max.} = \frac{3{\cdot}76 \times 10^6 W}{uh^2} mg/m^3 \quad (1)$$

The distance from the chimney at which the maximum concentration occurs is about 10 to 15 times the height of the chimney under average meteorological conditions.

where: $Y_{max.}$ = the maximum concentration in mg/m^3 at ground level of the constituent in the source.

W = strength of source (lbs/sec.), e.g. of SO_2, fine dust or total flue gas.

u = wind speed (ft./sec.).

h = height of stack (ft.).

mg/m^3 = milligrams per cubic metre.

(For sulphur dioxide:—1 mg/m^3 = 0·35 p.p.m.)

If the gas emerging from the chimney is hot or has a definite vertical speed on emergence, the effective height of the chimney is increased. The amount of this depends both on the heat content of the gas and upon the wind speed, and various formulae have been proposed to express this rise. There is a critical wind speed for which the ground level concentration has a maximum value C.

The various formulae have been examined and, in the present state of knowledge on the subject, it is considered that the following formula*, derived from American sources (5), should be used for computing the maximum ground level concentrations C of gas from a hot source.

$$C = \frac{9 \times 10^6 W}{h\,(14vd + Q)} mg/m^3 \quad (2)$$

The distance from the chimney at which the maximum concentration occurs is about 25 to 35 times the height of the chimney.

where: W = strength of source (lb/sec.) as above

h = height of stack (ft.)

v = velocity of efflux. in ft./sec.

d = stack diameter (ft.)

Q = rate of heat output relative to air temperature (BThU per second)

This formula gives the maximum ground level concentration taking into account the variations of concentration with distance from the stack and with wind speed. Apart from wind speed it applies to average meteorological conditions and not to conditions of inversion. As it is based on observations relating only to gases having approximately the density of air, it may not be applicable to heavy gases such as effluents from chemical processes. For cold sources, equation (1) should be used and not equation (2).

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*We have had the opportunity of comparing this empirical formula, which is based on a limited number of observations with an as yet unpublished theoretical treatment by C. H. Bosanquet in amplification and extension of the treatment in Ref. (4): there is a substantial measure of agreement between the results.

When the number of stacks for a proposed power station or factory is considered it should be noted that if the gaseous effluent is divided equally amongst several chimneys close together the maximum concentration at ground level will be nearly equal to the sum of the concentrations from all the stacks and will necessarily exceed the maximum concentration which would occur if a single stack of the same height were used.

For small installations, and for large ones emitting cool gases, the thermal rise is unimportant and the chimney height is the only important design element controlling ground level concentration. On the other hand, for large units in which the total discharge of sensible heat is greater than 10,000 BThU/sec. combining two chimneys into one would theoretically send the smoke up nearly twice as high and divide the ground level concentration under average wind conditions by about four, or the maximum possible concentration by about two. It should be noted that increasing the quantity of gas increases the critical wind speed at which the maximum possible concentration occurs and so makes the occurrence of the latter less frequent.

There are good reasons (deducible from Ref. (4)) for supposing that increasing the velocity of emission of large discharges does not give any net increase of plume rise. The only reason for a high velocity of emission therefore is to avoid down-wash.

4. Dust Emission

In Ref. (4) the mechanism of dust deposition is explained and a method is given of calculating the average yearly rate of deposition at the point of maximum deposition in say tons per square mile per month. At this point the deposits are made up entirely of those particles that reach the ground under the influence of gravity, that is the larger particles in the dust grading. From our further study of the subject, we find that it is best to use the height of rise as calculated by the method given in Ref. (5) when calculating the dust deposition by the method given in Ref. (4). Further measurements to confirm the formula are being made.

References

(1) Report on the measures taken to obviate the emission of gritty particles by a Committee appointed by the Electricity Commissioners; H.M.S.O. 1932. (See also Reference 3.)

(2) "Study of Flow Phenomena in the Wake of Smoke Stacks" by R. H. Sherlock and E. A. Stalker, University of Michigan, U.S.A. Engineering Research Bulletin No. 29 and Mech. Eng. Vol. 62, No. 6, June 1940, page 455, and discussion in Vol. 63, February 1941, page 147.

(3) "Micrometeorology" by O. G. Sutton, McGraw-Hill Publishing Co., London 1953.

(4) Proc. I.M.E., Vol. 162, page 355, 1950, "Dust Deposition from Chimney Stacks" by C. H. Bosanquet, W. F. Carey and E. M. Halton.

(5) United States Atomic Energy Commission, Technical Information Service, Oak Ridge, Tennessee, "A Meteorological Survey of the Oak Ridge Area". Report ORD-99, November 1953, page 557.

(6) Defence Research Chemical Laboratories (Canada) Report No. 110, September 1952, "Application of Diffusion Theory to Dispersion of Stack Gas in the Atmosphere" by M. Katz. This paper discusses the value of Ref. (4).

APPENDIX VII

THE MEASUREMENT OF AIR POLLUTION

Memorandum by the Industrial Sub-Committee

1. In addition to the considerable work of the Fuel Research Station of the Department of Scientific and Industrial Research in special investigations of the concentration and nature of pollutants in the atmosphere, regular measurements of pollution are made by Local Authorities and others by standardised methods. These methods are described in detail in a brochure ("The Investigation of Atmospheric Pollution") issued by the Research Station. A brief summary of the methods now in use is given below, mainly as a guide to readers of this Report.

Deposited Matter

2. Measurements of deposited matter are made by means of the British Standard Deposit Gauge which collects the liquid (usually entirely rain-water) and solids falling on an accurately measured area of a little less than one square foot. Each month the material collected is analysed; in the undissolved fraction, tar, other combustible matter and ash are normally determined and from the aqueous fraction some data are obtained on the dissolved substances which it contains. The results of these analyses are expressed in grams of deposit per 100 square metres or in tons per square mile; where the latter units are employed it is important to recognise that the rates of deposition indicated by a single gauge may not apply over an area as large as one square mile. The gauge is subject to a number of limitations which are discussed in the above-mentioned brochure. In dry windy weather it may not collect all the fine dust which, nevertheless, can percolate into buildings, but, in general, it gives a useful measure of the extent of pollution by deposits. Over 600 of these instruments are in regular use.

Sulphur oxides

3. A simple method of obtaining a comparative measure of the concentration of sulphur dioxide in the air involves the exposure of a small cylinder coated with lead peroxide. The sulphur dioxide reacts with the coating to form lead sulphate which is determined by analysis after a suitable period of exposure, normally a month. The amount of sulphur absorbed by the instrument, when expressed in standard empirical units, is in general proportional to the concentration of sulphur dioxide in the air. The method thus affords a means of comparing the intensity of pollution of the air by sulphur at different places and times. The test cylinder is protected from rain and so is unaffected by sulphur oxides which may be dissolved in the rain-water and are collected in the liquid part of the deposit gauge sample. About 700 instruments of the lead-peroxide type are in regular use.

4. A "volumetric" method for determining the concentration of atmospheric sulphur dioxide in absolute units involves drawing a measured quantity of air through a solution of hydrogen peroxide which retains the sulphur in a form suitable for determination by titration with alkali. The results of this determination, which are expressed in parts per 100 million parts of air by volume, or in milligrams per 100 cubic metres of air, are affected by the presence of other acids (apart from carbon dioxide) and of alkali; but in general the amounts of these other substances are small in relation to the amount of sulphur dioxide. The apparatus is normally used to give a mean value for each 24 hours' operation, but under suitable conditions longer or shorter periods may be used. About 50 volumetric sulphur dioxide instruments are in regular use.

Smoke

5. The measurement of the concentration of smoke in the atmosphere is generally made by drawing a measured volume of air through a white filter paper and then assessing the weight of smoke from the blackness of the stain. Frequently the filter is a simple attachment to the volumetric sulphur dioxide instrument.

Filters of different size are employed, according to the smoke content of the atmosphere and the amount of air tested, so that a stain of suitable density is obtained. For making frequent measurements of smoke concentration an automatic filter which produces comparable stains at regular intervals without attention has distinct advantages. No such instruments are at present being manufactured commercially in this country. The assessment of the smoke stains on filter papers is made in terms of milligrams per 100 cubic metres, the relationship between stain density and the weight of smoke being based on an average calibration. When a substantial proportion of light-coloured particles of dust is present (which might be the case for example in the neighbourhood of a pulverised-fuel fired furnace operating without the emission of carbonaceous smoke) the existing method may be subject to error. A universal method for the determination of suspended impurity in the air, suitable for use by Local Authorities, has yet to be developed. About 90 daily smoke filters are in use in various parts of the country.

Daylight

6. Apparatus giving an integrated measurement of daylight which was used by a few Local Authorities before the war has been found to be unreliable. A design of photo-electric apparatus recently developed by the Fuel Research Station is undergoing tests.

The Use of Measurements

7. Examples of the practical uses of air pollution measurements are: (i) to identify local sources of excessive pollution and to indicate when the general concentration of pollution over an area is excessive in comparison with similar areas elsewhere, as a first step towards its abatement; (ii) to indicate changes in pollution over a period of years, in relation to industrial and other developments in the area; (iii) to provide information required by planning authorities, plant designers, etc.; (iv) to assist medical and other investigators studying the effects of pollution.

APPENDIX VIII

CHARACTERISTICS OF COAL FOR STEAM RAISING

Memorandum by the Industrial Sub-Committee

The main characteristics of coal which have a bearing on air pollution are:—

1. Type, conventionally classified as "rank" according to caking properties and volatile matter content.
2. Quality, defined by contents of combustible matter, ash, moisture and sulphur.
3. Size and range of sizes, as determined by screen analysis.
4. Natural coal dust.

1. Type

There is no fundamental difficulty in burning coals of all types (ranks) "smokelessly" in any kind of suitably designed, constructed and properly maintained conventional industrial boiler furnace. The emission from such furnaces of smoke, i.e., unburned or incompletely burned volatile matter producing more than a slight haze at the chimney top, can be avoided by competent stoking and by regulating the admission of primary and secondary air. Certain boiler plants, however, are "selective" in the type of fuel that can be burned efficiently in them. For example, when long-flame coals are used in types of boilers which present too short a path to the combustion gases, the time of passage is inadequate for complete combustion of the volatile matter which, moreover, is cooled by the boiler tubes and thus escapes as smoke.

Caking coals require more raking than feebly caking or non-caking coals to ensure the free passage of primary air through the fuel bed and to avoid

uneven combustion. Such disturbances will cause the spasmodic evolution of unburned volatile matter which requires the admission of secondary air over the fuel bed for its combustion. On the other hand, caking coals may hold back fine particles in the fuel bed by agglutination and prevent their entrainment by the combustion gases.

The degree of smoke emission from all types of coal is affected by certain operating conditions, as for example, soot blowing, lighting up and overloading of plant. Any portion of the fuel escaping as unburned volatile matter or solid carbon must be replaced by more coal, involving extra fuel consumption and giving rise to more smoke.

2. **Quality**

The quality of coal is of paramount importance in regard to fuel efficiency. It also affects air pollution as shown below.

(i) *Ash.*—As the ash content in the coal increases, so more unburned carbon is locked up in the combustion residue, but only after its corresponding volatile matter has been released to form a potential source of smoke. The loss of fuel as carbon in the ashes and clinker must be made up by additional coal increasing total consumption and causing further pollution. High ash necessitates more frequent and more thorough disturbance of the fuel bed by raking and slicing, whereby the release of grit and dust is facilitated allowing them to be more readily entrained by the flue gases; unless the grit and dust are arrested by auxiliary plant, they are emitted into the atmosphere.

In hand-fired boilers, high-ash coal makes greater demands on the manual effort of the stoker so that his attention to smoke abatement is distracted. This consideration applies in a smaller measure to mechanical stokers.

In pulverized fuel firing high ash calls for a correspondingly high capacity of grit and dust arresting plant, and pro rata adds to the portion discharged into the atmosphere. A high ash content requires more frequent and more intensive soot-blowing and temporarily may seriously overload the capacity of the arresting system.

The majority of existing pulverized fuel installations are not fitted with the most efficient grit arrestors and dust precipitators now available. The total residual ash slipping through these contrivances and emitted into the air is therefore very considerable, being at present rather more than 200,000 tons a year.

A substantial removal of ash from the coal supplied will mean a corresponding diminution of pollution of the air with solids. It will also result in a smaller dust burden being presented to the arresting plant, so that the capacity of this equipment can be reduced and its efficiency of dust elimination from the chimney gases raised.

(ii) *Moisture.*—Moisture in coal has no direct effect on air pollution, save when in excess it requires for its vaporisation extra coal, which adds potential polluting matter.

The presence of excessive moisture may cause the coal to hang up in hoppers and chutes and thereby give rise to uneven firing, which may easily lead to smoke production and grit emission.

(iii) *Sulphur.*—The significance of sulphur in coal is discussed in paragraphs 48–51 of the Report. The commonly accepted sulphur content in the average saleable coal sizes is 1·5 per cent. by weight. In "smalls" (less than ½ in. maximum size) the proportion of sulphur when related to the coal substance is much higher than in the larger sizes and in adequately washed coal. Expressed in pounds of sulphur per therm the excess may amount to more than 20 per cent. The extensive use of unwashed "smalls", therefore, entails a large addition to the pollution by sulphur oxides without compensating fuel value.

3. **Size**

The size of pieces and particles and especially the range of sizes of coal fed to boilers other than those using pulverised fuel, has an important bearing on the formation and emission of smoke and grit, since excessive fines tend to clog the fuel bed and impede the flow of primary air. The volatile matter released during the heating up stage on the grate may therefore escape complete combustion owing to inadequate contact with air of the right temperature at the right spot. Fines render the fuel bed uneven with the result that in some parts the flow of primary air is obstructed, and in others passes with increased velocity forming blowholes and carrying away grit and dust. In the absence of excessive fines and helped by the admission through adjustable openings of secondary air over the fuel bed, combustion of the smoke forming volatile matter will be practically complete.

4. **Natural Coal Dust**

The presence of "natural" coal dust in coals of all sizes presents a special and most serious problem of particle size. It is defined as the fraction of raw coal which passes a test sieve of 60 B.S. Mesh (0·25 m.m. aperture). It differs fundamentally from the other coal components in practically all its properties. This is largely due to the bulk of the friable fusain in the coal seam being concentrated in the dust during mining operations and subsequent handling of the coal. The volatile matter in this dust is low and generally contains less tar and more carbon dioxide than that of the massive coal. Natural dusts are feebly caking or non-caking. The ash content lies within a range of 12 to 20 per cent. and is remarkably constant in any one mining district. The chemical composition of the ash from dust differs significantly from that of the ash from its associated components, being usually of alkaline character, and hence more fusible.

The majority of run-of-mine coals contain from 2 to 6 per cent. of natural dust, but it may rise to 15 per cent. in untreated smalls, particularly when slurry is added to them.

It is common experience that excessive "fines" (smaller than $\frac{1}{8}$ in.) clog the fuel bed and interfere with the passage of air through it, but it is not always appreciated that the chief offender is the dust which lodges in the interstices and that in its absence the coarser grades of fines do not set up an undue pressure drop. Owing to its non-caking character and consequent inability to fuse and coalesce during the carbonisation stage, it is dislodged and lifted on raking and by forced draught, and is then carried off by the combustion gases, much of it being only partially burned or merely coked. In the sprinkler type of stoker the bulk of the dust never reaches the fuel bed.

Boiler furnaces fired with coals containing appreciable proportions of natural dust require to be provided with arresting equipment to avoid the emission of grit and dust.

The practice of "conditioning" dusty coals or fines by the limited addition of water or steam improves the distribution of air through the fuel bed and reduces the quantity of carry-over and consequent emission of grit and dust.

In pulverized fuel firing the ash from natural dust is discharged from the combustion chamber together with the ash dust from the bulk of the coal. The grit and dust leaving mechanical or hand-fired boilers burning dusty coals contains a large proportion of ash derived from natural dust.

APPENDIX IX

DOMESTIC APPLIANCES

Memorandum by the Domestic Appliances Sub-Committee

1. Introduction

Over 35 million tons of house coal and about 6 million tons of solid smokeless fuels are burnt annually by domestic consumers; some 19 million tons of the bituminous coal is burnt by domestic consumers in the black areas. Domestic chimneys are responsible for nearly half the total amount of smoke discharged into the atmosphere; and the nuisance is the more serious since not only is domestic smoke discharged at a low level and is thus less easily dispersed into the upper air, but also it is produced mainly during the winter months—the very time when fogs are most likely to occur.

Domestic smokelessness might be achieved in two main ways: by developing and installing appliances capable of burning bituminous coal smokelessly; or, alternatively, by transferring from bituminous coal to smokeless fuels. We have examined the problem from both angles, and have concluded that the necessary reduction in domestic smoke can, in the main, be achieved only by changing the fuel; that is, by the use of smokeless fuels in suitable appliances. But this poses another problem: the great majority of houses are not equipped to burn the most common types of solid smokeless fuels; in this appendix we consider therefore the question of the provision of suitable appliances.

In reaching the conclusion that domestic smokelessness can be achieved only by changing fuels, we have taken account of the fact that any reduction in the quantity of fuel burnt as raw coal would result in a proportionate reduction in smoke emission, and that such a reduction in consumption might be effected by replacing less efficient types of appliances by ones of higher efficiency. But the resultant decrease in smoke would not be large enough; nor would the replacement of old-fashioned fires by special types with reduced smoke emission when burning bituminous coal be the answer.

2. The Possibility of Burning Bituminous Coal with Less Smoke

We have considered carefully the prospect of burning bituminous coal with a substantial reduction of smoke.

We have reviewed the factors which determine the smoke emission resulting from the combustion of bituminous coal, and have concluded that there is no prospect of developing an open fire which will burn coal completely smokelessly. With a closed type of appliance smokeless combustion is possible, but the practical difficulties are severe. The necessity for maintaining a high temperature in the combustion zone, and for supplying pre-heated secondary air to it in the correct proportions, mean that the practical problems are accentuated at the low and varying rates of burning which are required for a room-heating appliance.

There are, however, prospects of being able to burn coal with reduced smoke emission as compared with the present simple open fire grate. While figures cannot yet be quoted, it should be possible, with closed types of appliances operated continuously, to effect a substantial reduction without making the stove too complicated; increasing complication means a higher price and the need for more careful control by the user.

With open fires it is difficult to predict what degree of reduction it should be possible to achieve. Some designs of down-draught burning fires on the market give, under the best conditions, a smoke emission of about one-third of that of the conventional fire; the smoke increases, however, as the rate of burning is reduced. Also, since the design of these fires permits them to be operated in the conventional up-draught manner, the degree of smoke elimination depends on the skill and co-operation of the user. At the request of the Committee, the British Coal Utilization Research Association carried out in conjunction with Messrs. Radiation Ltd. an experimental study of a

down-draught open fire and confirmed broadly a smoke reduction of approximately the order stated. There is some evidence to show that the presence of a restricted chimney throat, whether in an open fire or an openable stove, results in some reduction of emergent smoke per pound of fuel burned.

Experimental work is proceeding on the measurement of smoke emission of various types of open and closed-fire appliance. Some appliance manufacturers are known to be working on new designs which they hope will reduce smoke. Although it is unlikely that the degree of smoke reduction finally achieved with such appliances will be sufficient to be acceptable for black areas, we consider their development should be encouraged with the object of reducing air pollution in fringe or rural areas.

3. The Development of Domestic Solid-Fuel Burning Appliances

As part of the background of the problems to be considered, we have reviewed the more recent history of the development of domestic solid-fuel burning appliances.

The development by the gas undertakings, in collaboration with the manufacturers, of simple open fire grates suitable for burning gas coke began during the 1920's, and in subsequent years large numbers were installed in some areas. From the 1930's there was a slow but steady extension in the development and use of openable stoves designed to burn anthracite or gas coke.

Since 1945 there have been striking increases in the activities of the solid-fuel appliance manufacturers, arising largely from the recommendations for domestic heating of the Egerton and Simon Committees. Greatly improved designs of cooking appliances, including free-standing cookers as well as the various types of combination grate, have also been developed, and numerous designs of openable stoves and open fires have appeared. With few exceptions these new designs are required to be capable of burning coke or anthracite in addition to coal.

During the last few years the use of coke-burning open fires, under the general title of "improved open fires", has increased rapidly. Most of these are at present being used to burn coal, on which fuel their efficiency is only a little higher than that of the old-fashioned types, and that by virtue of the better controllability. In addition to the simple types, many designs to give convection as well as radiation have been produced.

Very recently there have been further trends in design, the long-term influence of which is likely to be significant. "Throat restrictors" have been introduced to limit excessive ventilation; in general they are more effective in this respect than the old adjustable canopy. Throat restrictors are to be found both as separate units for insertion in existing chimneys and as integral features of new appliances.

Freestanding open fires, incorporating throat restrictors and giving convection as well as direct radiation from the fire, are being produced. Some are suitable for attachment to existing conventional fireplace openings, while others are designed for installation in chimney recesses.

The improvements in design which have taken place over the last seven or eight years have largely resulted from official action in introducing standards of performance and a procedure for testing and recommending solid-fuel burning domestic appliances.

4. Procedure for Testing and Recommending Appliances

(a) *Solid Fuel*

In 1947, arising from the recommendations of the Egerton and Simon Reports, schedules of test and performance standards, prepared by the Ministry of Fuel and Power in consultation with the Fuel Research Station of the Department of Scientific and Industrial Research and agreed by representative organisations of the manufacturers, were introduced for the purpose of testing and recommending domestic solid-fuel burning appliances for use in average dwellings. These standards required all classes of appliance to be capable of operation

with both bituminous coal and smokeless fuel (anthracite or coke), and were introduced for a prescribed period during which account was taken of practical experience and new developments in design to enable revised standards to be formulated with appropriately higher minimum efficiencies. In 1953 revised Standards and Methods of Test giving complete requirements were brought into force for a further prescribed period. These revised Standards set out the performance required when burning coke and when burning bituminous coal, coke being considered as sufficiently representative of all solid smokeless fuels. For all types of open fire it is a requirement that provision shall be made for the incorporation of a gas ignition burner. Appliances which meet the Standards and are of a suitable price are recommended by the Ministry of Fuel and Power for installation in average dwellings and included in the List of Recommended Appliances published by the Coal Utilisation Council. It is a condition of approval of tenders for local authority houses that the main heating appliances shall be selected from the List. This List also contains appliances of equivalent performance, but which are considered too costly for use in average dwellings. The testing of appliances for recommendation is a continuous process and revised editions of the List are published at approximately six-monthly intervals. Under the new procedure instituted in 1953 all appliances previously recommended are being re-examined and tested to the new Standards.

(b) *Gas and Electricity*

A similar procedure exists for gas and electrical appliances. Domestic gas appliances are tested at the Watson House Centre and, when approved by the Centre, are placed on the *List of Tested and Approved Domestic Gas Appliances*, which is prepared at the request of the Ministry of Fuel and Power.

A *List of Tested and Approved Domestic Electrical Appliances for Local Authority Housing* is also compiled, at the request of the Ministry of Fuel and Power, by the Electrical Development Association's Testing and Approvals Committee. Members of the Committee are appointed by the Council of the Association to represent all Area Electricity Boards in the United Kingdom.

Both lists are circulated to all housing authorities in England and Wales by the Ministry of Housing and Local Government, who recommend that appliances for new houses and flats built by local authorities should be selected from them.

5. Relative Efficiencies of Appliances

It has not yet been found possible to define or measure an "efficiency" from which the relative fuel consumption in the home of appliances of different types can be directly deduced. An attempt was made in Appendix II of the Report of the Ridley Committee to quote "room efficiencies" for the main types. These figures may be used for an approximate comparison between appliances which give a substantial proportion of their output in the form of radiation. They are however of limited application in the case of heaters whose output is predominantly in the form of convection, owing to the different physiological values of the two types of heat. The efficiencies refer to "continuous" heating, which is defined as heating a room for a period of five hours or more.

The main features which distinguish the new or "improved" type of appliance from the old are their ability to burn either coke and the other solid smokeless fuels or bituminous coals, and the ability of the user to control the rate of burning. In general the efficiency with coke is approximately one-third higher than with coal.

The improved type of simple open fire has a room-heating efficiency of 25 to 35 per cent. on coal and 35 to 45 per cent. on coke. For the old-fashioned open grate, which would burn coal and low temperature coke only, the efficiency is 20 to 30 per cent. on coal and, owing to its lack of controllability, is usually nearer the lower end of the scale.

The efficiency of the improved grate is raised by fitting a throat restrictor to reduce the chimney air flow, by arranging that it provides convection in addition to radiation. The most efficient of the appliances giving a substantial

proportion of radiation is the openable stove, which has a room-heating efficiency of 45 to 55 per cent. on coke.

These efficiencies relate to appliances designed to give space heating only. It may be assumed that, in cases where a back boiler is fitted to provide domestic hot water in addition, the overall efficiency is higher but the room-heating efficiency will generally be a little lower than the figures quoted. The coke efficiencies will, however, as previously stated, remain at the value of approximately one-third higher than with coal.

The room efficiencies when burning anthracite and dry steam coal will generally be a little below the coke figures but well above the coal figures.

For electricity the appliance room efficiency is taken as 100 per cent.; for gas it is 45 to 55 per cent. for radiant heaters, and 55 to 65 per cent. for convector/radiant heaters.

For periods of heating of only an hour or so the effective efficiency of solid-fuel burning appliances will be much lower than the figures quoted because of the time taken to establish the fire and because of the fuel invariably left on the fire at the end of the period. The problem of assessment is, however, complicated under these conditions for all sources of heat, since it is persons rather than spaces who are being heated.

6. Points to Watch

(a) *Replacements*

The replacement of existing appliances raises a number of problems. Thus some existing fire-backs, particularly in older houses, are of such shapes that improved appliances cannot be correctly installed without replacing fire-backs. Secondly, coke cannot be burned at so high a rate as coal and despite the higher efficiency of appliances when burning coke, a change from bituminous coal to coke might in some cases result in inadequate heating in very cold weather; this might necessitate the installation of a larger or different type of appliance. Again, selection of open-fire appliances for burning coke should take account of the quality of coke available; in the case of less reactive cokes it is advisable to select appliances with wider firebar spaces.

(b) *Gas Ignition*

Since it is difficult to light a high-temperature coke fire by sticks and paper it is most desirable that, wherever a gas supply is available, provision should be made for gas ignition.

(c) *New Houses*

In new houses the selection of the more efficient types of solid-fuel appliance would be encouraged and facilitated by the provision, in place of the conventional surround, of a recess into which could be fitted a freestanding appliance. This would have the advantage not only of allowing the immediate installation of the existing more efficient types of appliance but also of facilitating their later replacement by other types if desired.

(d) *Installation*

We would emphasise the importance of correct installation of improved solid-fuel appliances, since otherwise there will be some loss of efficiency. The Coal Utilisation Council are devoting much attention to ensuring correct installation but we consider that there are still many appliances being installed by people without sufficient skill or experience; the solution must lie in intensification of instruction and advice.

(e) *Instructions and Advice*

It is necessary that clear and comprehensive working instructions are supplied to the users. This might best be achieved by the industries and organisations most concerned—the appliance makers and distributors, the fuel suppliers, and the C.U.C.—co-operating to ensure that there are adequate arrangements for instructing householders in the use of the appliances and fuels, and for the

maintenance and servicing of the appliances. On local authority housing estates these arrangements should be supplemented by advice from the authorities' own officers, such as the staff of Housing Departments, who are in regular contact with the tenants; written instructions similar to the *Hints on the Use of Coke*, given out by Nottingham Corporation, are a desirable practice.

7. **Reaction of the Public to Improved Solid-Fuel Appliances**

The evidence indicates that where improved solid-fuel burning domestic appliances are properly selected in relation to the particular needs, correctly installed, and are used in the way recommended by the manufacturers and with the proper fuels, they give a satisfactory performance both for room and water heating. It is clear that of the complaints received by local authorities many arise through the selection of appliances unsuitable in size or type and faulty installation.

The view is sometimes heard that the height of the front of some types of improved fires results in a lack of heat at foot level. This is generally the result of selecting a high-fronted appliance for fixing on a raised type of hearth. The openable type of stove does not appear popular—owing perhaps to the traditional preference for an open fire; this is unfortunate as this type of appliance has advantages both from the point of view of efficiency and of reducing air pollution.

8. **Number of Appliances required and Cost**

The numbers and types of appliances required to enable all domestic consumers in black areas to switch from bituminous coal to smokeless fuel cannot be estimated with any degree of precision, since so much depends on the pattern of future supplies of smokeless fuels and the extent to which households are already equipped with suitable appliances to burn those fuels.

Having regard to the number of registered consumers of house coal in black areas and the number of improved solid-fuel burning appliances known to be installed throughout the country we estimate that some seven million households in the black areas will need new appliances.

Production capacity of the appliance industries is adequate. Even after allowing for demands coming from outside the black areas, we are confident that replacements for all the black areas could be produced in advance of the availability of the additional smokeless fuels required.

The cost of replacing an old-fashioned solid-fuel burning appliance by an improved appliance of similar type will vary according to type, but in the majority of cases, i.e., those in which merely the replacement of a simple open fire is involved, the cost will be about £5-£6. Where open fires with back boilers are involved the cost will be more; for combination grates the replacement cost will be considerably higher and may amount to about £60 or over.

There would be an additional cost in most cases for provision of a gas connection and in some cases for renewal of surrounds, overmantels, fire-backs or hearths and for plumbing alterations.

APPENDIX X

ESTIMATED COSTS OF CONTINUOUS ROOM HEATING BY DIFFERENT FUELS

Memorandum by the Prices and Tariffs Sub-Committee

In paragraph 80 of the Committee's Report, it is stated that coke is a more efficient and economical fuel than raw coal for domestic heating. Table 1 of this Appendix summarises the evidence for this conclusion. It gives estimates of the cost of continuous (i.e., five hours or more per day) room heating by different types of fuel in typical appliances in which they can be satisfactorily used, in nine major towns of Great Britain. The prices and tariffs used for the calculations are those in force on 1st October, 1954, and are given in Tables 2

and 3. For each item there is a range of estimated cost, corresponding to the range of room efficiency shown in the first column of Table 1. This Table permits comparisons of the cost of using different fuels in a **similar appliance** but, for reasons given in the Note, the cost shown for using different fuels in **different types of appliances** cannot be directly compared.

It will be seen that for every type of appliance using solid fuel, coke costs less per useful therm than any other solid fuel.

As a substantial increase in the production of coke for domestic use might involve an increase in its price, Table I also includes estimated costs of using coke in the various appliances if its price were £1 a ton above the present levels. This is solely for purposes of illustration: it will be seen that even in these circumstances coke would still provide useful heat about as cheaply as house coal.

Notes to Table 1

(i) *Typical Room Heating Efficiencies*

The room heating efficiencies used for coal and coke are those given in Appendix II of the Ridley Report (Cmd. 8647). Efficiencies when burning "Coalite" and "Rexco" have been assumed to be the same as those for coke.

Cost comparisons based on these estimates are subject to the following qualifications:

(*a*) Results achieved in practice may vary considerably from these typical figures assumed because of differences in the actual situation of the room and the appliance, in the manner of using the appliance, and in the wants of the user.

(*b*) The costs of using different fuels in different types of appliance cannot be directly compared because when heat is supplied mainly by convection a higher room temperature is required for personal comfort than when the heat is radiated from a high-temperature source.

(ii) I = cost under flat rate;

II = cost under two-part or lower block rate (see Tables 2 and 3).

TABLE I

Estimated Cost of Continuous (Five hours or more) Room Heating in Selected Cities

Typical Room Heating Efficiencies (i)	Type of Appliance	Cost in Pence per Useful Therm (for prices and tariffs used see Table 2)								
		London	Birmingham	Cardiff	Glasgow	Leeds	Liverpool	Manchester	Newcastle-on-Tyne	Sheffield
	A. *Ordinary pre-war grate (stool-bottomed grate with front fret)*									
20—30	(1) burning coal	28 —18½	23½—15½	23 —15	23 —15	22 —14½	23½—15½	23 —15½	21 —14	22 —14½
25—35	(2) burning "Coalite"	30 —21½	27 —19½	30 —21½	30 —21½	25 —18	27 —19	27 —19	28½—20½	25 —18
25—35	(3) burning "Rexco"	30½—22	28 —20	—	—	28 —20	27½—20	26½—19	30½—22	26½—19
	B. *Simple improved open fire*									
25—35	(1) burning coal	22½—16	18½—13½	18½—13	18½—13	17½—12½	18½—13½	18½—13½	16½—12	17½—12½
35—45	(2) burning coke—									
	(*a*) present prices	16½—12½	15½—12	14½—11½	14 —11	14½—11	14½—11	14½—11½	14 —11	15 —11½
	(*b*) prices increased by £1 a ton	19 —14½	18 —14	17½—13½	17 —13	17 —13	17 —13	17½—13½	16½—13	17½—13½
35—45	(3) burning "Coalite"	21½—17	19½—15	21½—16½	21½—16½	18 —14	19½—15	19 —15	20½—16	18 —14
35—45	(4) burning "Rexco"	22 —17	20 —15½	—	—	20 —15½	20 —15½	19 —15	22 —17	19 —14½
	C. *Improved open fire with restricted throat or with convection heating*									
30—40	(1) burning coal	18½—14	15½—11½	15 —11½	15 —11½	14½—11	15½—11½	15½—11½	14 —10½	14½—11
40—50	(2) burning coke—									
	(*a*) present prices	14½—11½	13½—11	13 —10½	12½—10	12½—10	12½—10	13 —10½	12 — 9½	13 —10½
	(*b*) prices increased by £1 a ton	16½—13½	16 —12½	15 —12	14½—12	15 —12	15 —12	15 —12	14½—11½	15½—12
40—50	(3) burning "Coalite"	19 —15	17 —13½	19 —15	19 —15	15½—12½	17 —13½	16½—13½	18 —14½	15½—12½
40—50	(4) burning "Rexco"	19 —15	17½—14	—	—	17½—14	17½—14	16½—13½	19 —15½	16½—13
	D. *Openable Stove*									
35—45	(1) burning coal	16 —12½	13½—10½	13 —10	13 —10	12½— 9½	13½—10½	13½—10½	12 — 9	12½— 9½
45—55	(2) burning coke—									
	(*a*) present prices	12½—10½	12 —10	11½— 9½	11 — 9	11 — 9	11 — 9	11½— 9½	11 — 9	11½— 9½
	(*b*) prices increased by £1 a ton	14½—12	14 —11½	13½—11	13 —10½	13 —11	13 —11	13½—11	13 —10½	13½—11
45—55	(3) burning "Coalite"	17 —13½	15 —12½	16½—13½	16½—13½	14 —11½	15 —12½	15 —12	16 —13	14 —11½
45—55	(4) burning "Rexco"	17 —14	15½—13	—	—	15½—13	15½—12½	15 —12	17 —14	14½—12
	E. *Closed Stove*									
60—70	(1) burning coke—									
	(*a*) present prices	9½— 8	9 — 8	8½— 7½	8½— 7	8½— 7	8½— 7	8½— 7½	8 — 7	8½— 7½
	(*b*) prices increased by £1 a ton	11 — 9½	10½— 9	10 — 8½	10 — 8½	10 — 8½	10 — 8½	10 — 8½	9½— 8	10 — 8½
60—70	(2) burning "Coalite"	12½—11	11½— 9½	12½—10½	12½—10½	10½— 9	11 — 9½	11 — 9½	12 —10	10½— 9
60—70	(3) burning "Rexco"	12½—11	11½—10	—	—	11½—10	11½—10	11 — 9½	13 —11	11 — 9½
	F. *Gas Fire*									
45—55	(1) Radiant (ii) I	42 —35	39 —32	44 —36	43— 35	46 —38	43 —35	43 —35	37 —30	33 —27
	II	34 —27	35 —29	31 —25	39 —32	40 —33	35 —29	33 —27	24 —20	27 —22
55—65	(2) Radiant with convection I	35 —29	32 —27	36 —30	35 —30	38 —32	35 —30	35 —30	30 —25	27 —23
	II	27 —23	29 —24	25 —22	32 —27	33 —28	29 —24	27 —23	20 —17	22 —18
100	G. *Electric Fire*	29½	29½	25	25½	25½	25	25½	25½	25½

TABLE 2

Prices and Tariffs used in calculating Costs in Table I

Note.—The prices used are those current at 1st October, 1954, except for coal, "Coalite" (large), and "Rexco" (large), where the basic price is used (i.e., the price before adjustment is made for summer rebate or winter surcharge).

		London	Birmingham	Cardiff	Glasgow	Leeds	Liverpool	Manchester	Newcastle-on-Tyne	Sheffield
Electricity	per unit (assuming all heating is at the follow-on rate in a block tariff)	1d.	1d.	0·85d.	0·875d.	0·875d.	0·85d.	0·875d.	0·875d.	0·875d.
Gas I.	Flat rate per therm	19·1d.	17·5d.	19·7d.	19·5d.	20·75d.	19·25d.	19·25d.	16·5d.	14·7d.
II.	2-part, or lower block rate (see Table 3)	15·1d.	15·7d.	14·0d.	17·5d.	18·0d.	15·75d.	14·75d.	11·0d.	12·0d.
Coal (Group 4)	per ton—basic price (heat content 280 therms)	130/2d.	108/11d.	106/7d.	106/6d.	101/10d.	109/1d.	108/3d.	97/10d.	101/10d.
	pence per therm	5·58	4·67	4·57	4·56	4·36	4·68	4·64	4·19	4·36
Coke	per ton (heat content 265 therms)...	126/6d.	120/–	113/9d.	110/1d.	111/3d.	111/8d.	114/–	107/7d.	115/–
	pence per therm	5·73	5·43	5·15	4·98	5·04	5·06	5·16	4·87	5·21
"*Coalite*"	per ton (heat content 280 therms) ...	176/–	158/10d.	175/6d.	175/–	146/8d.	157/2d.	155/10d.	167/4d.	145/2d.
	pence per therm	7·54	6·81	7·52	7·50	6·29	6·74	6·68	7·17	6·22
"*Rexco*"	per ton (heat content 280 therms) ...	177/9d.	164/–	Not sold	Not sold	163/10d.	161/4d.	154/11d.	178/6d.	153/7d.
	pence per therm	7·62	7·03	—	—	7·02	6·91	6·64	7·65	6·58

TABLE 3

Domestic Gas Tariffs in Selected Cities at 1st October, 1954

	Flat Rate or Block Tariff (pence per therm)				Two-Part Tariff	Tariffs used in Table 2 (pence per therm)		Quarterly consumption required to make two-part tariff attractive (therms)
	1	2	3	4		I	II	
London								
(*a*) North Thames Gas Board	19·1	—	—	—	Standing Charge 22s. 9d. per quarter plus 15.1d. per therm.	19·1	15·1	68
(*b*) South Eastern Gas Board	20·0	—	—	—	Standing Charge based on number of rooms plus 16·0d. per therm			—
Birmingham	First 45 therms 17·5	Over 45 therms 15·7	—	—	None	17·5	15·7	—
Cardiff	First 23·75 therms 19·7	Next 23·75 therms 19·2	Next 47·5 therms 18·9	Over 95 therms 18·7	Standing Charge 13s. per quarter plus 14·0d. per therm	19·7	14·0	28
Glasgow	First 27 therms 19·5	Over 27 therms 17·5	—	—	None	19·5	17·5	—
Leeds	First 25 therms 20·75	Next 40 therms 18·75	Next 60 therms 17·75	Over 125 therms 16·0	None	20·75	18·0	—
Liverpool	First 65 therms 19·25	Over 65 therms 17·0	—	—	Standing charge 16s. 3d. per quarter plus 15·75d. per therm	19·25	15·75	56
Manchester	First 65 therms 19·25	Over 65 therms 17·0	—	—	Standing charge of 13s. per quarter plus 14·75d. per therm	19·25	14·75	35
Newcastle-on-Tyne ...	First 30 therms 16·5	Over 30 therms 11·0	—	—	None	16·5	11·0	—
Sheffield	First 30 therms 14·7	Next 30 therms 12·7	Over 60 therms 11·1	—	None	14·7	12·0	—

APPENDIX XI

THE PROVISION OF SMOKELESS FUELS

Memorandum by Dr. G. E. Foxwell

1. In their report the Committee have indicated that the first attack should be directed to the black areas where some 19 million tons of house coal are now burnt for domestic and similar purposes. The estimate of 19 million tons is based on the records of the Ministry of Fuel and Power and is accepted as the amount of smoky coal to be displaced. The objective should be to replace this coal by smokeless fuels within a reasonable period, probably 10 to 15 years. In addition, smokeless fuel would be required to meet an estimated "unsatisfied" demand of perhaps an additional 10 to 15 per cent. that will be released if and when the fuel is available.

2. The smokeless fuels that come into consideration for this purpose are:

Natural smokeless coals yielding less than 20 per cent. of volatile matter.

"Hard" coke derived from coke ovens making metallurgical coke.

Medium temperature coke made by special processes.

Gas coke.

Low temperature coke.

Town gas.

Electricity.

Oil.

3. The extensive use for this purpose of certain of these fuels is limited by available supplies or the cost of production and in the circumstances now ruling carbonization, which produces both coke and gas, is the most promising source of the greater part of the fuel required. It is necessary to be assured that it would be possible to provide from the national resources sufficient smokeless fuels to replace smoky house coal.

4. To put the present usage in perspective the present pattern of supply of fuels to consumers over the whole country is indicated below, taking no account of the efficiency of utilization; the figures, which can only be approximations, are stated in therms to render them comparable one with another.

Fuel for domestic purposes

	million therms
House coal	10,000
Anthracite and boiler fuel	600
Coke	750
Town gas	1,360
Electricity*	550
Oil	160

* includes lighting and power

General conditions for house coal replacement

5. In assessing the possibilities of replacement of house coal in the black areas, the following factors and conditions have been taken into account:

(1) The advance of technology may bring changes in the economic and physical pattern of fuel availability. These cannot be foreseen and this assessment has been made on a realistic basis of what is available today in the economic conditions now ruling.

(2) The traditional coking and gas coals now available are in short supply, while the demand for metallurgical coke is rising.

(3) The national coal requirements are increasing and it is therefore desirable that any solution of the problem of house coal replacement should result in reduced demand for coal.

(4) The evidence indicates that the present preference for the open fire will continue for some time to come in most parts of the country and for the purpose of this assessment it has been assumed that 80 per cent. of the smokeless fuel to be supplied in the black areas will replace coal burnt on open fires or their equivalent, and must therefore be of a quality suitable for that purpose.

(5) Any replacement smokeless fuel provided must give service which the normal consumer will regard as satisfactory; this will necessitate some changes in the technique of production and the provision of modern solid fuel appliances in the home. The quality of the fuel is therefore to be regarded as that appropriate for use on those appliances.

(6) Considerations relating to production costs and storage make it inevitable that the main winter space heating load be taken by solid fuel, a conclusion in line with the report of the Ridley and Simon Committees; this means that the bulk of the replacement of house coal must be by solid fuel.

(7) Domestic consumers should have the widest possible choice of methods of heating provided that in black areas they are smokeless.

(8) Coke has a higher thermal efficiency in use than coal and it has been assumed that, including an allowance for unsatisfied demand, 16 cwt. of coke burnt in a modern appliance is equivalent to 1 ton of house coal burnt in the older, out-of-date appliances now in common use.

(9) The object should be to replace house coal in black areas by solid smokeless fuel with the minimum call upon the national fuel supplies.

6. The general conclusion reached is that replacement of house coal in black areas is feasible, but it is not insisted that the particular pattern of supply here envisaged is the only one. Each smoke control area or smokeless zone must be supplied according to local conditions as governed by the availability of the various fuels, cost and consumer preference. Whatever pattern may be adopted must provide a service acceptable to the consumer and be within a national pattern of fuel usage based on the requirements of industry as well as the wishes of the householder.

Fuel diversion

7. The first step is to make the best use of the fuels we now have. The evidence indicates that much can be done by diversion of fuels from one user to another.

For example:

(1) Some industrial and other non-domestic users of coke could use instead bituminous coal or oil, and liberate the coke for domestic use in black areas.

(2) Significant tonnages of coking or gas coals are now used for purposes for which non-coking coal or fuel oil would be equally suitable.

8. There is a limit to the extent to which coke can be released in this way because of the special uses to which coke is put in many industries, the selective character of the plant in use and the cost of making the replacements. It is assumed that the carbonization industry is prepared reasonably to adapt its technique to the fuels available.

9. A distinction must be drawn between what is technically possible and what is administratively feasible and it must be borne in mind that the producers of additional coke or of coke that is liberated for transfer must be assured of markets for their products. No coke must be released unless there is certainty that it can be used elsewhere almost immediately and that suitable alternative fuels are available for the existing users of that coke. It is visualised that fuels will be transferred from one user to another mainly by agreement or in response to commercial inducements, and inevitably this must be a gradual process.

10. Transport costs should be kept to the minimum. Except for anthracite, natural smokeless fuels are used mainly in or near the coalfields of South Wales, Scotland and Kent, where they are produced. Consumers seem prepared to pay considerable transport costs on anthracite and high-quality manufactured smokeless fuels. The present production and increase in coke required is or would be

mainly produced in or near the black areas, and it is unlikely that the transport costs involved in coke diversion would be considerable.

Provision of solid smokeless fuel other than from the gas industry

11. Estimates of smokeless fuel available now or within the next three years have been obtained from all the authorities and interests concerned and the figures (which obviously must be regarded to some extent as estimates and approximations) are summarized in Tables I and II.

TABLE I

	Tons	*Total*
Already used for domestic purposes; diversion improbable:		
Anthracite and smokeless coals	2,110,000	
Hard coke and other carbonized fuels	1,170,000	
		3,280,000
Not used for domestic purposes; diversion probable:		
Anthracite and smokeless coals...	808,000	
Hard coke	600,000	
		1,408,000
New production available for domestic purposes over next three years:		
Anthracite and smokeless coals	1,220,000	
Hard coke and other carbonized fuels	1,140,000	
		2,360,000
		7,048,000

The appliances in which these fuels can be used or are used are as follows (Table II):

TABLE II

	Open Fire Tons	*Closed Appliances Tons*
Already used for domestic purposes:		
Anthracite and smokeless coals...	755,000	1,355,000
Hard coke and other carbonized fuels	500,000	670,000
Probably transferable:		
Anthracite and smokeless coals...	—	808,000
Hard coke and other carbonized fuels	200,000	400,000
New production:		
Anthracite and smokeless coals...	—	1,220,000
Hard coke and other carbonized fuels	940,000	200,000
	2,395,000	4,653,000

12. In explanation of these figures it may be said that—

(1) It is not known how much of the 2·11 million tons of natural smokeless coal is used outside the black areas, but it is regarded as unlikely that any significant amount of this can be diverted from present uses. Anthracite and some of the other coal is used in special appliances all over the country and it is unlikely that the supply to these appliances could be cut off. Because there are special appliances and techniques indigenous to Wales, for burning Welsh dry steam coals in an open fire, these and certain other Welsh low-volatile coals are regarded as usable only in Wales where householders are accustomed to their use.

(2) Over three-quarters of the present production of oven coke (also termed "hard coke") is already supplied to blast furnace foundries and other industries for special purposes. Part of the remaining 2 million tons of hard coke is used in the black areas and much of the remainder could only be used for domestic purposes in closed stoves or boilers if cut to smaller sizes at

considerable waste and cost; some, however, can be transferred, and as the National Coal Board's new coke oven plants come into production some further quantity will be available. Coke produced in coke ovens is generally suitable for domestic boilers and closed stoves.

(3) There are plans for extending the production of low temperature coke over the next three years and these have been taken into account in the foregoing Tables; possible production beyond this period is not included in Tables I and II.

13. The position arising from the fuel transfers and new production given in Tables I and II is as follows:

TABLE III

	Total	Total made up of:	
	million tons	Open fires million tons	Closed fires million tons
1. Bituminous coal to be displaced in black areas	19·00	15·20	3·80
2. Solid smokless fuel equivalent to the coal in line 1	15·20	12·16	3·04
3. Solid smokeless fuels transferable and new production by 1958 from Tables I and II ...	3·768	1·14	2·628
4. Deficiency in terms of solid smokeless fuel (line 2—line 3)	11·432	11·02	0·412

Thus, from these sources can be produced most of the closed fire fuel needed, but there remains a large gap amounting to about 11 million tons of open fire domestic fuel, equivalent on the 16 cwt. replacement basis to some 13·8 million tons of house coal. It remains to consider how this can be filled.

Possibilities of increased production other than from the gas and electricity industries

14. The replacement of house coal for continuous room heating by electricity from coal-fired power stations would materially increase the national demand for coal. Allowing for some future increase in efficiency of electricity generation, between 1·2 and 1·5 tons of electricity coal would be needed to replace a ton of house coal burnt on the old domestic open grate now in general use. Inferior grades of coal usable in electricity generation tend to be somewhat more freely available than other grades, but there is an absolute shortage of coal of all types; consequently, if only for this reason, it does not appear to be nationally desirable to stimulate the use for space heating of electricity derived from fuel-fired stations.

15. Application of the carbonization process to this purpose, on the other hand, could result in an appreciable saving of coal but the present plans of the gas industry and the National Coal Board make no provision for the increased amount of coke required. Moreover, the Gas Council maintain that by reason of the new coal price structure it has now for the first time in the history of the industry, become uneconomic to carbonise coal and to produce coke for sale and that the fulfilment of the programme of coke production which they envisage is entirely dependent on the revision of the coal price structure or in some other way making the programme economic. The programme of gas production outlined in the Gas Council publication "Fuel for the Nation" involves a reduction in the expansion of carbonisation—and consequently of coke production—to the minimum. The National Coal Board maintain that carbonization coals are costly to mine and that the prices charged for them reflect their calorific value as well as fulfilling the normal function of the price mechanism in equating supply and demand.

16. As the next step, the possibilities have been examined, therefore, of expanding production from sources other than the gas industry before considering what could be done by that industry. Table I indicates that present producers have plans for modest increases in production, but it is necessary to consider what can be done in addition to this.

17. The National Coal Board do not expect to be able to give any appreciable assistance through the increased production of natural smokeless fuels. Such assistance as can be forecast has already been taken into account in Tables I and II. These coals would be suitable for closed stoves only, or their equivalent, or for open fires in South Wales.

18. It is understood that the National Coal Board do not visualise the production of additional hard coke (oven coke) for the domestic market beyond that already projected and do not regard this as coming within their province. In their view, the production and marketing of open-grate coke is properly undertaken by the gas industry.

19. There would not appear to be any financial inducement for the production of open-grate coke at coke oven plants, and in particular for the construction of merchant coking plants. Oven coke is already usually about 12s. a ton dearer than gas coke in most towns, and up to 20s. dearer in some. The coke oven owners, moreover, plan to undertake a large programme of expansion to meet the growing needs for iron and steel manufacture and are faced with increasing shortage of good coking coal to meet this programme. First grade coking coals should be reserved for the manufacture of metallurgical coke and not burnt in the domestic grates.

20. The cost of oven coke would be further increased if it were to become necessary to cut and stock substantial quantities and to manufacture to open-grate specification by blending coals or modifying the process in new and costly plants.

21. A limitation of production in coke ovens not owned by the gas industry would arise if ovens were sited at or near the colleries supplying the coal. Suitable coke could be made by blending coals from different districts, however, at central plants and in this case the ovens could be sited in the black areas near the point at which gas and coke are to be used. If transport costs or other difficulties limited the site of the plant to the colliery area, the gas (and coke) might require transmission (or transport) over long distances to the point of use, with consequent heavy costs. It is generally uneconomic to transport both the coke and the gas for more than a few miles.

22. As a temporary measure it might be possible for the National Coal Board to produce reactive coke from certain obsolescent coke ovens. Design data are being obtained by the National Coal Board, but the amount would be probably less than 0·5 million tons a year.

23. Little further production of "Phurnacite" other than that now in train can be foreseen because the market for this specialised product at present prices seems to be nearing saturation, and the supplies of suitable coal are stated to be very limited.

24. The "Coalite" process requires coal which is in strong demand for the carbonising industries and for this and economic reasons no substantial increase is anticipated in production of this product above that now planned, though the ultimate expansion might be to treble the present production.

25. More could be done in carbonising non-coking or very weakly coking coals as practised at Granton gasworks, Edinburgh, and by the National Carbonising Company. Coal could be found by using for this purpose some of the bituminous coal now burnt in domestic grates in black areas. It is, however, not known what proportion of present domestic coal would be suitable for treatment by this process, and admittedly the coal required is of the "large" or "graded" sizes for which there is strong demand at present.

26. The conclusion from these investigations is, therefore, that while there are modest prospects of increasing the supply of solid smokeless fuels by certain of these established processes, the total quantity provided would fall a long way short of the quantity required to bridge the gap shown in Table III.

27. Information is published from time to time about processes for producing smokeless or near-smokeless fuel that are in the experimental or pilot plant stage, but until such processes reach the production stage and their limitations and costs become known, it is unrealistic to base plans upon them.

28. It is therefore the gas industry, by means of coke and gas, assisted by the electricity industry, to which the community must look to provide the replacement for most of the open-grate house coal and to bridge the gap revealed by this analysis. The warning is repeated that this conclusion is flexible, depending upon what may be the future development of the technique of the production of fuels and energy.

The use of gas and electricity

29. Between 1938 and 1953 the domestic use of gas rose from 900 million therms to 1,360 million therms and electricity from 5,000 million kWh (= 170 million therms) to 16,400 million kWh (560 million therms). The increasing use by the householder of these refined sources of heat reflects his rising standard of living and the difficulty of securing as much house coal as he needs. Gas, being virtually sulphur-free, is from the angle of atmospheric pollution the ideal domestic fuel. Gas, and to a greater extent electricity, suffer from the high cost of meeting the peak-load and seasonal-load demands inseparable from winter space heating. It is in relation to the physical difficulties and cost of meeting this load that both the Simon and Ridley Committees insisted that the main winter space heating load should be taken by solid fuel. Until seasonal-load gas or electricity can be produced very much more cheaply in relation to coal than today and storage difficulties in meeting peak demands during a few days intense winter cold can be resolved at reasonable cost, these findings must be accepted.

Closing the gap

30. The estimates here made so far of fuels available from sources other than the gas and electricity industries have left some 14 million tons of house coal still to be replaced by smokeless fuel in the black areas. It has here been assumed that within the period under consideration some 10 per cent. of this may be replaced by electricity. In adopting this figure developments are not ruled out which would result in electricity providing a larger proportion of the whole requirement but one must bear in mind the increasing needs of industry for power now and in the future and the likelihood that coal supplies will be stretched to the limit to maintain the rising curve of industrial productivity.

31. The Gas Council foresee the possibility of transferring some 4·6 million tons of coke from other users into the domestic market in the black areas. Some large coke will be needed for non-industrial premises and it is here assumed that 3 million tons of this transferred gas coke (equivalent to 3·75 million tons of house coal) will be available for the open fire. It is anticipated that much of the 4·6 million tons of coke mentioned will be replaced by oil, and if the extending use of fuel oil should release more coke, the gap would be further bridged. The overall picture of the replacement of the 13·8 million tons of residual house coal with a modest contribution from electricity and without allowing for any additional use of fuel oil, is given in Table IV.

TABLE IV

	House coal in black areas million tons
Coal remaining to be replaced in black areas	13·8
Replaced by electricity—10 per cent.	1·38
Remaining to be replaced	12·42
Replaced by transferring gas coke	3·75
Remaining to be replaced	8·67

32. Allowing for unsatisfied demand, the 8·67 million tons remaining to be displaced is probably a low estimate and should be increased to 10 million tons.

The position has thus been reached that when all possible use has been made of the available sources of smokeless fuels, some 10 million tons of smoky coal would need to be replaced from additional production in gas retorts. Allowing for part of the gas and coke going to industrial uses, it has been computed that this will require the carbonisation of an additional 10 million tons of coal. The normal increased production visualised by the gas industry would not meet this demand. If the required open-grate solid fuel is to be made available without waste of the national resources, it is essential that a market should be found for the gas that is produced simultaneously. The Gas Council have indicated that at present prices an equivalent heat service could be given by coke and gas combined in appropriate proportions at a less cost than by house coal. If the gas industry are to be responsible for the increased production to complete the replacement of smoky fuel in houses in black areas it will be necessary to envisage the use of both coke and gas for this purpose. From figures provided by the Gas Council of the use of gas and coke in modern houses, a feasible pattern of production and utilization of the products from the carbonization of this additional coal appears to be similar to that given in Table V.

TABLE V

	Per ton Coal carbonized	*Total per annum*
Open-grate coke	8 cwt.	4·0 million tons
Coke above and below open-grate sizes, for use in industry, etc., in smokeless zones	1½ cwt.	0·75 do.
Breeze for sale	1½ cwt.	0·75 do.
Gas used for domestic purposes—therms	36	360 million
Gas remaining to be sold outside the domestic market here visualised—therms	44	440 million

33. It can be anticipated safely that a market could be found for the gas remaining to be sold outside this specific domestic market within the period during which the expansion would take place, and the use of this gas would release coal.

Provision of coal for an expanded carbonisation programme

34. It is acknowledged that coking and gas coals, types 301, and 400-700, are in much demand, but the total annual production of these coals is more than 130 million tons. Some 53 million tons are now carbonized, leaving 77 million tons used mainly for burning and mostly replaceable by other fuels or coal of non-coking character. After making due allowance for obstacles now preventing much of this coal from being released for carbonization, it is considered that the coal needed for an expansion of carbonization can be made available by appropriate measures see Paragraphs 73-74 of the Committee's Report. Replacement by smokeless fuels would release an equivalent amount of house coal for other uses. Increased demands for metallurgical coke, on the other hand, will reduce the quantity of coking and coking-gas coals available for domestic smokeless fuel production.

35. There is also before the gas industry the prospect of blending gas coals of types 400, 500 and 600 with a high proportion of cheaper coal of low coking powers (types 800 and 900) and carbonizing the blend without loss of output and without incurring costs higher than those now entailed in the normal process of carbonizing graded gas coals. In this way there might be provided some 3 million or 4 million tons of the required 10 million tons from coals not now carbonized in gasworks. Blending, moreover, need not be confined to the 10 million tons additional carbonization capacity.

36. The coal necessary for the proposed additional carbonization programme could be secured therefore by a combination of several measures:

(1) Coal suitable for carbonization now used for burning in industry, central heating, etc. could be replaced by coal unsuitable for carbonization or by fuel oil.

(2) Displaced house coal of carbonizable quality could be reserved for coking as is increasingly the practice with the best Durham coking coals.

(3) The gas industry could adopt coal blending on a major scale not only for the new production but also in existing plants and should take a higher proportion of non-graded coal.

Domestic fuel outside the black areas

37. The calls upon the limited quantities of coking and gas coals available are so considerable that the utmost care must be taken not to use them unnecessarily. It may be that there will not be sufficient quantities of these coals to manufacture smokeless fuels for the general replacement of house coal on the lines here proposed throughout the whole country. The use of smokeless fuel outside the black areas should not be discouraged but the black areas should receive priority.

The quality of open-grate coke

38. It is important, as indicated elsewhere in the Committee's Report (paragraphs 78-79) that open-grate coke should have certain free-burning qualities and that there should be an adequate advisory service to the consumer.

Cost of solid smokeless fuel

39. It has been represented that additional cost will be entailed in producing coke having the necessary free-burning quality. Among the reasons given for this are the need for more extensive screening and coke preparation plant, the need for storage in summer and autumn months, changes in manufacturing processes involving additional costs or reduced yields of products, the need to cut additional tonnages of coke, more frequent deliveries in small quantities, higher capital charges on the new plant and the cost of the coke advisory service that would be needed. Consideration of the figures and arguments placed before the Committee suggests that the increased costs of coke production and supply over good standard present-day practice should not be considerable. Nevertheless, there are likely to be increased costs and it is believed with some confidence that domestic consumers will accept some increase in coke prices in return for a superior product that will burn freely and without smoke. Investigations have led to the conclusion that on account of the increased thermal efficiency of coke or, to put it another way, because the same heat service can be secured with less fuel, the annual cost to the householder will be no greater even though the price of coke is increased sufficiently to make the provision of the necessary improved open-grate coke a commercial proposition to the gas industry.

Conclusion

40. It is evident that the supply of smokeless fuels on a sufficient scale to replace the 19 million tons of house coal now used by domestic consumers in the black areas will not be easy, and it will take a number of years. But there is every reason to expect, that in the market conditions created by the extension of smokeless zones and the introduction of smoke control areas, increasing supplies of all types of smokeless fuels will come forward to meet consumers' demands. For many years to come these needs will be met mainly by solid smokeless fuels, and particularly by gas coke. But the possibility of large increases in gas coke supplies depends on the requisite coal supplies being available to the gas undertakings; on the extent to which the gas industry is able by blending or other means to widen the range of coals carbonized; on the enterprise they display in widening their markets for gas; and on the extent to which oil or non-coking coal releases coke now used by other than domestic consumers.

G. E. F.

APPENDIX XII

MEASURES IN OTHER COUNTRIES FOR THE ABATEMENT OF POLLUTION

Memorandum by the Fuel Research Station, Department of Scientific and Industrial Research, and the Chief Alkali Inspector, Ministry of Housing and Local Government.

1. As air pollution arises principally from the use—or rather misuse—of coal. it is not surprising that complaints of pollution by smoke, grit, and sulphur, and efforts to abate the pollution, have occupied public attention for a much longer period in Great Britain than in any other country. Records of complaints and of legislation towards abatement go back to the reign of Edward I in the thirteenth century. Since 1912, following the setting up of an Advisory Committee on Atmospheric Pollution, methods of measurement have been developed and applied at an increasing number of sites in various parts of this country, and research into the various problems, including methods of abatement has been steadily intensified.

2. Though there has been much publicity about the "smog" incidents in the Meuse Valley in Belgium in 1930, in which sixty people lost their lives, and in Donora, Pa., U.S.A., in 1948 when there were twenty deaths, there were no records of the level of pollution in those areas before or during the incidents. As a result of the scheme of measurements in this country, however, useful data are available on levels of pollution in London during the "smog" of December. 1952, for comparison with measurements over many years under more normal meteorological conditions.

3. It is only within the last few decades that really active interest in the problems of abatement of air pollution from fuel consuming equipment and from chemical and other works has been developed in countries other than Great Britain. Some other countries have followed our lead in investigation and research, but interest is not yet so great in other European countries as in this country, and legislative and administrative measures, in general, are not so advanced, in spite of the defects of some of the measures adopted here. In the U.S.A., however, interest and action in many areas have been developed rapidly within the last twenty years with obvious reduction in air pollution, particularly by smoke. It is clear that in general, the same sort of problems present themselves in America as in England and very similar measures are used for control purposes, but it appears that in the U.S.A. there has been more capital expenditure in this direction. It appears also that more attention is paid to local meteorological conditions in regard to the disposal of waste gases. In certain works where sulphur dioxide is a component of the waste gases, the operations are regulated by the ground concentration of sulphur dioxide downwind which is itself a function of local meteorological factors.

4. The United Kingdom is probably the only country in which there exists national legislation especially designed to keep the discharge of noxious and offensive gases from chemical works within tolerable limits. It is of interest, therefore, to consider what legal steps have been taken in recent years in parts of the U.S.A. to abate air pollution, especially in those areas where large quantities of bituminous coal were being used. Air pollution Ordinances in the U.S.A. are usually local for town areas, though a few apply to County areas and even to the whole of a State. In some instances there are Inter-State compacts to improve control, and there is an international compact between the U.S.A. and Canada to cover adjacent areas in the two countries.

5. The American Ordinances are more severe than the general law for the control of smoke pollution in Great Britain in that they restrict the type and quality of the coals that may be used in hand-fired industrial furnaces and in domestic heating appliances. For example, the St. Louis (Mo.) Ordinance forbids the use of solid fuel with a volatile matter content of more than 23 per cent. or of coal below 2″ size if it has an ash content greater than 12 per cent. or a sulphur content greater than 2 per cent. unless the fuels are used in furnaces

of approved design which can burn them smokelessly. The emission of smoke of a density equal to or greater than Ringelmann No. 2 is prohibited, except for a maximum of six minutes in one hour in excess of Ringelmann No. 2 or 9 minutes equal to Ringelmann No. 2 to allow for fires being cleaned or new fires to be started. The emission of fly ash is limited to an equivalent of 0·45 grain per cubic foot. All plans for new fuel-burning plants and plans for the repair or reconstruction of existing plants are subject to the approval of the Smoke Commissioner. In the event of contravention of the regulations, the Smoke Commissioner has power to cause the plant to be shut down. The administration of the Ordinance is controlled by the Smoke Commissioner assisted by a staff of over 20 including 15 inspectors. St. Louis has an area of about 64 square miles and a population of nearly 1 million.

6. There is no doubt that as a result of these activities in St. Louis, which have the strong support of local opinion, air pollution by smoke in that City has been very greatly reduced. It seems that the reduction of grit and dust emissions has not been so great, but the legal restriction of these emissions is not in general particularly stringent.

7. Other examples in the U.S.A. that might be specially mentioned are the Ordinances of Pittsburgh and Allegheny County, which in general follow the same lines as that of St. Louis. In Pittsburgh, however, solid fuel containing more than 20 per cent. of volatile matter must not be used in hand-fired equipment, as compared with 23 per cent. in St. Louis. The staff of the Bureau in Pittsburgh includes 10 inspectors for an area of about 54 square miles and a population of 700,000. Allegheny County, which includes a large steel industry, covers an area of 700 square miles and has a population of 840,000. The Bureau has a total staff of about 12 including 5 or 6 Inspectors. The Ordinance for the County is directed primarily towards the mitigation of pollution from industry and up to 1953 had not been concerned materially with pollution from domestic heating appliances. The limit of volatile matter for solid fuel used in hand-fired equipment is 23 per cent. This Ordinance too is similar to that of St. Louis, but there are a number of exceptions for special processes or industries in relation to smoke emission; and different maximum allowable emissions of grit and dust are prescribed for the several industries.

8. These Ordinances for St. Louis, Pittsburgh, and Allegheny County are typical of most of the local administrative and legislative arrangements which have been made in upwards of 250 cities in the U.S.A. for the mitigation of air pollution. Where such arrangements have been in operation for a few years there has been a marked reduction in pollution by smoke, but reduction in pollution by grit and dust has not been so marked, and the attention given to mitigation of pollution by sulphur and by noxious gases and fumes from chemical and similar works has not been so thorough or systematic as that given by the Alkali Inspectorate in Great Britain. The success achieved in the U.S.A. in reducing pollution by smoke is due to a large extent firstly to the determination of the public that pollution shall be reduced, and secondly to the availability of petroleum and natural gas in large quantities at competitive prices to replace coal for many purposes, and the availability of coals with a low content of volatile matter.

9. The situation in Los Angeles County differs considerably from that in most other parts of the U.S.A. and in this country, in that the area of Los Angeles is subject to frequent temperature inversion, which reduces dispersion and results in the accumulation of pollutants for extended periods. It is believed that under the influence of sunlight, reaction takes place between certain gaseous pollutants with the formation of very finely divided solid particles. The dispersion of such particles in the air has been termed "smog" and it is thought that the condition is principally responsible for plant damage, lachrymation and the personal inconvenience which is experienced so frequently. The potential reactive components are oxides of sulphur and nitrogen, ozone, organic materials, saturated and unsaturated hydrocarbons and the products of their reactions. Much larger quantities of petroleum oils, including motor spirit, are used in relation to the size of population than in almost any other part of the world. Little or no coal is consumed but air pollution is caused by hydrocarbons and other products

from the use of oil and by burning of household and garden refuse, the disposal of which is left to the individual householder.

10. Legislation prohibits the discharge of smoke as dark or darker than Ringelmann No. 2 for more than 3 minutes in one hour. Sulphur compounds may not be discharged in greater concentration than 0·2 per cent. by volume but in spite of this not very rigid requirement, the surphur dioxide content of the Los Angeles atmosphere compares favourably with that of other cities. In the matter of dust emission, the Ordinance provides a scale which varies in proportion to the total weight of raw material used up to a maximum discharge rate of 40 pounds per hour. It must be borne in mind that in Los Angeles no coal is burned, there are no cement factories and, in fact few processes are operated which, by their very nature, are gross emitters of dust.

11. Steam locomotives burning coal in the U.S.A. are normally mechanically fired and improvements have been made in the smokeless preparation of locomotives for service. As a consequence of restrictive Ordinances, research was undertaken to establish means for smoke abatement and this resulted in the development of a system whereby a number of over-fire steam-air injectors are placed on either side of the locomotive fireboxes. These supply additional secondary air and create a useful mixing of air and unburned combustible gases. The system is effective in reducing smoke discharge but, owing to the advent of the diesel locomotive, which, together with electrification, has to a great extent replaced the steam locomotive, the problem is no longer considered to be urgent and research on those lines has been discontinued.

12. In some parts of the U.S.A., great importance is attached to air pollution from diesel-engined road vehicles that may be caused by engines in poor condition. Special road patrols issue warnings and institute prosecutions where necessary.

13. Research in the U.S.A. which has been greatly intensified during the last few years and is now being undertaken on a very wide scale, is now covering such questions as:—precise analyses of gaseous and solid pollutants, investigation of photosyntheses and other reactions that may occur in the atmosphere with the production of harmful substances, the effect of air pollution on plant, animal and human life, the effect of meteorological conditions on the spread of air pollution, the development of improved instruments for measuring air pollution, and the technical aspects of control methods. In these researches the great National Institutes, as well as trade and professional organisations, play an active part. Facilities are excellent, ample accommodation and the most modern apparatus and instruments being available at many of the Research Centres.

14. In conclusion, there is much that can be learned and to some extent followed from the activities in relation to the abatement of air pollution in the U.S.A. It must be emphasized, however, that not all the methods adopted in other countries are usefully applicable in Great Britain owing to important differences in availability of fuel supplies, geographical and meteorological conditions, population density, and heat and power needs. In those countries, for example, with longer spells of really cold weather, houses must be heated as a whole by some system of central heating, whereas individual room heating is generally accepted as sufficient in this country.

APPENDIX XIII

Persons and Organisations with whom the Committee had discussions or from whom they received information or views. In some cases only particular points or aspects of the problem of air pollution were discussed.

The Agricultural Research Council.

The Ministry of Agriculture and Fisheries.

The Association of County Councils in Scotland.

The Association of Municipal Corporations.

Bateman's Stonecleaning Limited.

The Bexleyheath Ratepayers' and Residents' Association.

Birmingham County Borough Council.

C. E. Bowden, Esq., Senior Sanitary Inspector, Bristol County Borough Council.

Bradford County Borough Council.

The British Coal Utilisation Research Association.

The British Coking Industry Association.

The British Cotton Industry Research Association.

The British Electricity Authority.

The British Employers' Confederation.

The British Housewives' League.

The British Internal Combustion Engine Manufacturers' Association.

The British Internal Combustion Engine Research Association.

The British Iron and Steel Research Association.

The British Iron Founders' Association.

The British Medical Association.

The British Non-Ferrous Metals Research Association.

The British Oil Burner Manufacturers' Association.

The British Transport Commission.

The Canadian Pacific Railway Company.

Cardiff County Borough Council.

The Cement Makers' Federation.

The Chalk Farm Tenants' and Residents' Association

The Chamber of Coal Traders.

Charing Cross Hospital.

The Chemical Research Laboratory, Department of Industrial and Scientific Research.

Coalite and Chemical Products Limited.

The Coal Utilisation Council.

The Combustion Engineering Association.

The Commissioner of Police for the Metropolis.

The Convention of Royal Burghs of Scotland.

The Co-operative Union Ltd.

The Domestic Coal Consumers' Council.

Dudley County Borough Council.

The City of Edinburgh.

The Electrical Association for Women.

The Ethical Union.

G. W. Farquharson, Esq., Senior Smoke and Factories Inspector, Birmingham County Borough Council.

The Federation of British Industries.

The Fuel Efficiency Advisory Committee.

The Gas Council and representatives of some of the Gas Boards.

The General Register Office.

Glasgow Corporation.

J. Goodfellow, Esq., Chief Sanitary Inspector, Leeds County Borough Council.

J. Graham, Esq., Chief Sanitary Inspector, Manchester County Borough Council.

Dr. H. Hartley, Messrs. Radiation Ltd.

A. B. Hauldron, Esq., Chief Sanitary Inspector, Borough of Heston and Isleworth.

John T. Haynes, Esq., M.Inst.C.E.

The Ministry of Health.

Professor W. Hobson, B.Sc., M.D., D.P.H., Department of Social and Industrial Medicine, University of Sheffield.

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