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METEOROLOGICAL OFFICE, AIR MINISTRY.

ADVISORY COMMITTEE ON

ATMOSPHERIC POLLUTION

REPORT ON OBSERVATIONS IN THE YEAR ENDING MARCH 31st, 1924.

FORMING THE TENTH REPORT OF THE COMMITTEE FOR THE INVESTIGATION OF ATMOSPHERIC POLLUTION.

Published by the Authority of the Meteorological Committee.

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METEOROLOGICAL OFFICE, AIR MINISTRY.

Advisory Committee on Atmospheric Pollution

REPORT ON OBSERVATIONS IN THE YEAR ENDING MARCH 31, 1924.

Forming the Tenth Report of the Committee for the Investigation of Atmospheric Pollution

CONTENTS.

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INTRODUCTION AND SUMMARY OF THE YEAR'S OPERATIONS.

(1) The Advisory Committee and the Technical Sub-Committee.

During the year the Committee consisted of the following:—

Appointed by the Meteorological Committee.

Sir Napier Shaw, F.R.S. (*Chairman*).
Professor H. B. Baker, F.R.S. (Royal College of Science).
Dr. T. L. Bailey (Chief Alkali Inspector).
Dr. Joseph Cates (Medical Officer of Health, Surrey).
Captain C. J. P. Cave (Past President of the Meteorological Society).
Mr. J. G. Clark (Chemist—Gas Light and Coke Co.).
Professor J. B. Cohen, F.R.S. (Professor of Organic Chemistry of University of Leeds).
Dr. H. A. Des Vœux (Hon. Treasurer, Coal Smoke Abatement Society).
Lieut.-Colonel E. Gold, D.S.O., F.R.S. (Assistant Director, Meteorological Office).
Dr. J. S. Owens, Consulting Engineer (Hon. Secretary).
Sir John Russell, F.R.S. (Director of Rothamsted Experimental Station, Harpenden).
Mr. W. B. Smith (Member of Departmental Committee on Smoke Abatement. Representative of Corporation of Glasgow).
Mr. F. J. W. Whipple (Superintendent, British Rainfall Organization, Meteorological Office).

Appointed by the Department of Scientific and Industrial Research.

Dr. Margaret Fishenden (Fuel Research Board).

Nominated by Co-operating Municipal Authorities.

Dr. John Robertson	Birmingham.
Mr. A. R. Tankard	Kingston-upon-Hull.
Dr. W. Hanna	Liverpool.
Dr. W. J. Howarth	City of London.
Mr. Henry Mills	London County Council.
Mr. W. Osborn Thorp	Malvern.
Professor W. Haldane Gee	Manchester.
Dr. R. W. Simpson	Newcastle-on-Tyne.
Dr. J. B. Wilkinson	Oldham.
Dr. J. R. Ashworth	Rochdale.
Mr. F. Hauxwell	St. Helens.
Mr. J. Baxendell	Southport.
Mr. John Fyfe	Stirling.

The Committee is assisted by a Technical Sub-Committee, which consists of the following:—

Sir Napier Shaw, F.R.S. (*Chairman*)
Mr. J. G. Clark
Dr. J. S. Owens
Sir John Russell, F.R.S.
Mr. F. J. W. Whipple
Professor W. Haldane Gee
Professor H. B. Baker, F.R.S.
} of the Advisory Committee,

together with—

Mr. J. H. Coste (Chief Chemist, London County Council),
Professor J. T. McGregor Morris (East London College and Illuminating Engineering Society),
Mr. L. F. Richardson (Westminster Training College),
Mr. J. W. Walsh (National Physical Laboratory).

The Committee had also the services of Mr. G. M. Watson, B.Sc., A.R.C.S., A.I.C., as Professional Assistant.

Four meetings of the Committee have been held during the year and two of the Technical Sub-Committee.

(2) Acknowledgments of Assistance.

The Committee acknowledge the provisions made by the Meteorological Office, Air Ministry, as in past years, for Mr. Watson's services, and for the incidental expenses of the central establishment of the inquiry in London.

They have also to acknowledge the provision made by Professor H. B. Baker's kind assistance for a laboratory in the Imperial College of Science and Technology, South Kensington, and for the use of the ground for the purpose of the visibility research.

As in previous years all expenses for provision, maintenance and management of gauges, recorders, and other instruments at the stations, the results of which are recorded in this Report, have been borne by the muncipal or local authorities themselves.

The increasing interest displayed by the public in the results obtained by the Committee is recognised. This is evidenced not only by the number of references in the public press, but also by the application of the Committee's methods to inquiries into specific cases of pollution and by the commencement of observations on atmospheric pollution at new centres.

(3) Future Organisation of Inquiry.

In the last *Report* reference was made to the regulations under which the Committee act and the desire on the part of the Committee that an inquiry should be held into the future organisation of the investigation.

Such an inquiry has not been held to date. Negotiations are now on foot and it is hoped that as a result of them the operations of the Committee may be continued.

(4) Results Obtained in the Year 1923–24.

The work for the year ended March 31st, 1924, is referred to in this *Report* under eight sections. Three of them deal with the results obtained by the use of the standard instruments which have already been described; the remaining sections deal with aspects of the subject which are in an experimental stage, as well as particular observations which are of special interest in connection with the study of atmospheric pollution.

Since the publication of the *Ninth Annual Report* several new stations have commenced observations, and there are now in operation in England and Scotland forty-five standard gauges under eighteen authorities, as set forth in the next section. It is to be regretted, however, that only one station has been set up in the open country; that is at Lawes Agricultural Trust, Rothamsted, Harpenden, and while the study of atmospheric pollution is doubtless of greatest interest in cities it would be advantageous if one or two more country stations could be started.

In the last *Report*, tables were given which included the average of the past five years for comparison with the current year. In this *Report*, such averages are omitted, except for places which had not the full five years, and in these cases the five-year average is again included.

In Section 2, the results obtained with the automatic recorder or filter are described, but curves for hourly variation at two new stations only are included as these permit comparison with the curves for other stations published in previous reports, and in addition present certain peculiarities which are of considerable interest.

In considering the results of the automatic recorder, attention must be drawn to the arbitrary division of the days into "Z days" and "ordinary days," which division is based upon the quantity of impurity present. Days having a maximum below Shade 4 or 1·28 milligrammes per cubic metre, are ranked as "ordinary," and those having maximum of Shade 4 or above this limit are ranked as "Z days." It is essential that some such division should be adopted, and provided the basis upon which the division is made is clearly understood the conclusions are not likely to be misinterpreted.

Good progress has been made during the year with the investigation of impurity of the air by means of the jet dust counter. Of special interest is the reference to the presence of organic or mould particles in considerable numbers during the autumn months.

Reports have arrived from some of the foreign countries provided with dust counters by the Meteorological Section of the International Union of Geodesy and Geophysics, the most valuable and complete figures being sent from the United States Weather Bureau at Washington, in connection with which the first systematic observations of dust in the upper air have been made under the superintendence of Dr. H. H. Kimball. These observations are referred to in Section 7.

It is hoped that during the coming year similar observations may be made in England, but it has not been possible to arrange for this during the current year.

Researches bearing upon new methods of inquiry have been carried on, notably that into the transparency of the atmosphere as affected by suspended impurity. Useful results have been obtained by the instruments referred to in the last *Report* under the heading "Researches on the Effect of Atmospheric Pollution upon Visibility."

A new instrument designed by Dr. J. S. Owens for the measurement of coarse dust such as is met with in grain warehouses and similar places is described in Section 6.

The method of measuring water drops in the air, referred to in the last *Report* is still in an experimental stage and progress in this direction has been somewhat slow owing to certain difficulties met with which are being overcome, but chiefly to the lack of sufficient assistance and the amount of other work already in hand.

SECTION 1.—RESULTS OBTAINED BY THE STANDARD GAUGE FOR THE COLLECTION OF DEPOSITED MATTER.

(1) Number of Stations.

The method of measurement of deposit by means of the standard gauge has been fully described in previous reports. Eighteen authorities have taken part in the investigation during the current year, and 45 gauges have been in operation as follows:—

Meteorological Office, London.	2.	One old type standard gauge and one stoneware.
City of London	1.	Old type gauge.
County of London	6.	Old type gauges.
Birmingham	3.	Old type gauges.
Blackburn	2.	Stoneware gauges.
Bournville—Birmingham	1.	Old type gauge.
Glasgow	9.	Old type standard gauges.
Huddersfield	2.	One old type standard gauge and one stoneware.
Kingston-upon-Hull	1.	Old type gauge.
Kingston-upon-Thames	1.	Stoneware gauge.
Leeds	4.	Stoneware gauges.
Liverpool	1.	Old type gauge.
Marple—Cheshire	1.	Stoneware gauge.
Newcastle-on-Tyne	1.	Old type gauge.
Rochdale	2.	One old type standard gauge and one stoneware.
Rothamsted	1.	Stoneware gauge.
St. Helens	1.	Old type gauge.
Salford	3.	Stoneware gauges.
Southport	2.	Stoneware gauges.
Wakefield	1.	Old type gauge.

(2) Stations which have not Complete Returns.

Out of the 45 stations above referred to, 34 have complete results and these are used in the discussion and classification which follows. Eleven stations are not included in the discussion, for the following reasons.

Birmingham—Aston.—In this station, several months' observations are missing; the four-year average is not complete for May and June, while the current year's results omit July and November.

Birmingham, South Western.—The three months of May, June and July are missing for this station, although the 4-year average figures are complete.

Bournville, Birmingham.—This station, which is operated by Messrs. Cadbury Bros., commenced operations in August last. The complete year is therefore not available.

Huddersfield — Cooper Bridge and Deighton.—These stations, which were started by the County

Borough of Huddersfield Sewage Disposal Works, in July, 1923, have therefore three months of the year missing.

Cheshire—Marple.—This station is operated under the County Borough of Salford and commenced operations in September, 1923. There are therefore five months missing.

Rochdale (Stoneware Gauge).—Observations with this gauge were not commenced until July, 1923.

Salford—Mode Wheel.—This station commenced observations in June and has therefore two months missing.

Salford—Regent Square.—The gauge, which was situated previously in Regent Road, was shifted to Regent Square and commenced there in June, so that the months of April and May are missing.

Wakefield.—This is another new station which commenced in January, 1924, so that nine months of the year are missing.

London—Meteorological Office (Stoneware Gauge).—This is the experimental stoneware gauge which was placed upon the roof of the Meteorological Office, and owing to the abnormal conditions it has been thought best to omit the returns from the discussion below.

The gauge has now been shifted to Ravenscourt Park, where it is placed beside one of the old type gauges for comparison.

(3) Classification of Deposit into Groups A, B, C and D.

In the tables of deposit for the different stations the annual mean monthly deposit has been classified into groups A, B, C and D on the basis adopted in previous reports. A table showing the limits of each group was given in the *Ninth Report* and the same limits have been adopted for this year.

The highest monthly deposit for the year for each station is shown in black type in the tables and the lowest in italics. In the figures showing Summer and Winter totals in the tables of mean monthly figures for the year, the highest figure of all the stations is shown in black type and the lowest in italics.

(4) Highest and Lowest Deposit for the General Average and for the Year

In Table 1 the highest and lowest results are given for the year and for the general average.

TABLE 1.—*The Highest and Lowest Results for the General Averages and for the Year* 1923–24.

	General Average.	1923–24.
Most rainfall	Rochdale	Blackburn.
Least rainfall	London — Wandsworth Common.	London—Golden Lane.
Most tar	Newcastle-on-Tyne Liverpool.	Newcastle-on-Tyne.
Least tar	Southport — Hesketh Park.	Leeds—Headingley.
Most carbonaceous.	Newcastle-on-Tyne	Newcastle-on-Tyne.
Least carbonaceous,	Rothamsted	Leeds—Headingley.
Most insoluble ash	Birmingham — Central.	Newcastle-on-Tyne.
Least " "	Rothamsted	Leeds—Headingley.
Most volatile salts	London — Southwark Park.	Glasgow—Blythswood Square. Glasgow — Richmond Park.
Least " "	London — Wandsworth Common.	Leeds—Headingley.
Most soluble ash	St. Helens	Blackburn.
Least " "	Rothamsted	Rothamsted.
Most deposit	Rochdale	Newcastle-on-Tyne.
Least "	Rothamsted	Leeds—Headingley.
Most sulphates	London — Southwark Park.	Liverpool.
Least "	Southport — Hesketh Park.	Leeds—Headingley.
Most chlorine	St. Helens	St. Helens.
Least "	Birmingham — Central.	Kingston-on-Thames.
Most ammonia	London — Golden Lane.	Liverpool.
Least "	Southport — Hesketh Park.	Southport—Hesketh Park.

(5) Comparison of Monthly Values for the Year with the Five Years' Average.

In Table 2 the mean monthly deposit for the current year is compared with the same figure for the 5 years' average.

TABLE 2.—*Comparison of the Mean of the Monthly Deposits for the Current Year with the same figure for the 5 years' average.*

Where the deposit for the current year is higher than the average, it is marked H.

Where the deposit for the current year is lower than the average, it is marked L.

Where the deposit for the current year is equal to the average, it is marked =.

Station	Rainfall.	Insoluble. Tar.	Insoluble. Carbonaceous other than Tar.	Insoluble. Ash.	Soluble. Loss on Ignition.	Soluble. Ash.	Total Solids.	Included in Soluble Matter. Sulphate (SO_3).	Included in Soluble Matter. Chlorine (Cl).	Included in Soluble Matter. Ammonia $(NH)_3$.
London :—										
Golden Lane	L	L	H	H	H	L	H	L	L	L
Meteorological Office	L	H	H	H	L	L	L	L	L	H
Archbishop's Park	H	L	L	L	L	H	L	L	L	=
Finsbury Park	L	L	L	L	L	L	L	L	L	=
Ravenscourt Park	L	L	L	L	L	L	L	L	L	L
London—*cont.*										
Southwark Park	—	L	L	L	L	L	L	L	L	L
Victoria Park	H	L	H	L	L	L	L	L	L	=
Wandsworth Common.	H	L	H	H	L	L	H	L	L	H
Birmingham Central	L	L	L	L	L	L	L	L	L	H
Blackburn Technical College.	H	L	L	L	H	H	H	H	H	H
Kingston-upon-Hull	H	H	L	H	H	L	L	L	H	H
Leeds :—										
Headingley	L	=	L	L	L	L	L	L	L	L
Hunslet	H	L	L	L	H	H	L	H	H	H
Park Square	H	L	L	L	H	L	L	L	H	L
York Road	L	=	H	H	L	H	H	L	H	L
Liverpool	H	L	H	H	H	H	H	L	H	L
Newcastle-on-Tyne	L	H	H	H	L	L	H	H	L	L
Rochdale	L		H		H		H	—	—	—
Rothamsted	H	=	L	H	L	L	L	—	—	—
St. Helens	H	L	H	L	L	L	L	L	L	L
Southport— Hesketh Park	H	=	H	L	L	L	L	L	L	L
Southport— Woodvale Moss	H		L		L		L	—	—	—
Glasgow :—										
Alexandra Park	H	L	L	H	H	L	H	L	H	L
Bellahouston Park	H	L	L	H	H	H	H	L	L	L
Blythswood Square	L	=	L	L	H	L	L	L	=	L
Botanic Gardens	L	L	L	H	H	H	H	L	L	L
Queen's Park	L	L	H	L	H	L	L	L	L	L
Richmond Park	H	L	L	L	H	H	H	L	H	L
Rochill Park	L	L	L	L	H	L	L	L	L	L
Tollcross Park	H	L	L	H	H	H	H	L	L	L
Victoria Park	H	L	H	H	H	L	H	L	L	L

Referring to this table, we can now compare the monthly values for the whole year with the 5 years' average.

Rainfall.—Out of 31 stations the rainfall in the current year was lower than the average in 13 and higher in 17, while in 1 station, that is, London—*Southwark Park*, it was equal to the average.

Tar.—Out of 28 stations the deposit of tar was lower than the average in 21, higher in 3 and equal to the average in 4.

Insoluble Carbonaceous Matter.—Out of 29 stations the deposit for the current year was lower than the average in 18 and higher in 11.

Insoluble Ash.—Out of 29 stations the deposit was lower than the average in 16 and higher in 13.

Soluble Loss on Ignition.—Out of 29 stations this was lower than the average in 14 and higher in 15.

Soluble Ash.—Out of 29 stations the deposit was lower than the average in 20 and higher in 9.

Total Deposit.—Out of 31 stations the deposit was lower than the average in 18 and higher in 13.

Sulphates.—Out of 28 stations the deposit was lower than the average in 25 and higher in 3.

Chlorine.—Out of 28 stations the deposit was lower than the average in 19, higher in 8 and equal to the average in 1.

Ammonia.—Out of 28 stations the deposit was lower than the average in 19, higher in 6 and equal to the average in 3.

The conditions shown in Table 2 are not so favourable as during the previous year; this is seen from the incidence of total deposit, where in last year 23 stations out of 27 showed a deposit below the average, while during the current year only 18 out of 31 showed an improvement. In Table 2, 5 new stations, which include Blackburn and the 4 Leeds stations, are shown, and in these the comparison is made with the previous year since the average figure is not available.

(6) Comparison of Summer and Winter Deposits.

TABLE 3.—*Highest and Lowest Results for the Summer and Winter of the Current Year based on Summer and Winter Totals.*

	General Average.	1923–24
S Most rainfall	Rochdale	Blackburn.
S Least "	London — Wandsworth Common.	London — Golden Lane.
W Most "	Rochdale	Blackburn.
W Least rainfall	London — Wandsworth Common.	Leeds—Headingley.
S Most tar	Liverpool	Newcastle-on-Tyne.
S Least "	Southport — Hesketh Park.	Leeds—Headingley.
W Most "	Newcastle-on-Tyne	Newcastle-on-Tyne.
W Least "	Southport — Hesketh Park.	Leeds—Headingley.
S Most carbonaceous	Birmingham — Central.	Liverpool.
S Least "	Southport — Hesketh Park.	Leeds—Headingley.
W Most "	Newcastle-on-Tyne	Newcastle-on-Tyne.
W Least "	Rothamsted	Leeds—Headingley.
S Most insoluble ash	Birmingham — Central.	Newcastle-on-Tyne.
S Least " "	Southport — Hesketh Park.	Kingston-on-Thames.
W Most " "	Birmingham — Central.	Newcastle-on-Tyne.
W Least " "	Rothamsted	Leeds—Headingley.
S Most volatile salts	Glasgow — Blythswood Square.	Blackburn.

		General Average.	1923–24.
S	Least volatile salts	Rothamsted	Leeds—Headingley.
W	Most ,, ,,	London — Southwark Park.	Glasgow — Richmond Park.
W	Least ,, ,,	London — Wandsworth Common.	Leeds—Headingley.
S	Most soluble ash	St. Helens	Blackburn.
S	Least ,, ,,	Rothamsted	Rothamsted.
W	Most ,, ,,	St. Helens	Blackburn.
W	Least ,, ,,	Rothamsted	Rothamsted.
	Most deposit	Rochdale	Rochdale.
S	Least ,,	Rothamsted	Leeds—Headingley.
W	Most ,,	Birmingham—Central.	Newcastle-on-Tyne.
W	Least ,,	Rothamsted	Leeds—Headingley.
S	Most sulphates	London — Southwark Park.	St. Helens.
S	Least ,,	Southport — Hesketh Park.	Southport — Hesketh Park.
W	Most ,,	London — Southwark Park.	Salford.
W	Least ,,	London — Wandsworth Common.	Leeds—Headingley.
S	Most chlorine	St. Helens	St. Helens.
S	Least ,,	Birmingham—Central.	Kingston-on-Thames.
W	Most ,,	St. Helens	Salford.
W	Least ,,	Birmingham—Central.	Kingston-on-Thames.
S	Most ammonia	London — Golden Lane.	Liverpool.
S	Least ,,	Southport — Hesketh Park.	Southport — Hesketh Park.
W	Most ,,	Liverpool	Blackburn.
W	Least ,,	Southport — Hesketh Park.	Southport—Hesketh Park.

In Table 3 the incidence of deposit in summer and winter is compared, based upon the total for the six months of summer and winter. The letters "S" and "W" in the first column refer respectively to summer and winter and the table indicates the station which gives the highest deposit of each of the elements of pollution in summer and winter respectively.

Table 3 calls for little comment, but attention may be directed to the incidence of total deposit for the current year—the highest for the summer was in Rochdale, and the lowest in Leeds—Headingley, while in winter the greatest deposit was in Newcastle-on-Tyne, the least again at Leeds—Headingley. The greatest total deposit for the five years' average, was also in Rochdale in the summer, but was in Birmingham—Central in the winter, the least being in both cases in Rothamsted. Here again, it must be remembered that Leeds—Headingley, which shows a very low deposit, has not sufficient observations yet to provide a five years' average.

The deposit of tar was greatest in Newcastle-on Tyne in both summer and winter and the least at Leeds—Headingley for both seasons, for the current year.

(7) Incidence of Deposit at Different Stations.

Table 4.—*Comparison of Mean Monthly Deposit for Summer (April–September) and Winter (October–March) of the Current Year.*

Summer deposit greater indicated by S.

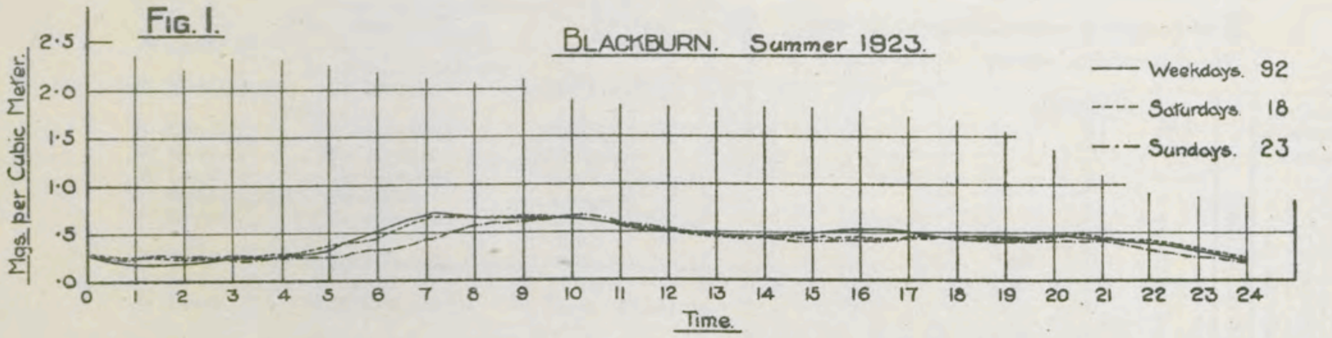
Winter deposit greater indicated by W.

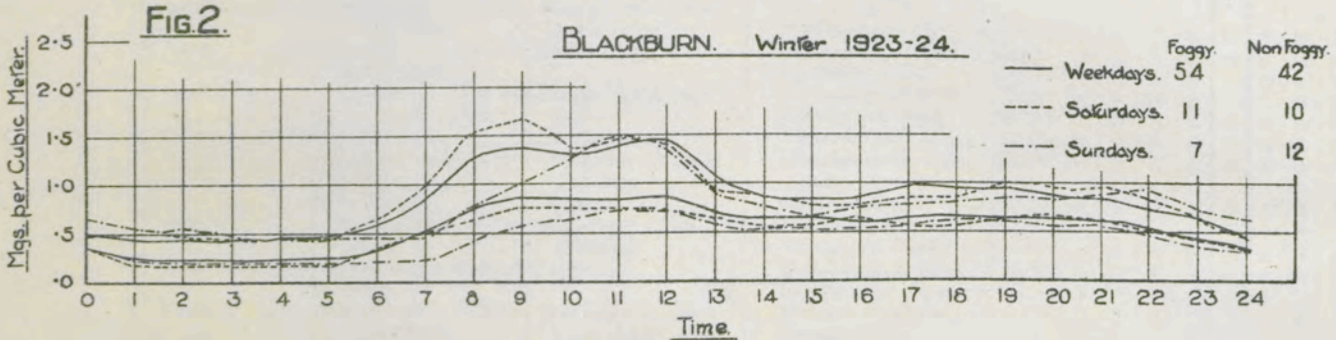
Station.	Rainfall.	Insoluble. Tar.	Insoluble. Carbonaceous other than Tar.	Insoluble. Ash.	Soluble. Loss on Ignition.	Soluble. Ash.	Total Solids.	Included in Soluble Matter. Sulphate (SO_3).	Included in Soluble Matter. Chlorine (Cl).	Included in Soluble Matter. Ammonia (NH_3).
London :—										
Meteorological Office	W	W	S	S	S	W	W	W	W	S
Archbishop's Park	W	W	W	S	W	W	S	W	W	W
Finsbury Park	W	W	W	S	W	W	S	W	W	S
Ravenscourt Park	W	W	W	S	W	W	S	W	W	W
Southwark Park	W	W	W	W	S	S	S	W	W	W
Victora Park	W	W	W	S	W	W	W	W	W	W
Wandsworth Common.	W	W	W	S	W	W	W	W	W	W
Golden Lane	W	W	S	S	W	W	W	W	W	S
Glasgow :—										
Alexandra Park	S	S	S	S	W	W	S	S	S	S
Bellahouston Park	S	W	W	W	W	S	W	S	W	S
Blythswood Square	S	W	S	W	W	S	W	W	W	S
Botanic Gardens	S	S	S	S	W	S	S	S	W	S
Queen's Park	S	S	S	S	W	S	S	S	W	S
Richmond Park	S	S	W	S	W	W	W	W	S	S
Ruchill Park	S	S	S	S	W	W	W	W	W	S
Tollcross Park	S	W	S	S	W	S	S	S	W	S
Victoria Park	S	W	S	S	W	S	W	S	W	S
Birmingham Central	S	S	S	S	W	W	S	S	W	W
Blackburn Technical College.	S	S	S	S	S	S	S	S	W	W
Blackburn Fever Hospital.	W		W		S		S	—	—	—
Kingston-upon-Hull	S	S	W	W	S	W	W	W	W	W
Kingston-on-Thames	W	W	W	W	W	W	W	W	W	W
Leeds :—										
Headingley	S	W	S	S	S	S	S	S	W	S
Hunslet	S	W	W	W	W	W	W	W	W	W
Park Square	S	W	S	S	W	W	S	W	W	W
York Road	S	W	S	S	S	W	S	W	W	S
Liverpool	S	W	S	S	S	W	S	W	W	S
Newcastle-on-Tyne	S	W	W	W	W	W	W	W	W	S
Rochdale (Old Type Gauge).	W		S		S		S	—	—	—
Rothamsted	W	—	S	S	S	W	S	—	—	—
St. Helens	W	S	S	S	S	S	S	S	S	S
Salford County Borough.	W	W	S	W	W	W	W	W	W	S
Southport— Hesketh Park	W	S	W	S	W	W	W	W	W	W
Southport— Woodvale Moss	S		S		W		S	—	—	—

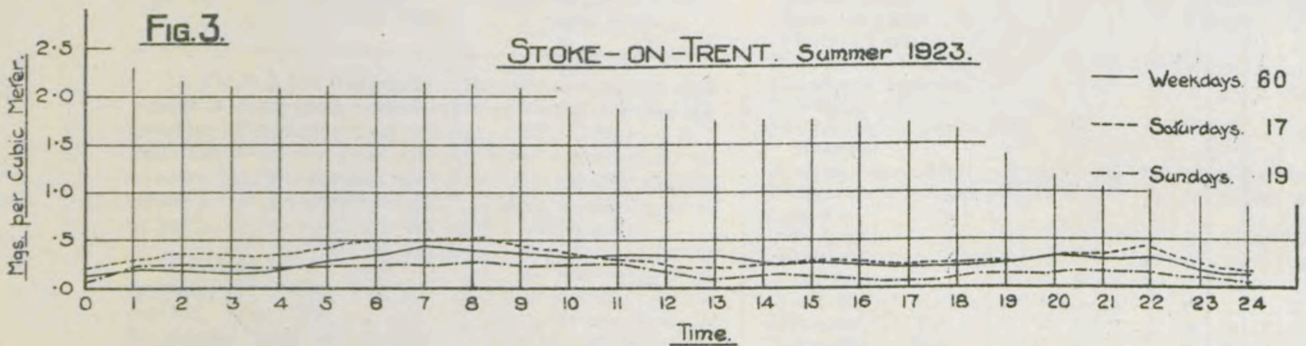
We may now compare the incidence of deposit at the different stations in summer and in winter. Referring to Table 4: *Rainfall.*—Out of 34 stations,

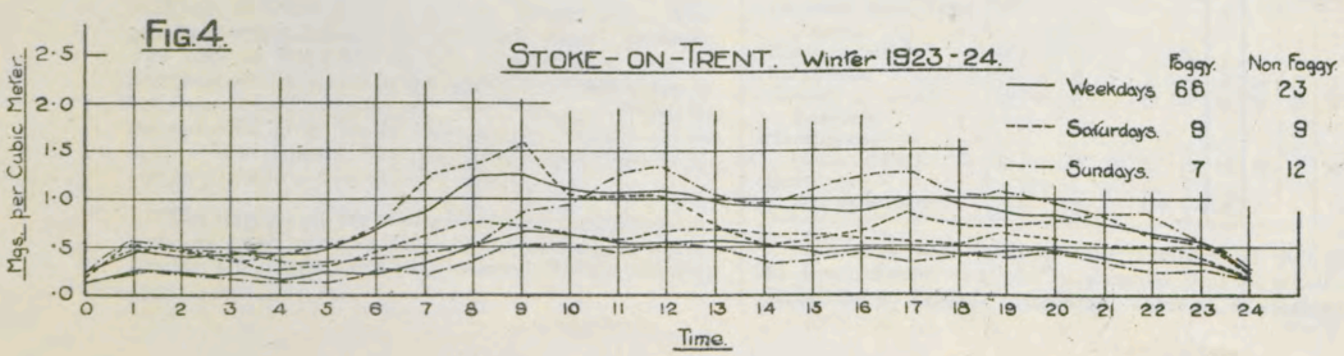
To Face Page 9.

SUSPENDED IMPURITY IN THE AIR









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the winter rainfall was higher in 15 while the summer was higher in 19.

Tar.—Out of 30 stations, the winter deposit of tar was greater in 19, while the summer deposit was greater in 11.

Carbonaceous Matter.—Out of 31 stations, the deposit was greater in winter in 12 and in summer in 19.

Insoluble Ash.—Out of 31 stations the winter deposit was greater in 7 and the summer in 24.

Soluble Loss on Ignition.—Out of 31 stations, the winter deposit was greater in 21 and the summer deposit in 10.

Soluble Ash.—Out of 31 stations, the winter deposit was greater in 20 and the summer in 11.

Total Deposit.—Out of 34 stations the winter deposit was higher in 15 and the summer in 19.

A large amount of insoluble matter, as indicated under "Insoluble Ash" above, is mainly responsible for the preponderance of the summer deposit over the winter.

Sulphates.—Out of 30 stations, the winter deposit was higher in 19 and the summer in 11.

This corresponds with the distribution of the tar and as both tar and sulphates are derived from the combustion of fuel, which is greater in the winter, the incidence of these impurities is such as would be expected.

Chlorine.—Out of 29 stations, the winter deposit was higher in 25, while in 4 only was the deposit higher in summer.

This is somewhat similar to the distribution indicated in last year's *Report* and fits in with the theory that sea-spray is an important source of chlorine.

Ammonia.—Out of 30 stations, in 11 the winter deposit was the higher and in 19 the summer deposit.

As pointed out in previous Reports, the figures for ammonia cannot be taken as very accurate, owing to the long time during which the water collected remains in the bottles before the analysis.

(8) Stoneware Gauge.

In the table showing the number of stations at work, the type of gauge used is indicated opposite the station, and it will be noted that ten stoneware gauges are now in operation, including the experimental gauge used by the Committee for comparison with the standard.

(9) Positions of Gauges.

In previous annual reports maps have been included showing the positions of the deposit gauges in a number of localities. Since this was done, additional stations for observations with the deposit gauge, generally the new pattern with stoneware collecting vessel, have been established.

In addition several automatic filters are now in regular use, as referred to in Section 2 of this *Report.*

SECTION 2.—RESULTS OBTAINED WITH AUTOMATIC FILTER.

(1) Instruments in Use.

In addition to the ten instruments mentioned in the *Ninth Report*, two new instruments have been put in operation, one in Stoke-on-Trent and one in Blackburn.

The records have been dealt with on similar lines to the *Eighth* and *Ninth Reports*. A somewhat arbitrary division into days of much smoke haze, called "Z" days, and "Ordinary" days has been made. Days in which the smoke haze was not at any time abnormally thick are designated "ordinary" days, and those in which, probably owing to the prevailing atmospheric conditions, the smoke haze was at some time very thick, as "Z" days.

As stated previously, the limit dividing the two was fixed at days having a maximum impurity at any time equal to or over 1·28 milligrammes per cubic metre—equivalent to Shade 4 of the standard scale of shades.

Again, the days of the week have been divided into weekdays, excluding Saturdays, referred to throughout as "weekdays," Saturdays and Sundays, for the reasons stated in previous reports.

It has not been thought necessary to show again curves of distribution of impurity for stations such as London and Glasgow, the distribution of which has already been examined in previous reports. The results of the two new stations, Stoke and Blackburn, above referred to, have been plotted so as to bring out the hourly distribution for the summer and winter periods. It will, therefore, be of interest to examine the distribution in these towns and compare it with that for other places.

(2) Results for Blackburn and Stoke-on-Trent.

Blackburn.—On referring to the curves for Blackburn, Figs. 1 and 2, it will be noted that these are plotted from the results of a considerable number of days in all cases, so that the distribution indicated can be regarded as fairly representative.

Records are available for 269 days out of the year, about 100 days being lost owing to various causes. Of this number, 133 days are in the summer, that is, between April and September, while 136 are in the winter. Before examining the graphs in Figs. 1 and 2 it is of interest to note that of the 136 winter days, 72 ranked as "Z" days, and 64 as "ordinary." In other words, on the available data, 53 per cent. of the winter days were "Z" days, giving Shade 4, or 1·28 milligrammes per cubic metre or more, while 47 per cent. were "ordinary."

Referring to the curves :—The hourly distribution is broadly similar to that found in other cities, such as Glasgow and London. There is the same rapid increase in impurity rising to a maximum in the forenoon. There is then a gradual tendency to fall,

(*Continued on page 27.*)

1923–24. LONDON.	Rain-fall.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).								
		Insoluble Matter.			Soluble Matter.			Included in Soluble Matter.		
		Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition.	Ash.	Total Solids.	Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
METEOROLOGICAL OFFICE. (Soot Gauge.)										
April	37	19	286	469	126	305	1,205	99	58	6
May	55	21	281	456	171	370	1,299	110	74	11
June	*11*	*8*	*79*	233	62	*135*	*517*	*36*	37	*3*
July	75	27	248	**540**	179	420	1,414	124	**124**	**15**
August	32	16	**369**	380	130	195	1,090	63	46	6
September	33	12	85	311	*55*	145	608	66	47	7
October	**134**	**31**	287	496	119	427	1,360	156	107	11
November	34	14	179	323	114	223	853	92	*36*	6
December	53	19	167	413	127	372	1,098	127	94	8
January	70	26	309	451	**181**	**559**	**1,526**	**256**	93	13
February	11	13	147	337	81	158	736	52	51	3
March	12	*8*	111	*153*	81	208	561	68	60	4
Mean Monthly	47	18 C	212 B	380 B	119 B	293 B	1,022 B	104	69	8
Summer Total	243	103	1,348	2,389	723	1,570	6,133	498	386	48
Winter Total	314	111	1,200	2,173	703	1,947	6,134	751	441	45
Annual Total	557	214	2,548	4,562	1,426	3,517	12,267	1,249	827	93
METEOROLOGICAL OFFICE. (Stoneware Gauge.)										
April	40	12	163	509	160	309	1,153	118	58	8
May	60	6	102	517	119	293	1,037	92	54	9
June	12	6	86	321	29	54	496	20	27	2
July	88	7	143	598	194	390	1,332	119	72	15
August	33	13	95	370	131	147	756	61	50	5
September	33	24	56	326	5	137	548	49	31	5
October	67	8	133	396	159	187	883	83	43	7
November	17	12	159	300	85	190	746	39	53	7
December	50	6	155	334	179	293	967	138	66	5
January	61	16	361	566	257	356	1,556	177	82	9
February	11	6	136	285	94	203	724	86	Trace	Trace
March	15	11	225	499	84	203	1,022	79	,,	,,
Mean Monthly	41	11 B	151 B	418 B	125 B	230 B	935 B	88	45	6
Summer Total	266	68	645	2,641	638	1,330	5,322	459	292	44
Winter Total	221	59	1,169	2,380	858	1,432	5,898	602	244	28
Annual Total	487	127	1,814	5,021	1,496	2,762	11,220	1,061	536	72
FINSBURY PARK.										
April	37	14	113	443	59	224	853	69	39	5
May	49	8	**213**	480	76	277	1,054	90	43	7
June	*10*	4	71	221	*37*	123	456	41	*21*	3
July	65	7	160	**534**	143	288	**1,132**	68	57	**13**
August	45	6	90	197	181	137	611	80	36	8
September	27	4	77	167	69	186	503	61	33	*2*
October	**125**	11	202	363	63	**387**	1,026	134	**83**	15
November	35	11	141	329	84	212	777	91	42	3
December	54	**16**	182	345	108	306	957	126	52	6
January	73	8	163	234	**219**	297	921	**139**	51	8
February	13	4	121	299	47	*111*	582	*45*	25	3
March	16	*1*	*29*	*44*	59	133	*266*	64	23	2
Mean Monthly	46	8 B	130 B	305 B	95 B	223 B	761 B	84	42	6
Summer Total	233	43	724	2,042	565	1,235	4,609	409	229	38
Winter Total	316	51	838	1,614	580	1,446	4,529	599	276	37
Annual Total	549	94	1,562	3,656	1,145	2,681	9,138	1,008	505	75

LONDON. ARCHBISHOP'S PARK.	Rainfall.		Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).																		
			Insoluble Matter.						Soluble Matter.				Total Solids.		Included in Soluble Matter.					
			Tar.		Carbon-aceous other than Tar.		Ash.		Loss on Ignition.		Ash.				Sulphates (SO_3).		Chlorine (Cl).		Ammonia (NH_3).	
1920–24	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923 24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.
April	51	34	21	8	409	184	**1,017**	**1,418**	**179**	137	338	296	**1,964**	**2,043**	179	133	63	35	13	10
May	30	52	12	9	241	189	385	220	134	**150**	268	401	1,040	969	105	163	59	49	10	15
June	*17*	*12*	*8*	*3*	152	75	409	491	109	56	245	*165*	923	790	*52*	*68*	67	*26*	*6*	7
July	**63**	74	13	9	305	239	506	410	*91*	95	302	392	1,217	1,145	99	116	**76**	54	11	13
August	41	39	11	14	*147*	*35*	264	202	165	78	*212*	273	799	602	99	118	57	51	9	12
September	52	25	13	4	230	117	468	180	105	49	*212*	200	1,028	550	110	87	61	28	13	7
October	43	**107**	12	**26**	**437**	**466**	345	779	153	149	**389**	**453**	1,335	1,873	170	187	59	58	13	**19**
November	33	35	14	8	221	161	343	219	157	119	351	314	1,085	821	165	119	55	48	15	9
December	49	50	**29**	14	290	244	375	285	**179**	141	337	344	1,210	1,028	**181**	**192**	67	**63**	**17**	15
January	51	71	9	10	165	258	*197*	289	131	120	271	336	*774*	1,013	146	173	*49*	57	15	15
February	37	16	12	10	219	156	403	193	95	86	337	211	1,066	656	150	106	*49*	36	9	*6*
March	33	15	10	6	212	101	266	*116*	115	*25*	265	220	869	*468*	136	121	58	54	8	11
Mean Monthly	42	44	14 B	10 B	252 B	185 B	415 B	400 B	134 B	100 B	294 B	301 B	1,109 B	996 B	133	132	60	47	12	12
Summer Total	254	236	78	47	1,484	839	3,049	2,921	783	565	1,577	1,727	6,971	6,099	644	685	383	243	62	64
Winter Total	246	294	86	74	1,544	1,386	1,929	1,881	830	640	1,950	1,878	6,339	5,859	948	898	337	316	77	75
Annual Total	500	530	164	121	3,028	2,225	4,978	4,802	1,613	1,205	3,527	3,605	13,310	11,958	1,592	1,583	720	559	139	139

1923–24. LONDON. RAVENSCOURT PARK.	Rain-fall.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).								
		Insoluble Matter.			Soluble Matter.		Total Solids.	Included in Soluble Matter.		
		Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition.	Ash.		Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
April	33	9	181	698	69	221	1,178	76	36	6
May	51	8	167	345	92	268	880	*10*	43	10
June	*8*	*2*	66	190	*28*	*99*	*385*	36	*13*	*3*
July	69	12	**198**	**804**	103	319	**1,436**	87	43	10
August	40	9	86	300	120	240	755	123	31	11
September	31	8	*62*	*175*	40	143	428	57	24	7
October	**125**	8	114	254	124	**327**	827	111	**66**	12
November	34	**28**	143	365	75	194	805	82	39	9
December	54	12	126	327	123	217	805	107	42	8
January	64	8	158	229	**134**	321	850	**129**	47	**13**
February	11	9	121	333	66	137	666	59	31	4
March	20	13	119	333	67	139	671	56	35	5
Mean Monthly	45	11 B	128 B	363 B	86 B	219 B	807 B	78	37	8
Summer Total	232	48	760	2,512	452	1,290	5,062	389	190	47
Winter Total	308	78	781	1,841	589	1,335	4,624	544	260	51
Annual Total	540	126	1,541	4,353	1,041	2,625	9,686	933	450	98
SOUTHWARK PARK.										
April	34	5	229	499	95	190	1,018	76	41	5
May	44	11	315	473	160	249	1,208	119	56	13
June	*12*	6	193	416	*38*	149	802	*51*	26	5
July	69	5	183	427	124	306	1,045	83	57	12
August	40	4	263*	—*	**363**	480	847	66	36	6
September	26	8	153	290	64	**685**	1,200	79	36	10
October	**112**	9	261	471	134	293	1,168	123	65	**15**
November	40	7	160	223	72	194	656	84	49	7
December	48	11	**352**	**923**	135	243	**1,664**	104	**70**	11
January	65	**21**	333	465	90	286	1,195	**124**	58	12
February	16	*1*	146	275	69	*132*	*623*	60	36	*4*
March	16	5	184	294	79	167	729	91	*25*	5
Mean Monthly	43	8 B	228† B	432† B	119 B	281 B	1,013 B	88	46	9
Summer Total	225	39	1,073	2,105	844	2,059	6,120	474	252	51
Winter Total	297	54	1,436	2,651	579	1,315	6,035	586	303	54
Annual Total	522	93	2,509	4,756	1,423	3,374	12,155	1,060	555	105
WANDSWORTH COMMON.										
April	34	5	185	372	68	193	823	57	41	7
May	53	4	142	301	79	272	798	92	66	9
June	*8*	*3*	176	**503**	*30*	*86*	798	*30*	*21*	*3*
July	66	5	179	458	59	277	978	94	59	10
August	43	5	293*	—*	128	171	*304*	70	38	7
September	30	*3*	101	395	60	127	686	**204**	26	5
October	**122**	4	92	258	84	258	696	108	**68**	10
November	34	4	69	106	75	191	445	71	37	4
December	49	**12**	**267**	427	69	299	1,074	104	65	9
January	75	6	167	304	**186**	**420**	**1,083**	189	61	7
February	10	*3*	165	468	49	97	782	34	28	**23**
March	12	5	117	241	53	110	526	42	31	*3*
Mean Monthly	45	5 B	151† B	348† B	78 B	208 B	749 B	91	45	8
Summer Total	234	25	783	2,029	424	1,126	4,387	547	251	41
Winter Total	302	34	877	1,804	516	1,375	4,606	548	290	56
Annual Total	536	59	1,660	3,833	940	2,501	8,993	1,095	541	97

* Ash lost—returned with combustible matter. † August omitted.

1923–24. LONDON. VICTORIA PARK.	Rain-fall.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).								
		Insoluble Matter.			Soluble Matter.		Total Solids.	Included in Soluble Matter.		
		Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition.	Ash.		Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
April	35	4	122	324	69	230	749	86	33	*4*
May	50	2	137	395	75	278	887	92	47	11
June	*12*	*1*	*87*	230	58	128	*504*	*51*	*20*	*4*
July	54	5	117	344	120	319	905	109	46	10
August	56	9	96	258	139	223	725	99	43	12
September	29	5	106	253	99	173	636	77	37	8
October	**126**	7	166	300	**163**	**416**	**1,052**	**153**	**104**	13
November	37	**10**	186	**429**	92	207	924	90	47	8
December	51	9	**224**	352	132	317	1,034	145	56	7
January	67	5	159	*202*	107	197	670	114	55	**15**
February	15	3	119	245	68	158	593	72	30	*4*
March	14	6	139	247	*40*	*79*	511	70	31	*4*
Mean Monthly	45	6 B	138 B	298 B	97 B	227 B	766 B	97	46	8
Summer Total	236	26	665	1,804	560	1,351	4,406	514	226	49
Winter Total	310	40	993	1,775	602	1,374	4,784	644	323	51
Annual Total	546	66	1,658	3,579	1,162	2,725	9,190	1,158	549	100
GOLDEN LANE.										
April	34	5	246	383	121	282	1,037	120	55	23
May	32	**9**	600	790	256	435	2,090	268	77	32
June	*10*	3	224	350	109	*176*	862	*84*	29	*7*
July	66	3	269	428	265	423	1,388	178	94	37
August	27	5	480	684	165	361	1,695	192	64	27
September	20	*2*	191	304	160	263	920	136	*4*	13
October	**105**	7	**623**	**832**	**421**	**969**	**2,852**	**505**	**104**	**42**
November	34	*2*	*105*	*189*	232	286	*814*	136	60	*7*
December	51	4	253	350	*101*	365	1,073	167	76	18
January	78	7	358	449	345	471	1,630	259	103	31
February	15	8	299	527	129	310	1,273	138	60	14
March	15	7	263	386	140	243	1,039	103	58	11
Mean Monthly	*41*	5 B	326 C	472 B	204 B	382 B	1,389 B	191	65	**22**
Summer Total	*189*	27	2,010	2,939	1,076	1,940	7,992	978	323	139
Winter Total	298	35	1,901	2,733	1,368	2,644	8,681	1,308	461	123
Annual Total	487	62	3,911	5,672	2,444	4,584	16,673	2,286	784	262
GLASGOW. ALEXANDRA PARK.										
April	75	10	93	205	127	141	*576*	115	46	16
May	53	5	132	269	118	217	741	99	88	13
June	22	**24**	162	499	87	*110*	882	*46*	75	8
July	86	17	**650**	**2,003**	*81*	385	**3,136**	**178**	136	**26**
August	**137**	*1*	82	223	256	**595**	1,157	168	97	10
September	110	12	117	269	159	333	890	124	121	23
October	91	3	64	175	399	553	1,194	150	**168**	14
November	66	23	165	269	301	471	1,229	139	83	7
December	69	8	95	*126*	**482**	339	1,050	109	66	10
January	73	6	104	217	375	165	867	157	44	11
February	*13*	10	159	239	86	127	621	50	*28*	*3*
March	15	3	*27*	261	102	202	595	55	67	4
Mean Monthly	67	10 B	154 B	396 B	215 B	303 B	1,078 B	116	85	12
Summer Total	483	69	1,236	3,468	828	1,781	7,382	730	563	96
Winter Total	327	53	614	1,287	1,745	1,857	5,556	660	456	49
Annual Total	810	122	1,850	4,755	2,573	3,638	12,938	1,390	1,019	145

Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).

1923–24. GLASGOW. Bellahouston Park.	Rain-fall.	Insoluble Matter. Tar.	Insoluble Matter. Carbon-aceous other than Tar.	Insoluble Matter. Ash.	Soluble Matter. Loss on Ignition.	Soluble Matter. Ash.	Total Solids	Included in Soluble Matter. Sul-phates (SO_3).	Included in Soluble Matter. Chlor-ine (Cl).	Included in Soluble Matter. Am-monia (NH_3).
April	76	9	90	242	200	230	771	177	34	17
May	50	4	87	237	109	269	706	92	47	9
June	32	18	95	283	97	144	637	95	30	7
July	74	9	114	277	206	627	1,233	180	55	15
August	142	5	99	241	362	657	1,364	140	84	8
September	137	4	69	199	246	359	877	155	68	16
October	107	7	59	184	375	527	1,152	178	123	25
November	75	6	104	342	295	720	1,467	115	106	10
December	76	5	106	178	614	555	1,458	152	49	11
January	88	29	113	205	338	37	722	173	49	7
February	13	3	111	186	52	137	489	50	18	3
March	18	14	139	394	136	185	868	83	26	4
Mean Monthly	74	9 B	99 A	247 B	253 C	371 B	979 B	133	57	11
Summer Total	511	49	554	1,479	1,220	2,286	5,588	839	318	72
Winter Total	377	64	632	1,489	1,810	2,161	6,156	751	371	60
Annual Total	888	113	1,186	2,968	3,030	4,447	11,744	1,590	689	132

Blythswood Square.	Rain-fall.	Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition.	Ash.	Total Solids	Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
April	31	18	155	383	212	294	1,062	204	63	20
May	52	8	153	368	170	269	968	108	57	18
June*	—	—	—	—	—	—	—	—	—	—
July	88	11	450	556	361	626	2,004	224	70	37
August	136	5	89	145	260	374	873	128	62	6
September	134	14	256	236	153	472	1,131	213	111	28
October	105	18	131	274	389	369	1,181	162	169	21
November	75	33	170	266	301	446	1,216	213	117	9
December	73	12	107	107	700	345	1,271	231	69	14
January	85	28	199	360	626	279	1,492	268	64	17
February	16	9	289	474	133	152	1,057	70	29	4
March	12	16	201	429	161	191	998	118	57	8
Mean Monthly	73	16 C	200 B	327 B	315 C	347 B	1,205 B	176	78	16
Summer Total	441	56	1,103	1,688	1,156	2,035	6,038	877	363	109
Winter Total	366	116	1,097	1,910	2,310	1,782	7,215	1062	505	73
Annual Total	807	172	2,200	3,598	3,466	3,817	13,253	1,939	868	182

Botanic Gardens.	Rain-fall.	Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition.	Ash.	Total Solids	Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
April	68	61	538	1,302	275	490	2,666	319	29	17
May	56	9	171	488	72	252	992	129	59	6
June	24	8	125	404	84	143	764	84	25	5
July	92	2	101	420	253	642	1,418	228	48	14
August	131	3	85	285	204	561	1,138	147	74	2
September	132	7	67	185	204	374	837	166	73	17
October	112	9	92	261	452	566	1,380	171	123	9
November	73	9	104	333	235	478	1,159	136	118	6
December	74	3	79	172	623	769	1,646	180	56	7
January†	—	—	—	—	—	—	—	—	—	—
February	15	7	2	9	102	164	284	78	22	2
March	17	2	111	275	73	165	626	115	24	3
Mean Monthly	72	11 B	134 B	376 B	234 C	419 B	1,174 B	159	59	8
Summer Total	503	90	1,087	3,084	1,092	2,462	7,815	1,073	308	61
Winter Total	291	30	388	1,050	1,485	2,142	5,095	680	343	27
Annual Total	794	120	1,475	4,134	2,577	4,604	12,910	1,753	651	88

* Carboy tampered with. † Carboy broken.

Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).

1923–24. GLASGOW. Queen's Park.	Rain-fall.	Insoluble Matter. Tar.	Insoluble Matter. Carbon-aceous other than Tar.	Insoluble Matter. Ash.	Soluble Matter. Loss on Ignition	Soluble Matter. Ash.	Total Solids.	Included in Soluble Matter. Sul-phates (SO_3).	Included in Soluble Matter. Chlor-ine (Cl).	Included in Soluble Matter. Am-monia (NH_3).
April	79	15	91	283	82	193	664	136	25	15
May	52	4	89	250	99	218	660	71	47	5
June	29	4	338	211	55	100	708	47	36	4
July	75	13	113	234	101	387	848	130	41	17
August	125	15	114	309	209	368	1,015	124	45	4
September	131	19	173	215	212	320	939	117	65	24
October	109	4	42	119	253	404	822	121	82	11
November	73	8	55	148	234	372	817	85	105	7
December	78	3	63	116	469	330	981	133	54	11
January	87	4	71	153	328	82	638	126	74	9
February	13	11	83	130	63	84	371	43	18	1
March	23	13	310	406	96	114	939	76	26	5
Mean Monthly	73	9 B	129 B	214 B	192 B	248 B	792 B	101	51	9
Summer Total	491	70	918	1,502	758	1,586	4,834	625	259	69
Winter Total	383	43	624	1,072	1,443	1,386	4,568	584	359	44
Annual Total	874	113	1,542	2,574	2,201	2,972	9,402	1,209	618	113

Richmond Park.	Rain-fall.	Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition	Ash.	Total Solids.	Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
April	77	18	161	412	134	162	887	132	28	20
May	51	10	152	400	116	221	899	128	59	10
June	27	13	127	297	75	69	581	53	34	8
July	84	7	84	314	194	531	1,130	140	73	17
August	133	23	215	544	547	1,158	2,487	217	289	3
September	137	14	230	456	217	305	1,222	212	90	29
October	100	11	180	318	384	369	1,262	165	140	22
November	66	11	115	315	258	439	1,138	170	102	4
December	78	18	161	304	1,263	1,245	2,991	192	66	9
January	79	14	246	582	346	214	1,402	243	43	24
February	15	7	96	138	115	117	473	74	21	6
March	16	11	236	639	132	213	1,231	62	23	8
Mean Monthly	72	13 B	167 B	393 B	315 C	420 B	1,308 B	149	81	13
Summer Total	509	85	969	2,423	1,283	2,446	7,206	882	573	87
Winter Total	354	72	1,034	2,296	2,498	2,597	8,497	906	395	73
Annual Total	863	157	2,003	4,719	3,781	5,043	15,703	1,788	968	160

Ruchill Park.	Rain-fall.	Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition	Ash.	Total Solids.	Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
April	36	11	86	193	213	220	723	148	28	19
May	61	9	98	194	123	221	645	90	65	5
June	21	15	128	219	61	104	527	64	31	5
July	98	5	368	316	126	384	1,199	134	80	17
August	136	10	138	146	226	463	983	112	62	4
September	126	12	71	126	91	296	596	141	82	23
October	139	9	78	167	514	533	1,301	218	152	13
November	77	8	96	149	381	454	1,088	128	104	9
December	78	10	75	116	490	146	837	136	62	10
January	99	10	95	117	216	277	715	136	50	7
February	21	13	97	202	56	199	567	68	29	3
March	20	8	94	295	74	146	617	62	23	4
Mean Monthly	76	10 B	119 B	187 A	214 B	287 B	817 B	120	64	10
Summer Total	478	62	889	1,194	840	1,688	4,673	689	348	73
Winter Total	434	58	535	1,046	1,731	1,755	5,125	748	420	46
Annual Total	912	120	1,424	2,240	2,571	3,443	9,798	1,437	768	119

1923–24. GLASGOW. TOLLCROSS PARK.	Rain-fall.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).								
		Insoluble Matter.			Soluble Matter.		Total Solids.	Included in Soluble Matter.		
		Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition.	Ash.		Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
April	70	8	73	225	203	197	706	136	*8*	18
May	57	11	107	336	241	548	1,243	263	54	9
June	26	12	**359**	336	*61*	176	944	88	30	7
July	88	8	216	**1,266**	234	**810**	**2,534**	184	59	15
August	**143**	*5*	97	381	390	637	1,510	189	58	6
September	123	9	147	414	209	428	1,207	203	71	**23**
October	104	6	81	240	486	604	1,417	**267**	**129**	15
November	71	**23**	77	263	300	366	1,029	132	103	11
December	74	10	171	328	**1,074**	620	2,203	128	52	7
January	78	8	98	269	138	201	714	143	39	7
February	*16*	6	*67*	*121*	90	124	*408*	76	22	*3*
March	*16*	10	173	446	90	*101*	820	*58*	18	4
Mean Monthly	72	10 B	139 B	385 B	293 C	401 B	1,228 B	156	54	10
Summer Total	507	53	999	2,958	1,338	2,796	8,144	1,063	280	78
Winter Total	359	63	667	1,667	2,178	2,016	6,591	804	363	47
Annual Total	866	116	1,666	4,625	3,516	4,812	14,735	1,867	643	125
VICTORIA PARK.										
April	88	6	**333**	193	259	485	1,276	**192**	18	18
May	53	3	106	226	100	261	696	97	52	12
June	20	*1*	60	344	*62*	*106*	*573*	*63*	*19*	7
July	68	16	234	387	114	433	1,184	158	39	17
August	**138**	13	111	489	182	484	1,279	127	59	10
September	137	13	163	251	176	**586**	1,189	152	76	**30**
October	102	11	225	289	**453**	508	**1,486**	178	**158**	22
November	71	13	119	293	449	499	1373	177	131	6
December	81	3	*55*	*96*	374	461	989	102	60	10
January	87	2	85	178	237	188	690	155	43	10
February	*18*	13	133	302	88	161	697	66	24	4
March	20	**26**	241	**585**	124	127	1,103	69	25	*1*
Mean Monthly	74	10 B	155 B	303 B	218 B	358 B	1,044 B	128	59	12
Summer Total	504	52	1,007	1,890	893	2,355	6,197	789	263	94
Winter Total	379	68	858	1,743	1,725	1,944	6,338	747	441	53
Annual Total	883	120	1,865	3,633	2,618	4,299	12,535	1,536	704	147
BIRMINGHAM. BOURNVILLE.										
April	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—
June	—	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	—	—	—	—
August	72	10	124	372	116	145	767	·29	22	4
September	77	10	97	299	139	262	807	92	46	2
October	94	8	67	145	169	206	595	64	51	2
November	54	7	55	103	108	155	428	46	46	2
December	81	7	196	191	108	166	668	43	38	2
January	70	8	176	129	101	162	576	38	36	2
February	18	5	121	103	103	128	460	33	32	1
March	29	6	76	140	139	119	480	36	33	1
Mean Monthly	62	8 B	114 B	185 A	123 B	168 B	598 B	48	38	2
Summer Total	149	20	221	671	255	407	1,574	121	68	6
Winter Total	346	41	691	811	728	936	3,207	260	236	10
Annual Total	495	61	912	1,482	983	1,343	4,781	381	304	16

BIRMINGHAM. *ASTON.	Rainfall.		Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).																	
			Insoluble Matter.						Soluble Matter.				Total Solids.		Included in Soluble Matter.					
			Tar.		Carbon-aceous other than Tar.		Ash.		Loss on Ignition.		Ash.				Sulphates (SO_3).		Chlorine (Cl).		Ammonia (NH_3).	
	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.
April	64	58	10	9	187	198	635	700	98	70	331	363	1,261	1,340	133	133	31	22	6	5
May	—	40	—	9	—	172	—	746	—	59	—	230	—	1,216	—	112	—	17	—	5
June	—	117	—	5	—	551	—	110	—	49	—	119	—	834	—	61	—	15	—	2
July	94	—	10	—	282	—	1,074	—	160	—	358	—	1,884	—	190	—	38	—	6	—
August	43	53	13	14	244	228	941	934	105	106	265	289	1,568	1,571	122	129	17	19	4	3
September	54	61	8	7	220	201	486	531	96	104	309	352	1,119	1,195	122	111	17	19	5	6
October	50	78	7	8	138	172	435	468	101	126	270	339	951	1,113	123	132	19	23	7	15
November	27	—	35	—	182	—	392	—	83	—	236	—	928	—	124	—	16	—	4	—
December	65	66	7	8	168	146	353	255	105	104	274	323	907	836	147	132	29	23	4	5
January	54	58	9	9	149	216	389	472	99	115	273	320	919	1,132	123	128	26	19	5	5
February	49	14	9	7	161	85	441	239	87	73	233	134	931	538	111	56	21	21	3	1
March	34	18	12	8	179	154	577	396	85	58	208	138	1,061	754	101	60	21	15	3	1
Mean Monthly	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Summer Total	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Winter Total	279	234	79	40	977	773	2,587	1,830	560	476	1,494	1,254	5,697	4,373	729	508	132	101	26	27
Annual Total	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CENTRAL.																				
April	75	58	17	15	331	376	892	**948**	135	117	400	336	1,775	**1,792**	198	161	50	54	11	9
May	42	42	14	14	392	350	**1,151**	771	133	121	417	316	**2,107**	1,572	185	163	60	24	**21**	10
June	58	83	21	**29**	349	313	961	916	126	*85*	318	220	1,775	1,563	176	91	55	26	16	*3*
July	**601**	**129**	13	13	372	249	933	563	152	153	445	390	1,915	1,368	217	176	53	52	15	13
August	8	52	14	18	358	302	903	847	136	158	387	**462**	1,798	1,787	176	**200**	30	40	9	12
September	50	70	19	14	351	*163*	1,009	537	155	119	413	317	1,947	1,150	211	136	*28*	28	11	14
October	49	86	14	12	**396**	230	1,075	700	161	**212**	394	427	2,040	1,581	202	183	34	41	9	12
November	45	47	14	12	325	281	772	700	146	146	410	412	1,666	1,551	219	174	37	43	19	**64**
December	98	71	**23**	13	392	**466**	743	*244*	**186**	147	**570**	398	1,914	1,268	**289**	166	**65**	51	12	14
January	59	61	*12*	*11*	307	321	791	601	163	146	437	392	1,710	1,471	230	157	44	44	7	10
February	68	*15*	15	14	*269*	218	*695*	576	128	96	387	231	*1,494*	1,135	207	93	45	47	7	5
March	*27*	21	13	12	302	179	801	487	*117*	94	*298*	*191*	1,531	*963*	*143*	*71*	39	43	*5*	4
Mean Monthly	62	61	16 C	15 C	345 C	287 B	894 C	657 C	145 B	133 B	406 B	341 B	1,806 C	1,433 B	204	148	45	41	12	14
Summer Total	402	434	98	103	2,153	1,753	5,849	4,582	837	753	2,380	2,041	11,317	9,232	1,163	927	276	224	83	61
Winter Total	346	301	91	74	1,991	1,695	4,877	3,308	901	841	2,496	2,051	10,355	7,969	1,290	844	264	269	59	109
Annual Total	748	735	189	177	4,144	3,448	10,726	7,890	1,738	1,594	4,876	4,092	21,672	17,201	2,453	1,771	540	493	142	170

* No returns made for May and June for the four years from which average is obtained.

BIRMINGHAM. South-Western.	Rainfall.		Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres). Insoluble Matter. Tar.		Carbonaceous other than Tar.		Ash.		Soluble Matter. Loss on Ignition.		Ash.		Total Solids.		Included in Soluble Matter. Sulphates (SO_3).		Chlorine (Cl).		Ammonia (NH_3).	
	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.
April	72	65	3	4	79	68	247	246	79	38	248	186	656	542	125	119	18	3	6	3
May	49	—	3	—	103	—	**303**	—	71	—	203	—	683	—	79	—	11	—	7	—
June	64	—	*2*	—	83	—	222	—	97	—	243	—	647	—	132	—	*6*	—	9	—
July	**117**	—	*2*	—	**113**	—	228	—	**99**	—	**353**	—	**795**	—	**179**	—	**25**	—	**11**	—
August	84	63	4	**5**	69	68	103	194	97	103	260	250	533	620	99	103	13	24	7	5
September	52	68	3	*3*	51	28	118	140	62	61	195	235	429	467	79	109	9	8	4	4
October	52	**81**	3	4	47	17	123	112	65	80	177	203	415	416	69	74	16	12	3	2
November	*31*	—	4	—	67	—	139	—	*38*	—	*143*	—	391	—	69	—	11	—	*2*	—
December	70	73	**5**	4	44	47	86	121	56	50	195	186	386	408	97	88	19	22	3	2
January	64	64	3	*3*	*30*	34	*79*	102	60	54	164	144	*335*	337	*64*	63	15	8	3	2
February	54	*21*	4	4	46	53	136	145	58	67	165	85	409	354	71	47	12	18	3	1
March	38	23	**5**	5	67	70	243	224	71	35	169	146	556	470	67	41	11	8	*2*	1
Mean Monthly	62	—	3 A	—	67 A	—	169 A	—	71 A	—	210 B	—	520 B	—	94	—	14	—	5	—
Summer Total	438	—	17	—	498	—	1,221	—	505	—	1,502	—	3,743	—	693	—	82	—	44	—
Winter Total	309	262	24	20	301	221	806	704	348	286	1,013	754	2,492	1,985	437	313	84	68	16	8
Annual Total	747	—	41	—	799	—	2,027	—	853	—	2,515	—	6,235	—	1,130	—	166	—	60	—
BLACKBURN. Technical College.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.
April	71	60	32	34	310	431	662	636	161	381	332	526	1,497	2,008	152	*43*	104	*23*	12	*2*
May	43	106	33	25	611	**440**	**1,766**	1,211	112	202	266	686	**2,788**	2,564	117	147	58	41	18	9
June	83	33	25	28	522	369	1,587	752	133	249	350	532	2,617	1,930	152	144	94	41	27	6
July	123	139	*15*	**42**	**634**	272	910	975	194	263	282	113	2,035	2,665	101	187	**117**	39	7	5
August	149	**167**	**38**	*9*	397	334	913	**1,422**	191	**451**	336	1,231	1,875	**3,447**	195	**199**	110	106	10	7
September	87	142	27	24	*222*	419	380	684	*102*	304	223	**1,260**	*954*	2,691	107	127	62	100	8	9
October	*17*	129	29	16	272	337	*368*	590	153	412	*155*	949	977	2,304	*74*	143	*24*	**116**	*4*	11
November	79	164	34	15	381	258	600	*287*	201	211	400	557	1,616	1,328	85	143	73	96	**31**	12
December	137	162	28	20	312	250	512	511	332	279	**765**	469	1,949	1,529	137	153	81	105	11	7
January	94	83	21	16	368	219	523	482	135	343	297	599	1,344	1,659	76	163	33	82	*4*	10
February	**154**	*29*	22	13	301	*192*	407	453	**340**	255	580	*409*	1,650	*1,322*	84	151	54	75	15	8
March	33	55	26	16	235	348	409	488	164	*183*	384	487	1,218	1,522	**241**	48	60	79	5	**77**
Mean Monthly	89	**106**	28 C	22 C	380 C	322 C	753 C	708 C	185 B	294 C	364 B	**735** C	1710 C	2,081 C	127	137	72	75	13	14
Summer Total	556	**647**	170	162	2,696	2,265	6,218	5,680	893	**1,850**	1,789	**5,348**	11,766	15,305	824	847	545	350	82	38
Winter Total	514	**622**	160	96	1,869	1,604	2,819	2,811	1,325	1,683	2,581	**3,470**	8,754	9,664	697	801	325	553	70	**125**
Annual Total	1,070	1,269	330	258	4,565	3,869	9,037	8,491	2,218	3,533	4,370	8,818	20,520	24,969	1,521	1,648	870	903	152	163

BLACKBURN. (Fever Hospital). 1922–23.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres). Rainfall. 1922–23.	1923–24.	Insoluble Matter. 1922–23.	1923–24.	Soluble Matter. 1922–23.	1923–24.	Total Solids. 1922–23.	1923–24.
April	—	71	—	320	—	367	—	687
May	—	109	—	191	—	651	—	842
June	95	*36*	316	196	443	498	759	694
July	—	124	—	212	—	461	—	673
August	—	73	—	194	—	299	—	493
September	116	164	190	**538**	434	**1,000**	624	**1,538**
October	19	**224**	178	326	218	831	396	1,157
November	115	138	230	341	605	*152*	835	493
December	—	156	—	205	—	273	—	478
January	—	96	—	211	—	332	—	543
February	136	38	211	438	448	482	659	920
March	25	41	206	*150*	374	224	580	*374*
Mean Monthly	—	106	—	277	—	464	—	741
Summer Total	—	577	—	1,651	—	3,276	—	4,927
Winter Total	—	693	—	1,671	—	2,294	—	3,965
Annual Total	—	1,270	—	3,322	—	5,570	—	8,892

1923–24. HUDDERSFIELD. Cooper Bridge. (Old Type Gauge).	Rainfall.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres). Insoluble Matter. Tar.	Carbonaceous other than Tar.	Ash.	Soluble Matter. Loss on Ignition.	Ash.	Total Solids.	Included in Soluble Matter. Sulphates (SO_3).	Chlorine (Cl).	Ammonia (NH_3).
April	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—
June	—	—	—	—	—	—	—	—	—	—
July	72	8	73	175	156	462	874	219	42	14
August	54	8	50	76	316	425	875	215	50	33
September	42	2	49	87	296	270	704	185	23	27
October	48	4	113	173	527	503	1,320	389	20	68
November	66	1	51	205	264	476	997	249	66	33
December	46	4	78	135	321	367	905	187	42	15
January	36	6	48	132	161	278	625	132	40	14
February	13	6	70	107	157	208	548	100	43	14
March	26	8	113	173	214	240	748	146	41	21
Mean Monthly	45	5 B	72 A	140 A	268 C	359 B	844 B	202	41	27
Summer Total	168	18	172	338	768	1,157	2,453	619	115	74
Winter Total	235	29	473	925	1,644	2,072	5,143	1,203	252	165
Annual Total	403	47	645	1,263	2,412	3,229	7,596	1,822	367	239
Deighton. (New Type Gauge.)										
April	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—
June	—	—	—	—	—	—	—	—	—	—
July	106	10	186	256	126	223	801	68	55	6
August	68	10	112	256	141	130	649	61	35	4
September	51	5	95	126	59	108	393	44	24	5
October	65	8	208	242	169	221	848	85	15	7
November	125	1	269	517	332	436	1,555	86	119	10
December	59	6	118	333	450	182	1,089	142	42	10
January	60	6	117	216	173	222	734	66	55	15
February	35	6	146	341	132	348	973	97	83	17
March	26	14	57	169	99	225	564	71	28	8
Mean Monthly	66	7 B	145 B	273 B	187 B	233 B	845 B	80	51	9
Summer Total	225	25	393	638	326	461	1,843	173	114	15
Winter Total	370	41	915	1,818	1,355	1,634	5,763	547	342	67
Annual Total	595	66	1,308	2,456	1,681	2,095	7,606	720	456	82

1923–24.	Rain-fall.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).								
		Insoluble Matter.			Soluble Matter.		Total Solids.	Included in Soluble Matter.		
		Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition.	Ash.		Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
KINGSTON-UPON-HULL.										
April	41	13	233	438	149	367	1,200	151	76	13
May	89	22	294	544	250	457	1,567	211	108	18
June	10	5	145	391	142	277	960	110	54	4
July	69	11	283	614	240	462	1,610	219	83	14
August	69	13	209	364	241	360	1,187	168	115	12
September	76	18	161	307	198	384	1,068	212	84	12
October	33	9	189	326	176	465	1,165	197	80	10
November	66	22	318	661	265	606	1,872	280	132	18
December	77	15	213	312	177	303	1,020	211	109	18
January	47	11	282	344	179	297	1,113	158	77	13
February	27	12	272	574	222	530	1,610	207	118	14
March	21	7	292	587	184	350	1,420	170	67	9
Mean Monthly	52	13 B	241 B	455 B	202 B	405 B	1,316 B	191	92	13
Summer Total	354	82	1,325	2,658	1,220	2,307	7,592	1,071	520	73
Winter Total	271	76	1,566	2,804	1,203	2,551	8,200	1,223	583	82
Annual Total	625	158	2,891	5,462	2,423	4,858	15,792	2,294	1,103	155
KINGSTON-UPON-THAMES.										
April	43	16	20	236	77	114	463	37	19	6
May	78	7	77	133	187	232	636	110	54	14
June	9	3	21	24	40	73	161	31	11	3
July	112	4	20	118	134	202	478	73	19	4
August	50	6	34	79	100	141	360	46	36	4
September	11	4	7	26	106	109	252	49	24	4
October	136	9	54	77	110	166	416	47	37	6
November	52	10	56	96	137	290	589	183	53	7
December	64	9	73	157	129	191	559	70	21	7
January	84	20	152	157	117	402	848	123	46	13
February	22	21	117	305	100	189	732	86	24	6
March	31	19	130	344	139	220	852	94	31	6
Mean Monthly	58	11 B	63 A	146 A	115 B	194 B	529 B	79	31	7
Summer Total	303	40	179	616	644	871	2,350	346	163	35
Winter Total	389	88	582	1,136	732	1,458	3,996	603	212	45
Annual Total	692	128	761	1,752	1,376	2,329	6,346	949	375	80
CHESHIRE. MARPLE.										
April	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—
June	—	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	—	—	—	—
August	—	—	—	—	—	—	—	—	—	—
September	117	6	53	21	409	161	650	191	59	8
October	111	8	103	6	132	124	373	91	88	3
November	81	9	92	120	147	217	585	358	98	3
December	106	—	76	47	191	138	452	138	73	4
January	92	6	53	26	191	156	432	—	47	3
February	26	15	94	212	53	153	527	64	64	3
March	21	6	44	221	67	138	476	65	62	5
Mean Monthly	—	—	—	—	—	—	—	—	—	—
Summer Total	—	—	—	—	—	—	—	—	—	—
Winter Total	437	44	462	632	781	926	2,845	716	432	22
Annual Total	—	—	—	—	—	—	—	—	—	—

	Rainfall.		Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).																	
			Insoluble Matter.						Soluble Matter.				Total Solids.		Included in Soluble Matter.					
			Tar.		Carbon-aceous other than Tar.		Ash.		Loss on Ignition.		Ash.				Sulphates (SO_3).		Chlorine (Cl).		Ammonia (NH_3).	
	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	2 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.
LEEDS. HEADINGLEY.																				
April	—	60	—	Trace	—	22	—	47	—	60	—	133	—	262	—	33	—	24	—	4
May	—	75	—	0	—	34	—	48	—	30	—	120	—	232	—	62	—	45	—	6
June	41	16	9	0	103	5	66	15	122	13	272	82	572	115	87	28	41	16	4	1
July	96	92	1	2	26	44	90	27	134	111	153	111	404	295	118	63	19	3	29	0
August	95	66	3	4	83	80	73	43	76	92	191	171	426	390	170	54	19	53	12	18
September	64	59	5	2	78	27	69	40	63	106	115	97	330	272	137	69	25	59	3	4
October	24	57	4	3	16	40	44	42	27	79	105	114	241	278	44	43	33	57	2	4
November	29	—	1	—	16	—	19	—	41	—	122	—	199	—	50	—	35	—	3	—
December	82	57	1	3	8	27	18	20	82	80	131	137	240	267	57	37	41	46	4	5
January	33	44	1	3	11	22	19	38	46	96	93	131	170	290	31	45	46	53	1	3
February	91	17	0	2	23	14	53	31	127	62	91	116	294	225	64	28	55	45	3	1
March	27	31	1	7	34	14	86	56	49	86	148	93	318	256	56	45	44	37	2	3
Mean Monthly	58	52	2 A	2 A	40 A	30 A	54 A	37 A	81 B	74 A	142 A	119 A	319 A	262 A	81	46	36	40	6	4
Summer Total	296	368	18	8	290	212	298	220	395	412	731	714	1,732	1,566	512	309	104	200	48	33
Winter Total	286	206	8	18	108	117	239	187	417	403	690	591	1,462	1,316	302	198	254	238	15	16
Annual Total	582	574	26	26	398	329	537	407	812	815	1,421	1,305	3,194	2,882	814	507	358	438	63	49
LEEDS. HUNSLET.																				
April	50	65	50	16	281	268	1,123	883	231	207	652	621	2,337	1,995	285	262	110	91	12	15
May	0	76	41	5	382	182	1,170	383	99	212	398	575	2,090	1,357	90	208	77	121	8	15
June	36	18	32	3	66	120	714	297	180	77	352	179	1,344	676	138	61	62	44	5	5
July	84	97	5	8	241	250	842	690	151	136	370	312	1,609	1,396	147	140	67	58	21	2
August	106	72	12	1	252	229	781	565	170	87	382	231	1,597	1,113	160	109	74	7	25	10
September	60	49	17	1	199	52	633	151	109	107	350	213	1,308	524	124	110	60	7	9	8
October	20	48	17	7	215	187	490	429	108	145	275	222	1,105	990	129	89	56	87	7	5
November	30	61	17	2	133	217	216	340	102	132	174	452	642	1,143	74	192	54	140	10	78
December	80	78	21	14	154	185	256	370	176	251	208	424	815	1,244	121	223	95	102	13	18
January	25	52	18	13	106	198	195	662	66	258	163	754	548	1,885	58	354	66	93	4	4
February	87	21	4	13	362	237	1,064	630	87	107	542	248	2,059	1,235	208	74	87	85	5	5
March	21	31	10	13	241	217	668	612	97	288	323	683	1,339	1,813	76	353	50	113	7	13
Mean Monthly	50	56	20 C	8 B	219 B	195 B	679 C	501 B	132 B	167 B	349 B	410 B	1,399 B	1,281 B	151	181	71	79	10	15
Summer Total	336	377	157	34	1,421	1,101	5,263	2,969	940	826	2,504	2,131	10,285	7,061	1,144	890	450	328	80	55
Winter Total	263	291	87	62	1,211	1,241	2,889	3,043	636	1,181	1,685	2,783	6,508	8,310	666	1,285	408	620	46	123
Annual Total	599	668	244	96	2,632	2,342	8,152	6,012	1,576	2,007	4,189	4,914	16,793	15,371	1,810	2,175	858	948	126	178

Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).

LEEDS. PARK SQUARE.	Rainfall.		Insoluble Matter. Tar.		Carbonaceous other than Tar.		Ash.		Soluble Matter. Loss on Ignition.		Ash.		Total Solids.		Included in Soluble Matter. Sulphates (SO_3).		Chlorine (Cl).		Ammonia (NH_3).	
	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.	1 yr. aver.	1923–24.
April	50	61	23	8	165	135	538	431	149	122	328	196	1,203	892	**153**	87	79	37	4	*0*
May	*0*	75	27	11	204	**214**	**1,042**	**787**	86	**150**	193	**361**	**1,552**	**1,523**	95	155	*35*	60	3	8
June	41	*16*	**46**	4	**229**	138	376	305	155	65	**357**	*127*	1,163	*639*	132	*22*	73	39	4	2
July	92	**105**	21	6	202	151	598	422	92	84	311	316	1,224	979	104	103	73	63	9	5
August	**112**	57	10	*2*	188	151	483	397	**179**	*34*	291	194	1,151	778	104	74	56	68	8	6
September	60	58	7	*2*	150	201	402	525	96	58	179	231	834	1,017	86	75	60	35	5	1
October	21	53	8	4	187	207	349	387	83	106	184	232	811	936	*57*	85	56	95	*2*	5
November	31	72	15	4	146	114	262	355	131	172	*157*	301	711	946	71	113	63	136	3	5
December	83	73	11	**15**	138	138	482	461	83	146	334	219	1,048	979	131	**196**	100	**161**	4	**9**
January	33	46	8	12	*81*	125	*242*	*285*	85	111	196	268	*612*	801	61	106	81	97	3	3
February	90	22	11	14	220	142	600	422	90	132	289	202	1,210	912	143	53	**108**	81	**18**	3
March	21	30	*4*	10	111	*71*	321	338	*42*	126	188	258	666	803	60	111	50	*15*	2	3
Mean Monthly	53	56	16 C	8 B	168 B	149 B	475 B	426 B	106 B	109 B	251 B	242 B	1,016 B	934 B	100	98	70	74	5	4
Summer Total	355	372	134	33	1,138	990	3,439	2,867	757	513	1,659	1,425	7,127	5,828	674	516	376	302	33	22
Winter Total	279	296	57	59	883	797	2,256	2,248	514	793	1,348	1,480	5,058	5,377	523	664	458	585	32	28
Annual Total	634	668	191	92	2,021	1,787	5,695	5,115	1,271	1,306	3,007	2,905	12,185	11,205	1,197	1,180	834	887	65	50
LEEDS. YORK ROAD.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.	1922–23.	1923–24.
April	—	53	—	12	—	216	—	443	—	86	—	246	—	1,003	—	99	—	64	—	11
May	—	**78**	—	4	—	210	—	370	—	**574**	—	248	—	**1,406**	—	58	—	92	—	14
June	—	*14*	—	6	—	129	—	258	—	63	—	125	—	*581*	—	53	—	31	—	*2*
July	89	68	12	3	222	**273**	474	397	143	81	286	*122*	1,137	876	107	56	54	54	4	**15**
August	103	64	16	*1*	199	153	403	302	328	77	154	193	1,100	726	137	102	82	*4*	12	6
September	60	54	13	2	148	256	439	245	360	54	132	195	1,092	752	144	89	60	87	11	4
October	22	49	22	11	175	157	267	380	94	109	170	228	728	885	64	**290**	71	89	6	10
November	31	—	5	—	194	—	249	—	79	—	195	—	722	—	73	—	55	—	6	—
December	81	74	11	**21**	186	199	329	284	210	177	340	296	1,076	977	167	91	97	**96**	9	5
January	30	47	7	14	149	*122*	267	*203*	101	161	227	**304**	751	804	80	*19*	77	76	2	4
February	89	20	7	15	156	191	218	**537**	124	114	231	236	736	1,093	116	73	89	79	35	3
March	22	29	8	18	161	133	279	281	109	*41*	203	152	760	625	45	83	56	58	9	8
Mean Monthly	53	50	10 B	10 B	159 B	185 B	292 B	336 B	155 B	140 B	194 B	213 B	810 B	884 B	93	92	64	66	10	7
Summer Total	252	331	41	28	569	1,237	1,316	2,015	831	935	572	1,129	3,329	5,344	388	457	196	332	27	52
Winter Total	275	219	60	79	1,021	802	1,609	1,685	717	602	1,366	1,216	4,773	4,384	545	556	445	398	77	30
Annual Total	527	550	101	107	1,590	2,039	2,925	3,700	1,548	1,537	1,938	2,345	8,102	9,728	933	1,013	641	730	104	82

Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).

1923–24. NEWCASTLE-ON-TYNE.	Rainfall.	Insoluble Matter. Tar.	Carbonaceous other than Tar.	Ash.	Soluble Matter. Loss on Ignition.	Ash.	Total Solids.	Included in Soluble Matter. Sulphates (SO_3).	Chlorine (Cl).	Ammonia (NH_3).
April	58	28	502	993	208	383	2,114	153	58	9
May	60	40	500	946	**215**	334	2,035	201	55	9
June	24	33	*306*	794	*57*	229	1,419	*98*	*22*	*4*
July	40	66	726	1,556	137	442	2,927	211	46	**14**
August	91	21	376	796	164	400	1,757	206	45	13
September	35	49	521	822	91	259	1,742	130	27	6
October	48	153	1,003	1,153	125	394	2,828	221	44	8
November*	**96**	**295**	**5,106**	**2,755**	192	**826**	**9,174**	**369**	**99**	**14**
December*	60	56	1,833	1,991	**215**	477	4,572	293	40	11
January	47	79	458	639	168	374	1,718	191	43	8
February	27	67	1,022	1,439	169	322	3,019	150	26	5
March	*23*	*18*	424	*565*	103	*177*	*1,287*	*98*	*22*	*4*
Mean Monthly	51	**75** D	**1,065** D	**1,204** D	153 B	386 B	**2,883** D	193	44	9
Summer Total	308	237	2,931	5,907	872	2,047	11,994	999	253	55
Winter Total	301	**668**	**9,846**	**8,542**	972	2,570	**22,598**	1,322	274	50
Annual Total	609	905	12,777	14,449	1,844	4,617	34,592	2,321	527	105

Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).

ROCHDALE (Old Type Gauge.)	†Rainfall.		Insoluble Matter.		Soluble Matter.		Total Solids.	
1916–17 } 1920–24 }	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.
April	87	105	2,378	2,143	847	778	3,225	2,921
May	76	109	2,654	2,761	726	**1,230**	3,380	3,991
June	42	*33*	2,765	2,710	477	324	3,242	3,034
July	109	130	2,603	**4,294**	787	768	3,390	**5,062**
August	91	151	2,104	2,697	596	458	2,700	3,155
September	70	127	1,880	2,385	691	578	2,571	2,963
October	106	159	1,567	1,646	860	907	2,427	2,553
November	74	184	1,155	—	709	—	1,864	—
December	108	121	1,376	1,196	82	460	1,458	1,656
January	117	97	1,310	1,258	683	549	1,993	1,807
February	79	40	1,104 }	3,014 (Feb.–Mar.)	{ 528 }	854 (Feb.–Mar.)	{ 1,632 }	3,868 (Feb.–Mar.)
March	67	44	1,504 }		{ 492 }		{ 1,996 }	
Mean Monthly	85	108	1,867	2,191	623	628	2,490	2,819
Summer Total	475	655	14,384	16,990	4,124	4,136	18,508	**21,126**
Winter Total	551	645	8,016	7,114	3,354	2,770	11,370	9,884
Annual Total	1,026	1,300	22,399	24,104	7,479	6,906	29,878	31,010
(Stoneware Gauge.)								
April	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—
June	—	—	—	—	—	—	—	—
July	—	—	2,603	3,514	787	314	3,390	3,828
August	—	—	2,104	2,235	596	395	2,700	2,630
September	—	—	1,880	1,603	691	606	2,571	2,209
October	—	—	1,567	1,103	820	588	2,387	1,691
November	—	—	1,155	1,024	709	734	1,864	1,758
December	—	—	1,376	—	82	—	1,458	—
January	—	—	1,310	843	683	400	1,993	1,243
February	—	—	1,104	1,280	528	475	1,632	1,755
March	—	—	1,504	—	492	—	1,996	1,263
Mean Monthly	—	—	—	—	—	—	—	—
Summer Total	—	—	6,587	7,352	2,074	1,315	8,661	8,667
Winter Total	—	—	—	—	—	—	—	—
Annual Total	—	—	—	—	—	—	—	—

* Abnormal pollution caused by factories in neighbourhood.
† From range gauge.

LIVERPOOL.	Rainfall.		Insoluble Matter. Tar.		Carbonaceous other than Tar.		Ash.		Soluble Matter. Loss on Ignition.		Ash.		Total Solids.		Included in Soluble Matter. Sulphates (SO_3).		Chlorine (Cl).		Ammonia (NH_3).	
	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.
April	41	61	20	21	441	553	1,186	1,322	232	158	355	364	2,235	2,418	193	169	61	60	14	13
May	57	97	17	30	448	700	1,248	1,817	226	390	421	623	2,360	3,560	225	281	66	81	18	25
June	29	16	17	9	423	531	1,177	1,342	146	153	286	322	2,049	2,357	148	150	50	59	14	13
July	84	82	74	19	341	315	854	613	276	212	441	376	1,986	1,535	252	185	69	58	30	49
August	96	83	15	18	314	364	734	850	237	396	501	446	1,801	2,074	280	235	64	82	24	25
September	70	88	14	20	348	310	570	530	257	247	337	371	1,525	1,478	198	182	81	106	21	28
October	58	104	15	23	453	333	603	501	232	249	370	498	1,673	1,604	212	232	66	103	18	27
November	68	92	28	49	340	560	779	1,190	287	367	430	570	1,864	2,736	227	227	129	222	21	27
December	120	117	32	34	350	314	666	438	358	282	615	658	2,021	1,726	304	290	152	133	27	26
January	77	64	22	26	275	335	644	611	258	191	471	345	1,669	1,508	237	182	118	59	66	12
February	50	16	23	23	318	461	742	1,116	207	150	451	313	1,741	2,063	219	141	97	69	8	8
March	41	30	22	12	532	590	1,412	1,537	198	235	425	361	2,589	2,735	207	177	71	68	10	11
Mean Monthly	66	71	25 D	24 C	382 C	447 C	885 C	989 C	243 C	252 C	425 B	437 B	1,960 C	2,149 C	225	204	85	92	23	22
Summer Total	377	427	157	117	2,315	2,773	5,769	6,474	1,374	1,556	2,341	2,502	11956	13,422	1,296	1,202	391	446	121	153
Winter Total	414	423	142	167	2,268	2,593	4,846	5,393	1,540	1,474	2,762	2,745	11,557	12,372	1,406	1,249	633	654	150	111
Annual Total	791	850	299	284	4,583	5,366	10,615	11,867	2,914	3,030	5,103	5,247	23,513	25,794	2,702	2,451	1,024	1,100	271	264
ROTHAMSTED.*	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.	4 yr. aver.	1923–24.
April	42	37	—	—	63	38	87	103	168	50	103	89	421	280	—	—	—	—	—	—
May	37	40	—	—	85	52	107	70	92	87	91	35	375	244	—	—	—	—	—	—
June	22	14	—	—	82	82	137	226	64	62	98	50	381	420	—	—	—	—	—	—
July	81	96	—	—	77	141	133	200	187	249	141	102	538	692	—	—	—	—	—	—
August	46	55	—	—	75	57	84	74	79	43	105	20	343	194	—	—	—	—	—	—
September	59	62	—	—	54	68	62	53	151	197	114	73	381	391	—	—	—	—	—	—
October	48	117	—	—	48	31	77	26	84	45	128	33	337	135	—	—	—	—	—	—
November	42	35	—	—	32	8	73	29	78	33	205	77	388	147	—	—	—	—	—	—
December	61	73	—	—	50	42	95	88	114	189	169	132	427	451	—	—	—	—	—	—
January	53	67	—	—	27	37	62	116	121	161	150	121	360	435	—	—	—	—	—	—
February	41	11	—	—	52	38	103	122	91	27	181	75	427	262	—	—	—	—	—	—
March	41	23	—	—	42	47	75	93	121	85	192	27	431	252	—	—	—	—	—	—
Mean Monthly	48	53	—	—	57 A	53 A	91 A	100 A	113 B	102 B	140 A	70 A	401 A	325 A	—	—	—	—	—	—
Summer Total	287	304	—	—	436	438	610	726	741	688	652	369	2,439	2,221	—	—	—	—	—	—
Winter Total	286	326	—	—	251	203	485	474	609	540	1,025	465	2,370	1,682	—	—	—	—	—	—
Annual Total	573	630	—	—	687	641	1,095	1,200	1,350	1,228	1,677	834	4,809	3,903	—	—	—	—	—	—

* Figures unreliable—gauge cracked.

1923–24.	Rainfall.	Insoluble Matter. Tar.	Carbonaceous other than Tar.	Ash.	Soluble Matter. Loss on Ignition.	Ash.	Total Solids.	Included in Soluble Matter. Sulphates (SO_3).	Chlorine (Cl).	Ammonia (NH_3).
ST. HELEN'S.										
April	75	29	333	618	168	337	1,485	146	97	4
May	82	58	741	1,011	185	592	2,587	243	173	12
June	16	4	51	168	63	177	463	64	61	1
July	75	32	146	591	360	1,190	2,319	512	278	30
August	90	11	197	465	315	496	1,484	155	126	9
September	81	30	303	468	182	669	1,652	295	142	6
October	108	27	582	889	189	405	2,092	193	133	8
November	105	2	23	71	247	383	726	159	147	7
December	135	12	321	389	203	371	1,296	251	115	8
January	75	6	183	212	187	244	832	162	97	15
February	24	8	225	322	120	168	843	86	60	5
March	32	12	216	362	82	181	853	88	57	4
Mean Monthly	75	19 C	277 B	464 B	192 B	434 B	1,386 B	196	124	9
Summer Total	419	164	1,771	3,321	1,273	3,461	9,990	1,415	877	62
Winter Total	479	67	1,550	2,245	1,028	1,752	6,642	939	609	47
Annual Total	898	231	3,321	5,566	2,301	5,213	16,632	2,354	1,486	109
SALFORD. County Borough.										
April	66	18	287	451	159	251	1,166	105	66	5
May	98	32	404	549	380	333	1,698	202	117	7
June	17	18	351	461	77	203	1,110	89	48	5
July	103	37	380	506	184	184	1,291	125	92	7
August*	—	—	—	—	—	—	—	—	—	—
September	93	30	408	572	187	316	1,513	261	214	11
October	113	37	354	539	316	351	1,597	338	146	3
November	112	21	345	423	213	383	1,385	224	179	4
December	101	24	291	419	332	344	1,410	298	132	6
January	87	19	108	505	315	453	1,400	305	114	6
February	21	20	301	370	89	219	999	109	68	3
March	38	24	308	459	110	248	1149	99	87	2
Mean Monthly	77	25 D	321 C	477 B	215 B	299 B	1,337 B	196	115	5
Summer Total	377	135	1,830	2,539	987	1,287	6,778	782	537	35
Winter Total	472	145	1,707	2,715	1,375	1,998	7,940	1,373	726	24
Annual Total	849	280	3,537	5,254	2,362	3,285	14,718	2,155	1,263	59
SALFORD—Mode wheel. (Unofficial Gauge.)										
April	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—
June	20	26	249	106	111	165	657	106	63	10
July	104	11	235	682	198	218	1,344	80	104	8
August	107	11	616	152	246	493	1,518	169	129	6
September	109	20	398	338	218	329	1,303	278	155	8
October	116	20	364	475	137	359	1,355	369	152	3
November	118	60	493	687	189	530	1,959	475	246	12
December	106	11	605	1,183	212	255	2,266	269	126	7
January	88	72	712	573	318	496	2,171	324	123	6
February	23	20	412	436	89	226	1,183	117	77	6
March	36	20	427	467	95	206	1,215	92	80	6
Mean Monthly	83	27 C	451 C	510 B	181 B	328 B	1,497 B	228	125	7
Summer Total	340	68	1,498	1,278	773	1,205	4,822	633	451	32
Winter Total	487	203	3,013	3,821	1,040	2,072	10,149	1,646	804	40
Annual Total	827	271	4,511	5,099	1,813	3,277	14,971	2,279	1,255	72

Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).

* Results useless owing to leakage.

1923–24. SALFORD. Regent Square. (Unofficial Gauge.)	Rain-fall.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).								
		Insoluble Matter.			Soluble Matter.		Total Solids.	Included in Soluble Matter.		
		Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition.	Ash.		Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
April	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—
June	—	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	—	—	—	—
August	—	—	—	—	—	—	—	—	—	—
September	107	17	477	258	311	311	1,374	222	111	11
October	124	25	424	433	227	300	1,409	358	119	12
November	129	33	425	524			Water	Lost.		
December	110	22	377	544	231	255	1,429	266	144	6
January	80	—	228	543	303	416	1,490	383	111	7
February	24	25	430	488	94	219	1,256	125	69	4
March	38	17	480	580	64	269	1,410	127	92	6
Mean Monthly	—	—	—	—	—	—	—	—	—	—
Summer Total	—	—	—	—	—	—	—	—	—	—
Winter Total	376	89	1,939	2,588	919	1,459	6,994	1,259	535	35
Annual Total	—	—	—	—	—	—	—	—	—	—
SOUTHPORT. Hesketh Park.										
April	71	**11**	**158**	**229**	88	125	611	55	43	*Trace*
May	66	4	76	83	82	180	425	42	91	,,
June	*17*	*1*	71	64	*41*	83	260	*18*	*26*	,,
July	77	3	26	67	39	77	212	37	42	,,
August	114	3	73	75	192	176	519	78	91	3
September	94	4	*21*	45	108	118	296	44	84	1
October	120	4	50	39	119	180	392	65	127	*Trace*
November	**125**	6	87	129	**219**	**375**	**816**	**86**	**213**	,,
December	124	3	94	102	173	198	570	84	80	**8**
January	63	6	130	105	69	121	431	69	53	*Trace*
February	19	*1*	51	60	58	99	269	22	44	,,
March	30	2	22	*29*	82	*68*	*203*	36	30	,,
Mean Monthly	77	4 A	71 A	86 A	106 B	150 B	417 A	53	77	*1*
Summer Total	439	26	425	563	550	759	2,323	*274*	377	*4*
Winter Total	481	22	434	464	720	1,041	2,681	362	547	*8*
Annual Total	920	48	859	1,027	1,270	1,800	5,004	636	924	12

SOUTHPORT. (Woodvale Moss.) 1918–23.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).							
	Rainfall.		Insoluble Matter.		Soluble Matter.		Total Solids.	
	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.	5 yr. aver.	1923–24.
April	41	61	*77*	105	290	121	367	226
May	*40*	66	158	**317**	275	265	433	582
June	48	*14*	178	208	381	162	559	370
July	62	75	143	41	474	179	617	220
August	74	**107**	186	186	**669**	357	**855**	543
September	84	80	177	238	576	257	753	495
October	47	89	114	*28*	300	170	414	198
November	41	95	149	120	258	333	407	453
December	**87**	93	**218**	136	477	**462**	695	**598**
January	63	56	112	59	419	147	531	206
February	52	15	100	63	*247*	*69*	*347*	*132*
March	70	26	89	191	326	216	415	407
Mean Monthly	59	65	142	141	391	228	533	369
Summer Total	349	403	919	1,095	2,665	1,341	3,584	2,436
Winter Total	360	374	782	597	2,027	1,397	2,809	1,994
Annual	709	777	1,701	1,692	4,692	2,738	6,393	4,430

1923–24. WAKEFIELD.	Rain-fall.	Grammes per Square Dekametre (Metric Tons per Hundred Square Kilometres).								
		Insoluble Matter.			Soluble Matter.		Total Solids.	Included in Soluble Matter.		
		Tar.	Carbon-aceous other than Tar.	Ash.	Loss on Ignition.	Ash.		Sul-phates (SO_3).	Chlor-ine (Cl).	Am-monia (NH_3).
April	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—
June	—	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	—	—	—	—
August	—	—	—	—	—	—	—	—	—	—
September	—	—	—	—	—	—	—	—	—	—
October	—	—	—	—	—	—	—	—	—	—
November	—	—	—	—	—	—	—	—	—	—
December	—	—	—	—	—	—	—	—	—	—
January	43	34	258	232	915	1,833	3,272	1,052	145	7
February	24	24	207	242	584	710	1,767	455	169	6
March	24	32	211	236	699	734	1,912	414	126	9
Mean Monthly	—	—	—	—	—	—	—	—	—	—
Summer Total	—	—	—	—	—	—	—	—	—	—
Winter Total	91	90	676	710	2,198	3,277	6,951	1,921	440	22
Annual Total	—	—	—	—	—	—	—	—	—	—

(*continued from p.* 9.)

followed by a subsequent rise to a second, but lower maximum late in the afternoon.

The summer curve shows a uniformly lower impurity than the winter and the curves themselves are somewhat smoother, indicating steadier conditions. The distribution, however, has some important peculiarities; for instance, the rapid rise of impurity in the morning commences in the summer about 4 a.m., and reaches its maximum on weekdays and Saturdays at 7 a.m., while on Sundays the maximum is not reached until 10 a.m. Thus, it would seem that the people of Blackburn are early risers on weekdays, but take a long spell on Sunday mornings. Again, in the weekday and Saturday curves for both winter and summer there is a second maximum occurring between 10 and 12 in the forenoon. This is particularly well marked in the winter curves, where the second weekday maximum occurs at 12 o'clock on "Z" and "ordinary" days, and this is higher than the first maximum which occurs at 8 a.m. In both "Z" and "ordinary" weekdays the second maximum is higher than the first and there is a four-hour interval between them. It would seem, therefore, that in Blackburn there are two main sources of smoke which make their maxima at different times. We get a clue to the position by examining the Sunday curves, which show no evidence of this double maximum in the forenoon. One is therefore inclined to conclude that the first maximum is due to the industrial or factory furnaces and the second to domestic fires. In support of this is the fact that while in the winter the second maximum is higher than the first for weekdays, in the summer the first is higher than the second. This fits in well with the theory that the second maximum is due to domestic smoke.

The Sunday curves fall in all cases below the weekday or Saturday, indicating a greater purity of the air on Sundays due to suspension of factories. It is somewhat remarkable, however, that the curves for weekdays, Saturdays and Sundays lie very close together after the second maximum in the forenoon has been reached; the greatest difference in all cases is in the forenoon. This is particularly well marked in the winter "Z" days.

The relation between the total smoke on Sundays and on weekdays is as 2,000 to 3,077. This is based on the ordinary winter days, and if the Sunday smoke is assumed to be domestic while the weekday is domestic plus factory, the ratio of factory to domestic smoke becomes 1 : 1·85.

Stoke-on-Trent.—From Stoke-on-Trent there are records from a total of 222 days. Part of the year was not included owing to the instrument having been moved to avoid proximity to a source of special pollution. Included in the records are 126 winter days, 82 of which were ranked as "Z" days, and 44 as "ordinary." Thus, of the winter days recorded, 65 per cent. were "Z" days, and 35 per cent. "ordinary," as defined above, or, roughly speaking, Stoke-on-Trent appears to suffer from smoke haze on two out of every three days. This is, perhaps, not to be wondered at, since in the pottery industry it is most difficult to prevent smoke.

Turning now to the curves in Figs. 3 and 4, there is a definite rise in all the curves starting between 4 and 5 a.m. In all the cities for which curves are shown, the minimum amount of impurity is about 3 a.m., while between midnight and about 5 a.m., the quantity does not rise much above the minimum referred to. This is, therefore, the part of the 24 hours which has the purest air. In Stoke the impurity begins to increase about 4 a.m. on weekdays and about 5 a.m. on Sundays. On summer weekdays and Saturdays a maximum is reached between 7 and

8 a.m., in the winter on weekdays and Saturdays the maximum is somewhat later, between 8 and 9 a.m., while on Sundays in the winter, the maximum is delayed until about mid-day.

In both summer and winter curves, the impurity is maintained at a high level during the whole afternoon, with remarkable oscillations, producing maxima at intervals.

The impurity both in winter and summer does not decrease to any marked extent until about 10 p.m. and, as already mentioned, has its lowest value at about midnight.

Again, it is noticeable, referring to the winter ordinary days, that the amount of impurity on Sundays is not markedly less than on weekdays, the ratio between Sundays and weekdays being 2022 to 2398. It is evident that here there are conditions which make it impossible to apply the method already used for ascertaining the relation between factory and domestic smoke as this method is based on a cessation of factory smoke on Sundays. The general inference one would draw from the curves for Stoke appears to be that the sources of smoke obey no general rule as to starting and stopping, and this is what might be expected when dealing with pottery kilns, the firing of which would not follow any definite arrangement as to time, nor would the emission of smoke from such cease on Sundays.

There is definitely less smoke in the summer than in the winter as will be seen by comparing the summer curves with those for winter. This is doubtless due to the reduction in domestic smoke due to the warm weather.

A somewhat remarkable feature of all the Stoke curves for both summer and winter is the fact that in every case the Saturday forenoon maximum is the highest. This would be caused should there be a custom of lighting ovens on Friday night or Saturday morning, and on inquiry this was stated to be the case.

(3) Comparison of Different Days of the Week.

The method adopted in the last *Report* for comparing different days of the week by plotting the average amount of suspended impurity for each day of the week is open to objection, as a single bad smoke haze might place one day of the week at the top as regards maximum impurity, and particularly so if there were not a number of other less hazy days to reduce the average. The curve based on average impurity is therefore liable to mislead, and it cannot be inferred that because a day has a maximum in this curve it is the dirtiest day of the week. To get over this difficulty and obtain a fair comparison between the different days of the week, another method has been adopted.

In Table 5, for six stations the total number of each of the days of the week available is given, that is the number of Mondays, Tuesdays, etc., for which there are records available; also the number of such days which rank as "Z," as defined above, and finally, a figure showing the percentage of "Z" days so defined.

Table 5.—*Table showing for the Winter Months the Incidence of Smoke Fog on different days of the Week.*

—		London.					
		Victoria Street.	Westminster Bridge.	Meteorological Office, South Kensington.	Kew Observatory, Richmond.	Blackburn.	Stoke-on-Trent.
Monday	Total No.	17	18	14	20	19	19
	Z days	9	9	7	3	11	16
	%	53	50	50	15	58	84
Tuesday	Total No.	19	18	15	14	19	18
	Z days	13	9	8	1	11	14
	%	69	50	53	7	58	78
Wednesday	Total No.	14	19	15	16	20	17
	Z days	12	10	8	2	13	12
	%	86	53	53	13	65	71
Thursday	Total No.	18	20	12	21	20	17
	Z days	14	8	5	4	8	12
	%	78	40	42	19	40	71
Friday	Total No.	21	19	17	18	19	18
	Z days	10	8	9	3	11	12
	%	48	42	53	17	58	67
Saturday	Total No.	14	19	15	21	19	18
	Z days	3	5	5	1	9	9
	%	21	26	33	5	47	50
Sunday	Total No.	15	19	12	21	19	19
	Z days	5	1	5	3	7	7
	%	33	5	42	14	37	37

The results of this table have been plotted in Fig. 5, which brings out graphically the incidence of smoke haze. It is evident that there is a general tendency in practically all stations to a minimum of "Z" days towards the end of the week and a maximum near the beginning. An exception to this rule is at Kew, which shows a slight maximum in favour of Thursday, but the "Z" days are scattered comparatively uniformly over the week at Kew. In Victoria Street, Westminster, there is a maximum number of "Z" days on Wednesdays, with a minimum on Saturdays. At the Meteorological Office, South Kensington there is a maximum on Wednesdays and Fridays and a minimum on Saturdays. Westminster Bridge shows the same maximum on Wednesdays, but its minimum is on Sundays, the second lowest being on Saturdays. Stoke-on-Trent shows a maximum on Mondays and a minimum on Sundays, there being a practically steady fall during the week from Monday to the following Sunday. Blackburn has its maximum number of "Z" days on Wednesdays and its minimum on Sundays.

It would seem that there is some general tendency towards a maximum in the different stations about Wednesday, with a minimum on Saturday or Sunday

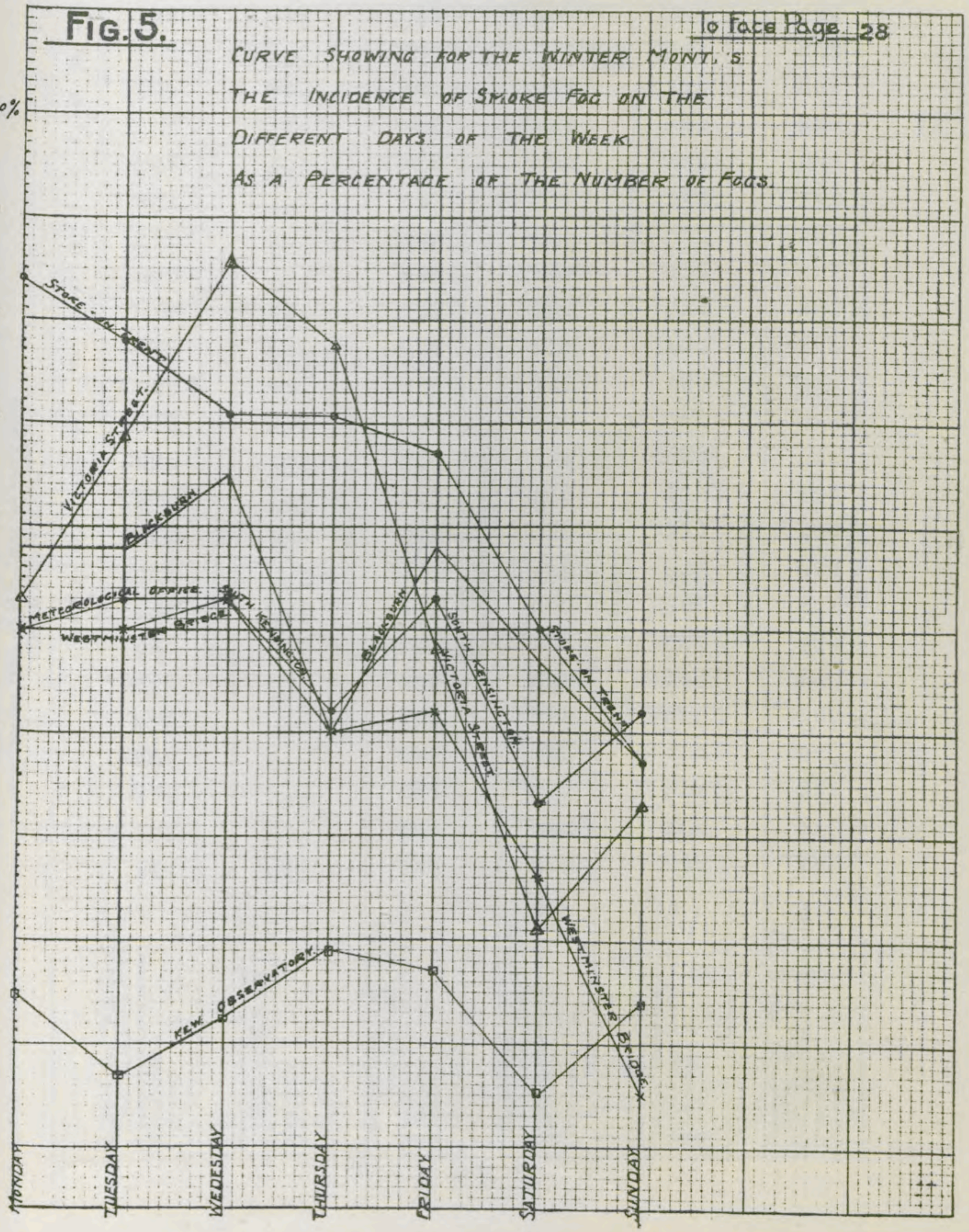


TABLE 6.—*Hourly Variations of Suspended Impurity, being the Average of the Number of Days shown.*
Summer, 1923. G.M.T. Mgs. per Cubic Metre.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
VICTORIA STREET, S.W.1.																								
Records taken "Summer Time" and converted to G.M.T. :—																								
67 weekdays without abnormal fog	·05	·04	·04	·05	·07	·16	·21	·25	·27	·26	·25	·22	·17	·16	·16	·15	·13	·13	·12	·11	·10	·09	·07	·06
.6 Saturdays ,, ,, ,,	·02	·02	·02	·02	·07	·13	·18	·18	·21	·20	·18	·15	·15	·15	·13	·14	·13	·10	·09	·08	·07	·05	·02	·02
1 Sundays ,, ,, ,,	·01	·01	·02	·02	·02	·03	·11	·20	·23	·20	·20	·17	·14	·11	·11	·11	·11	·11	·10	·07	·09	·07	·05	·03
WESTMINSTER BRIDGE.																								
Records taken "Summer Time" and converted to G.M.T. :—																								
58 weekdays without abnormal fog	·15	·15	·155	·155	·17	·235	·255	·255	·27	·245	·24	·225	·22	·215	·205	·205	·19	·19	·19	·205	·19	·185	·16	·16
19 Saturdays ,, ,, ,,	·205	·165	·16	·16	·165	·215	·265	·265	·26	·22	·225	·205	·19	·185	·175	·175	·175	·18	·18	·19	·185	·185	·18	·185
19 Sundays ,, ,, ,,	·135	·13	·13	·13	·135	·20	·205	·245	·245	·23	·235	·205	·20	·15	·15	·15	·15	·175	·175	·175	·18	·18	·155	·135
METEOROLOGICAL OFFICE, SOUTH KENSINGTON.																								
Records taken G.M.T. during "Summer Time" :—																								
64 weekdays without abnormal fog	·09	·09	·11	·15	·23	·38	·51	·47	·43	·43	·42	·38	·35	·34	·35	·34	·36	·35	·36	·37	·35	·30	·23	·17
12 Saturdays ,, ,, ,,	·21	·27	·21	·35	·32	·43	·53	·48	·45	·37	·37	·37	·32	·32	·32	·35	·40	·40	·40	·37	·27	·26	·09	·06
13 Sundays ,, ,, ,,	·05	·12	·10	·10	·15	·27	·35	·37	·37	·37	·42	·42	·35	·30	·25	·22	·22	·25	·30	·25	·22	·22	·17	·10
KEW OBSERVATORY, RICHMOND.																								
Records taken G.M.T. during "Summer Time" :—																								
75 weekdays without abnormal fog	·18	·16	·17	·18	·21	·30	·37	·36	·35	·32	·31	·29	·28	·28	·27	·27	·28	·29	·29	·31	·32	·27	·25	·23
18 Saturdays ,, ,, ,,	·27	·27	·32	·32	·28	·34	·34	·32	·32	·30	·34	·30	·28	·30	·25	·27	·27	·27	·28	·30	·32	·28	·25	·18
18 Sundays ,, ,, ,,	·18	·18	·21	·19	·16	·18	·23	·29	·29	·29	·25	·29	·25	·21	·14	·16	·19	·21	·19	·18	·18	·14	·12	·07
BLACKBURN.																								
Records taken "Summer Time" and converted to G.M.T. :—																								
92 weekdays without abnormal fog	·18	·18	·21	·24	·33	·53	·70	·67	·62	·63	·59	·52	·49	·49	·50	·52	·50	·48	·48	·49	·46	·40	·30	·25
18 Saturdays ,, ,, ,,	·21	·20	·21	·22	·33	·48	·65	·65	·65	·63	·58	·50	·45	·44	·45	·45	·45	·46	·46	·48	·49	·44	·36	·26
23 Sundays ,, ,, ,,	·21	·21	·20	·21	·22	·31	·43	·59	·63	·65	·59	·53	·47	·44	·43	·41	·45	·45	·45	·43	·43	·33	·28	·24
STOKE-ON-TRENT.																								
Records taken "Summer Time" and converted to G.M.T. :—																								
60 weekdays without abnormal fog	·20	·19	·18	·20	·30	·35	·42	·40	·37	·31	·36	·31	·32	·27	·29	·28	·21	·22	·24	·32	·30	·32	·19	·15
17 Saturdays ,, ,, ,,	·30	·36	·34	·36	·43	·50	·51	·51	·43	·38	·30	·24	·20	·23	·27	·23	·24	·24	·28	·32	·34	·41	·27	·21
19 Sundays ,, ,, ,,	·25	·26	·24	·21	·22	·23	·24	·28	·23	·24	·28	·18	·10	·14	·12	·08	·08	·10	·13	·14	·19	·16	·10	·08

TABLE 6 (cont.)—*Hourly Variations of Suspended Impurity, being the Average of the Number of Days shown.*
Winter, 1923–24. Mgs. per Cubic Metre.

47, VICTORIA STREET, S.W.1.

—	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
57 Z weekdays	·22	·19	·18	·16	·15	·17	·30	·65	1·37	1·83	1·52	1·28	1·16	1·05	1·01	·90	·81	·73	·67	·63	·59	·53	·43	·35
3 Z Saturdays	·21	·21	·21	·21	·21	·11	·43	1·06	1·81	2·30	2·46	1·71	1·28	·91	·69	·69	·69	·75	·91	·53	·69	·59	·43	·32
5 Z Sundays	·26	·19	·13	·10	·13	·13	·13	·38	·71	1·06	·89	1·02	·93	·83	·83	·64	·61	·61	·64	·74	·86	·89	·71	·58
31 ordinary weekdays	·24	·14	·11	·09	·09	·09	·20	·41	·67	·75	·69	·67	·63	·61	·58	·58	·56	·53	·51	·51	·47	·41	·35	·23
13 ordinary Saturdays	·21	·13	·12	·10	·10	·10	·20	·39	·60	·77	·71	·65	·55	·51	·45	·44	·48	·47	·48	·45	·45	·39	·36	·27
12 ordinary Sundays	·16	·11	·05	·04	·03	·03	·05	·13	·32	·44	·51	·48	·48	·41	·39	·39	·40	·39	·40	·45	·47	·41	·37	·29
WESTMINSTER BRIDGE.																								
51 Z weekdays	·37	·37	·34	·32	·33	·41	·62	·98	1·07	1·16	1·08	·91	·87	·94	·93	·95	·85	·79	·76	·77	·74	·65	·55	·42
7 Z Saturdays	·48	·39	·32	·27	·30	·36	·69	1·00	1·23	1·96	2·01	1·62	1·14	·78	·64	·60	·60	·69	·78	·78	·78	·69	·53	·32
2 Z Sundays	·24	·24	·16	·16	·16	·24	·32	·32	·80	·96	1·28	1·28	·96	·96	·96	·80	·80	·64	·64	·64	·64	·64	·32	·32
63 ordinary weekdays	·25	·22	·19	·19	·20	·24	·38	·56	·62	·66	·61	·55	·53	·50	·50	·53	·49	·47	·46	·45	·42	·38	·34	·27
17 ordinary Saturdays	·26	·21	·20	·19	·18	·24	·36	·49	·58	·60	·68	·57	·46	·42	·42	·39	·41	·41	·43	·43	·43	·46	·40	·31
22 ordinary Sundays	·20	·18	·17	·17	·15	·19	·23	·31	·46	·53	·55	·51	·45	·43	·41	·42	·41	·41	·43	·43	·41	·42	·31	·28
METEOROLOGICAL OFFICE, SOUTH KENSINGTON.																								
37 Z weekdays	·60	·53	·50	·46	·42	·47	·66	·93	1·25	1·29	1·22	1·24	1·18	1·07	1·02	·94	·97	1·06	1·12	1·09	1·00	·93	·82	·68
4 Z Saturdays	·48	·32	·40	·40	·40	·56	·72	·88	1·20	1·12	1·04	1·12	·96	·96	·96	·96	1·04	1·20	1·36	1·28	1·20	1·04	·72	·64
5 Z Sundays	·51	·45	·38	·32	·26	·32	·38	·77	1·14	1·14	1·08	1·27	1·14	1·01	·96	1·08	1·08	1·21	1·33	1·58	1·33	1·21	1·08	·83
34 ordinary weekdays	·25	·22	·17	·17	·22	·31	·44	·69	·75	·77	·74	·74	·72	·72	·72	·72	·74	·77	·78	·74	·66	·56	·42	·28
10 ordinary Saturdays	·29	·19	·13	·19	·10	·22	·48	·74	·83	·83	·74	·74	·70	·74	·74	·74	·74	·77	·77	·74	·70	·61	·54	·35
8 ordinary Sundays	·32	·32	·24	·24	·20	·24	·44	·48	·64	·76	·68	·68	·68	·72	·68	·64	·68	·72	·72	·80	·80	·76	·60	·52
KEW OBSERVATORY, RICHMOND.																								
15 Z weekdays	·47	·49	·49	·51	·47	·51	·60	·83	1·11	1·17	1·02	·83	·75	·75	·71	·73	·85	·87	·92	·87	·81	·68	·55	·41
2 Z Saturday	·94	1·09	1·09	·94	·78	·64	·64	·78	·94	·94	·64	·32	·32	·32	·32	·32	·47	·47	·78	·64	·64	·64	·47	·47
3 Z Sundays	·32	·32	·32	·21	·21	·21	·32	·32	·43	·53	·64	·85	·75	·85	·85	·85	·96	·96	1·17	1·38	1·28	1·28	1·06	·75
75 ordinary weekdays	·24	·24	·23	·23	·22	·24	·34	·41	·42	·39	·39	·36	·35	·33	·35	·36	·41	·41	·43	·43	·41	·38	·33	·29
20 ordinary Saturday	·21	·22	·19	·18	·16	·21	·32	·34	·34	·32	·32	·32	·32	·32	·32	·32	·32	·34	·35	·37	·35	·29	·26	·19
18 ordinary Sundays	·17	·14	·14	·12	·12	·12	·14	·27	·35	·37	·34	·34	·35	·35	·37	·35	·35	·37	·41	·43	·45	·41	·30	·29
BLACKBURN.																								
54 Z weekdays	·45	·42	·41	·45	·49	·59	·85	1·28	1·33	1·29	1·39	1·42	1·03	·87	·85	·86	·96	·94	·96	·89	·82	·72	·63	·48
11 Z Saturdays	·49	·45	·43	·43	·44	·61	·99	1·51	1·64	1·37	1·47	1·38	·91	·87	·77	·78	·83	·85	1·00	·96	·96	·85	·66	·46
7 Z Sundays	·53	·53	·43	·43	·43	·43	·46	·78	1·00	1·21	1·49	1·33	·89	·75	·67	·73	·78	·80	·85	·85	·89	·94	·75	·64
42 ordinary weekdays	·23	·22	·21	·21	·23	·31	·53	·79	·83	·81	·83	·83	·69	·64	·63	·60	·66	·65	·64	·63	·61	·54	·45	·33
10 ordinary Saturdays	·16	·16	·16	·16	·19	·32	·50	·67	·75	·72	·72	·71	·62	·58	·58	·61	·59	·58	·62	·64	·62	·54	·46	·34
12 ordinary Sundays	·21	·19	·19	·19	·19	·20	·21	·41	·57	·64	·71	·71	·59	·55	·55	·53	·57	·63	·61	·57	·57	·47	·39	·33
STOKE-ON-TRENT.																								
66 Z weekdays	·45	·40	·42	·41	·49	·71	·88	1·23	1·23	1·10	1·06	1·08	·99	·91	·90	·87	1·00	·95	·86	·85	·75	·65	·56	·27
9 Z Saturdays	·48	·45	·35	·45	·53	·73	1·22	1·36	1·60	1·07	1·01	1·01	·76	·55	·59	·66	·85	·73	·71	·76	·85	·61	·55	·21
7 Z Sundays	·59	·48	·41	·34	·37	·39	·44	·53	·87	·94	1·23	1·31	1·05	·98	1·10	1·21	1·26	1·03	1·07	·98	·87	·85	·59	·25
23 ordinary weekdays	·29	·25	·24	·19	·24	·24	·33	·55	·66	·61	·56	·55	·56	·52	·42	·46	·45	·40	·42	·45	·39	·33	·33	·16
9 ordinary Saturdays	·53	·48	·39	·28	·32	·46	·61	·78	·73	·61	·59	·67	·69	·61	·62	·59	·55	·51	·62	·59	·53	·50	·39	·19
12 ordinary Sundays	·27	·21	·19	·17	·15	·29	·21	·39	·53	·51	·47	·57	·49	·36	·37	·41	·35	·40	·39	·43	·32	·23	·24	·12

Thus four out of the six stations shown have a maximum on Wednesday, while two show a minimum on Saturday, and three a minimum on Sunday. It may be well to re-state here that the figures plotted show for each day of the week, the percentage of the total number of days on which the maximum impurity exceeds a certain figure, the figure being the same for all stations. The curve, therefore, shows the incidence of "Z" days as distributed over the week. It further permits an easy comparison to be made of the amount of suspended impurity at the different stations. Strictly speaking, such a comparison is not valid unless the same number of days is compared for each day of the week and for each place. Table 5 shows that there is not a great difference between the number of days compared for the different stations, so that the curves in Fig. 5 are roughly indicative of the quantity of impurity.

The figures for the hourly variation of impurity at the different stations are given in Table 6, the average for a number of days being given and the division already referred to being made into weekdays, Saturdays and Sundays. All times are converted to G.M.T. The summer, from April to September, is kept separate from the winter—from October to March, and again the winter days are divided into "Z" and "ordinary" days.

Owing to the change to summer time, introducing a complicating factor, the 21 days in April before summer time came into operation and the 14 days in September after the return to G.M.T. were omitted in the preparation of the figures for the summer months.

(4) COMPARISON BETWEEN THE AUTOMATIC FILTER AND THE JET DUST COUNTER.

In connection with the experiments on the measurement of visibility, and other work, many records taken by means of the jet dust counter have been examined and counted.

The counts have been compared with records taken simultaneously by means of the automatic filter, with the result shown in Fig. 6. As in the *Annual Report* for the year ending March 31st, 1923, the filter results, expressing the impurity in milligrammes per cubic metre are plotted as abcissæ against thousands of particles per cc., determined by means of the jet instrument, as ordinates.

COMPARISON OF AUTOMATIC FILTER AND JET DUST COUNTER RECORDS.

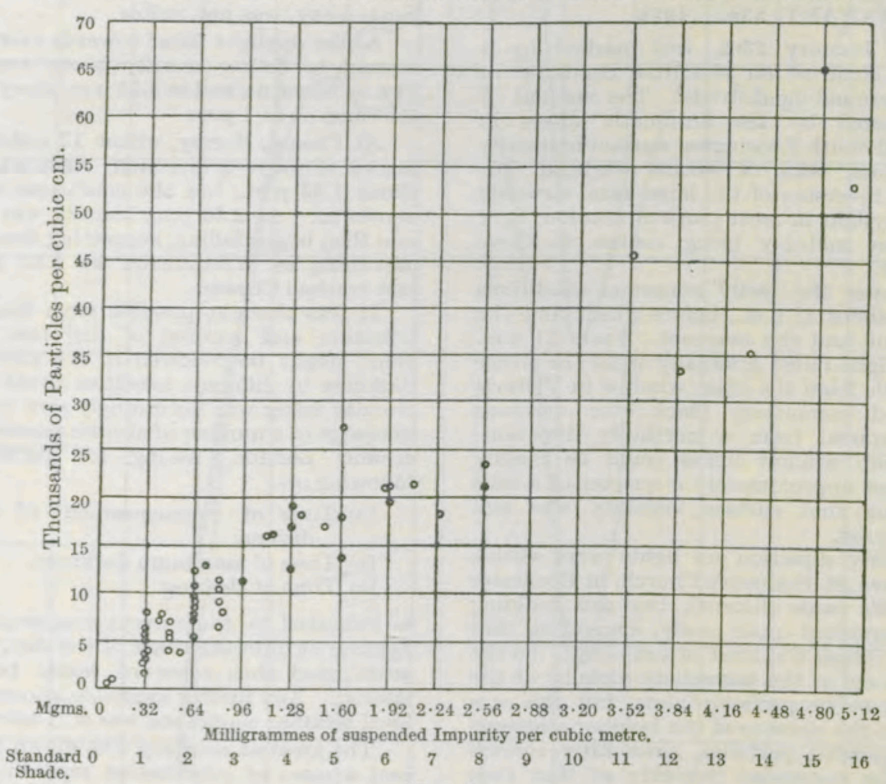


FIG. 6.

The two sets of results show a good agreement when allowance is made for the uncertainty which was referred to in the last *Annual Report* regarding the counts of very heavy records when the standard instrument was used. As already mentioned, the number of particles in dense records was then almost certainly under-estimated, so that the portion of the graph in the last *Annual Report*, representing more than 3·20 milligrammes of suspended matter per cubic metre cannot be regarded as reliable.

Referring to Fig. 6, the point representing 65,600 particles per cc. was obtained by the use of the instrument with the double slot. A record giving 82,300 was obtained during a fairly dense smoke haze on November 26th, 1923, when the amount of impurity indicated by the automatic filter was rapidly increasing. Conditions were not steady and the surprisingly light shade of the filter record is almost certainly due to the fact that the instrument did not operate continuously, and a rapid local variation in the intensity of the smoke haze may have been missed. The 65,600 result was obtained only a few minutes later, during the same smoke haze. Omitting the doubtful point, the remainder seem to indicate a straight line relationship between the number of particles per cc. and the total weight of the suspended matter per unit volume, pointing again to a remarkable uniformity in the size of particles usually present in the air.

From the graph it appears that ten thousand particles per cc. correspond with about 0·8 milligrammes per cubic metre, a fairly good agreement with the previous conclusion of 10,000 particles to a milligramme.

SECTION 3.—DARKNESS OF WEDNESDAY, JANUARY 23RD, 1924.

Wednesday, January 23rd, was marked by a smoke haze or cloud of an abnormal character in London and surrounding districts. The amount of impurity registered by the automatic filters in Westminster and South Kensington was not unusually large, but a thick bank of smoke overhead, due no doubt to an inversion of the lapse rate, seriously obscured the daylight in most parts of London, light conditions about mid-day being similar to those during the night.

In Westminster the really abnormal conditions commenced at about 11 a.m., before which time the morning was dull and sky overcast. From 11 a.m. to 1 p.m. the light failed gradually until the whole of the sky visible from the office window in Victoria Street appeared completely black, the darkness appearing to spread from a northerly direction; nevertheless shop window lights could be readily seen in the street approximately a quarter of a mile away, indicating that surface visibility was still comparatively good.

In a southerly direction no lights were visible further away than St. Stephen's Church, in Rochester Row (about 500 yards distant), but this building could be distinguished quite easily, suggesting that this was by no means the limit of visibility. To the naked eye, the air in the immediate vicinity of the office appeared to be perfectly clear, but this was no doubt due to the absence of the familiar scattered light from suspended particles, since filter records showed that the suspended impurity at that time varied between 1 and 2 milligrammes per cubic metre.

At 1.10 p.m. the sky towards the north became slightly luminous and of a rosy colour, but the south was still black. From this time the sky cleared from the north; at 1.30 p.m. it appeared grey in the north, about equal in depth to Shade 6 or 8 of the standard scale of shades used in matching records of the automatic filter as illuminated by a 100-watt gas-filled lamp about 3 feet above it. In the west the sky then appeared equal to about Shade 15.

About 1.30 p.m. an intermittent noise very much like distant thunder was heard.

During the next few minutes the light improved considerably, and the Rochester Row church became readily visible, but the Westminster Cathedral tower could not be distinguished. In a southerly direction nothing whatever was visible beyond the Rochester Row church, owing partly to the absence of suitable landmarks. At 1.45 p.m. a shower of very fine rain commenced and clouds of white mist could be seen blowing past the Victoria Street building towards the south.

Conditions then came back practically to normal, with some fluctuations apparently caused by the indeterminate wind which arose.

About 1.55 p.m. there was a particularly bright period, but at 2.5 p.m. the sky in the north had darkened again to Shade 6. At 3.5 p.m. the haze was white, rain was falling steadily and the wind was very indefinite. The sky was lighter than Shade 2, judged under conditions similar to those described above. The Cathedral tower, about 800 yards away, was not visible.

As the daylight failed towards evening, conditions seemed to follow exactly those experienced from 11 a.m. onwards, and at 5.35 p.m. everything appeared the same as at 1 p.m.

At Cheam, Surrey, about 12 miles from London in a south-westerly direction, there was a dark period about 1.33 p.m., but the conditions were not really abnormal. At 2.35 p.m. the sky was very dark and rain then began falling, suggesting that the conditions prevailing in Westminster at 1.45 p.m. had then just reached Cheam.

It was thought possible from this that the distribution and method of dispersal of the smoke cloud might be followed if the time of maximum darkness in different localities could be found. A circular letter was accordingly sent to the engineers in charge of a number of electric power stations in and around London, asking for particulars of the following:—

(*a*) Time of commencement of abnormal conditions,
(*b*) Time of maximum darkness,
(*c*) Time of clearing,

as indicated by the current consumption for electric lighting at different times of the day, of which it was anticipated that a record would be kept at each station. Any further available information regarding local weather conditions was also asked for.

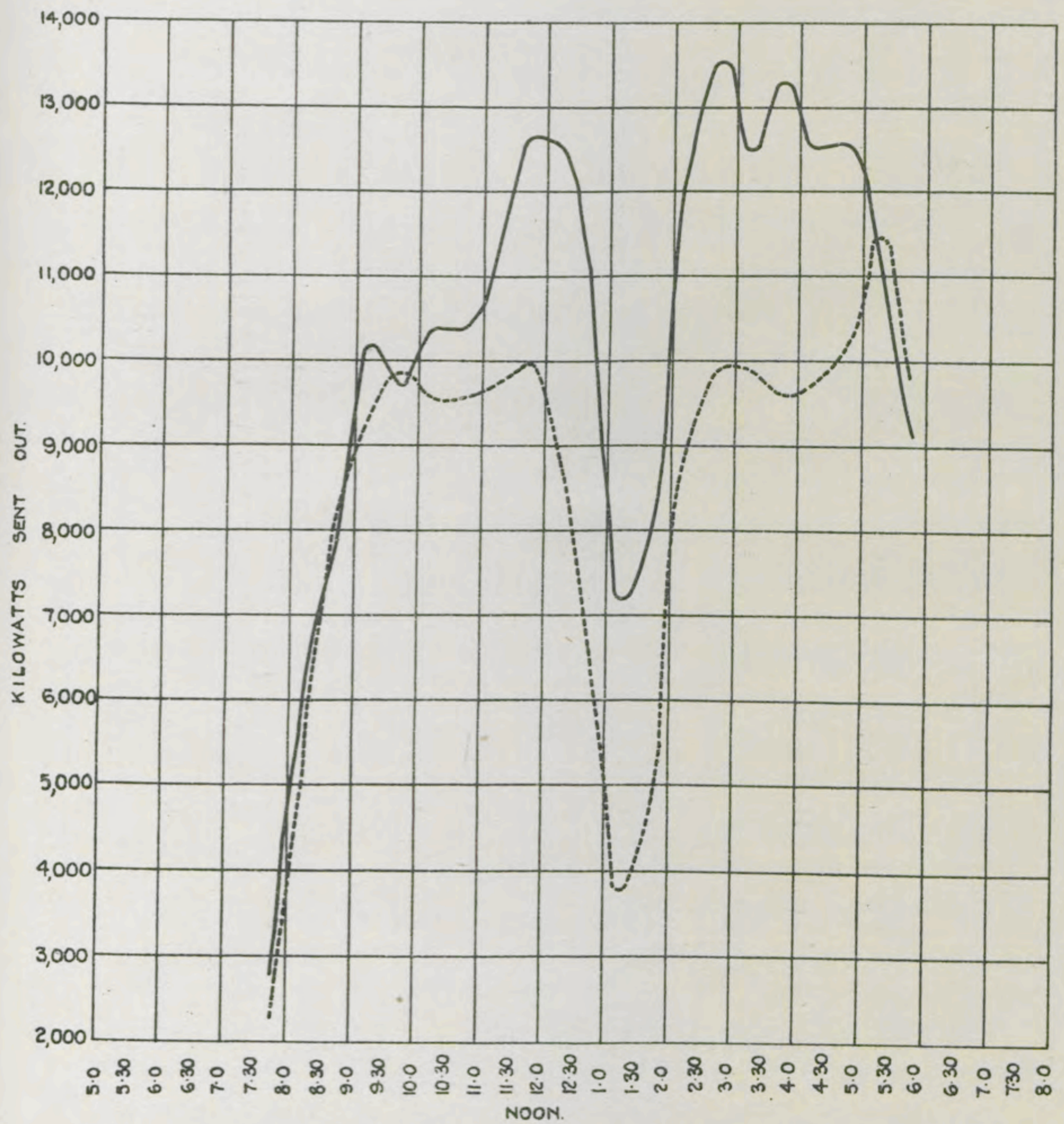
The greatest courtesy was shown by the engineers and a mass of information regarding local weather conditions, fog, etc., was furnished, but as regards the question in hand, the results were somewhat disappointing owing to the fact that no distinction could be made between electric lighting and power loads, and also that Wednesday was early closing day in many of the districts, which reduced the lighting load by an unknown amount.

FIG. 7. To Face Page 32

LOAD DIAGRAM. ELECTRIC POWER STATION. CITY ROAD.

WEDNESDAY. JANUARY 23RD 1924. ————

FRIDAY. FEBRUARY 1ST 1924. - - - - - -



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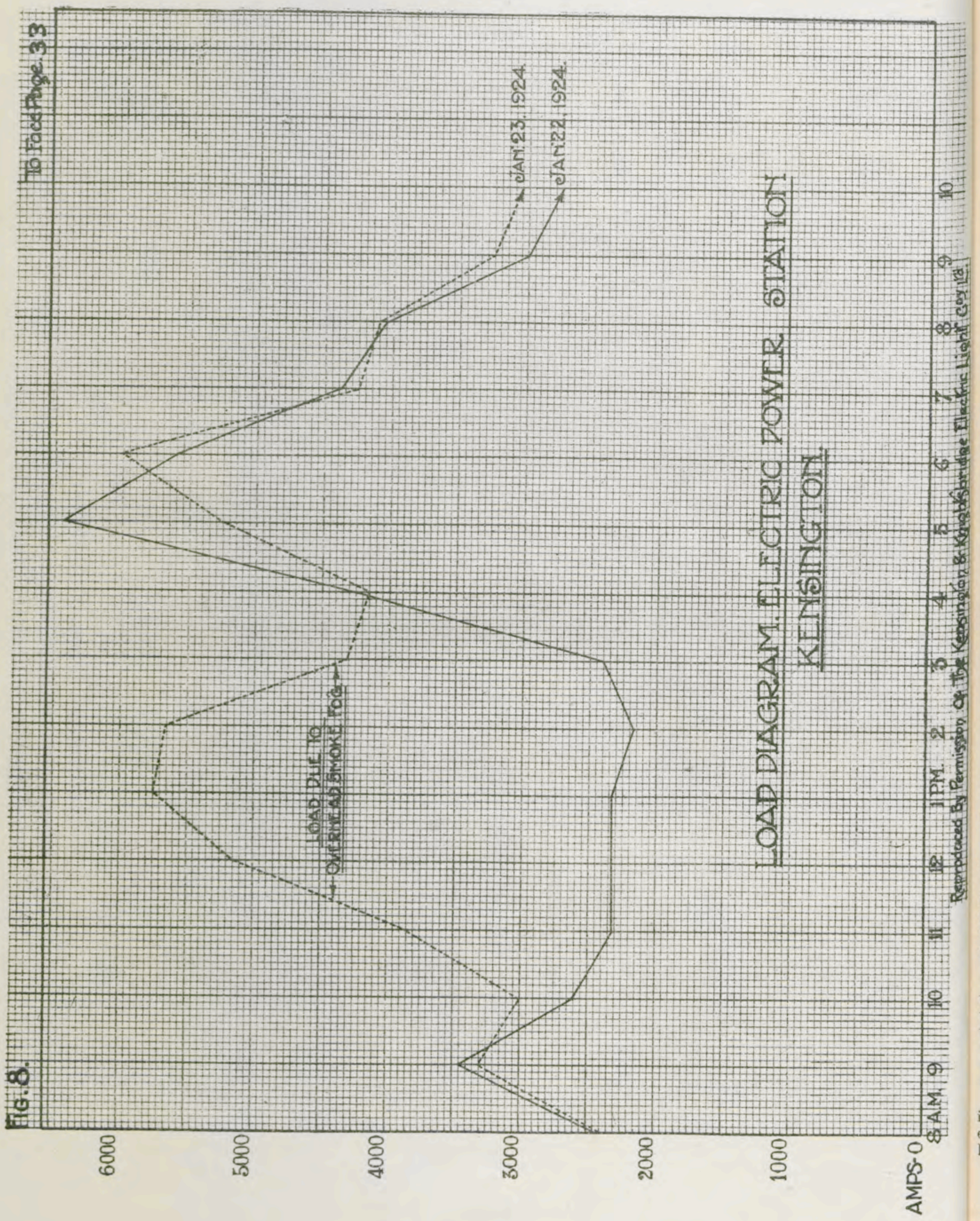

In eight cases, load diagrams for January 23rd and other days for comparison were sent and the required information was given for seventeen cases as far as could be deduced from the local curves by the station engineers.

Typical examples of load diagrams received from two stations, in an industrial part of the City and in a residential district near Hyde Park respectively, are given in Figs. 7 and 8.

With reference to the diagrams, the former shows a marked decrease about 1 p.m., due no doubt to the reduction of the power load during lunch time. In the case of the other station, it appears that the maximum load would be due to lighting, since there was no sudden falling off at 1 p.m.

The data received are summarised as far as possible in Table 7.

TABLE 7.—*Summary of Data relating to the Darkness of Wednesday, January 23rd, 1924.*

Power Station.	Time of Commencement of Abnormal Conditions.	Time of Maximum Darkness.	Time of Clearing	Remarks.
Bromley, Kent - - -	—	—	—	Conditions normal.
Cadogan Gardens, S.W. -	10.30 a.m.	3 p.m.	3.15 p.m.	Brighter period from 3.15–3.30 p.m.
Chelmsford - - -	—	—	—	No fog. Conditions normal.
City of London, Bankside -	9.15 a.m.	10.30 a.m. 11.30 a.m. 1 p.m.	—	Slight clearing at 11 a.m. Extract from weather log at station submitted. Load no indication on account of railway strike.
Croydon - - - -	8 a.m.	11.45 a.m.	2.30 p.m.	Not of excessive density.
Dartford, Kent - - -	—	—	—	Fog all day. Most of current used for power, therefore further information impossible.
Ealing - - - -	3 p.m.	—	After dark	Output increased by one-third at 3 p.m.
Guildford - - - -	—	—	—	Fog all day. Load during forenoon 28 per cent. higher than normal. Afternoon load no indication because of early closing.
Hammersmith - - -	8–8.30 a.m.	1.30 p.m.	—	Load diagram sent. Indication very good.
Hampstead, Finchley Road	noon	1 p.m.	—	Hardly abnormal. Slight maximum at 1 p.m.
Hertford - - - -	—	—	—	Conditions normal.
Hitchen - - - -	—	—	—	Conditions normal.
Holloway - - - -	11 a.m.	12.15 p.m.	3 p.m.	Increase of 20 per cent. above normal at 12.15 p.m.
Kensington and Knightsbridge.	9.15–10 a.m.	1–2 p.m.	4 p.m.	Load diagram attached. Most of output probably used for lighting. Diagrams of Prince Consort Road and Kensington Court stations similar.
Putney and Wandsworth (County of London Co.).	11 a.m.	2.30 p.m.	—	Heavy load from 11 a.m.–1 p.m. Abnormal all day. Load diagram submitted.
City Road (County of London Co.).	9 a.m.	2.45 p.m.	3.15 p.m.	Slight maximum at 9.15 a.m. and minimum at 9.45. Fluctuations during day. Load diagram attached.
Sutton and Croydon (County of London Co.).	8 a.m.	2.45 p.m.	—	Heavy load from 12.15 to 1 p.m.
Luton - - - -	—	—	—	Dull, but not abnormal.
Richmond, Surrey - -	9.30 a.m.	3 p.m.	—	Slight maximum at 10.15 a.m.
Sevenoaks - - - -	10.30-11 a.m.	11.30–12	1 p.m.	——
Sutton—High Street (S.M.E.T. & L. Co.).	—	3–4 p.m.	—	Figures of output submitted. Dark generally from mid-day to sunset. Slight maximum at 12 noon and 4 p.m.
Watford - - - -	—	—	—	Foggy, but not abnormal.
Wimbledon Park - -	9.30 a.m.	2–3 p.m.	3.30 p.m.	——
Woking - - - -	—	—	—	Slight fog from 7 a.m. to 4 p.m., with maximum at 10 a.m., but daylight not seriously affected.

The table shows that the effect was patchy and its density governed by local conditions. There was evidently at first an irregularly distributed accumulation of smoke over London with no definite movement, but early in the afternoon this drifted towards the south, the densest part passing Putney and Wandsworth at 2.30 p.m., Sutton and Croydon district at 2.45 p.m., and the Sutton Sub-station of South Metropolitan Co. from 3 to 4 p.m. The time of maximum given by the Metropolitan Electric tramways and Lighting Co., Ltd., Sutton, was 3 p.m.

It is probably not mere coincidence that all districts to the north of London were free from abnormal darkness whereas those to the south reported dark conditions all day. The comparison of Bromley, Guildford and Dartford with Hertford, Woking, Luton and Hitchin is of interest.

The northern limit of the darkness appears to have been Finchley Road, where there was a slight maximum at 1 p.m., but the conditions were hardly abnormal.

Observations at Croydon Aerodrome showed a completely overcast sky throughout the day, with very low clouds. At 8 a.m., 8.30 a.m., and 9.30 a.m., for instance, the height of the lowest clouds was less than 150 feet; most of the half-hourly observations gave the height as 225 feet and the highest recorded was 450 feet. Nevertheless no really abnormal darkness was experienced.

The result of the investigation, if not very definite, is supported by the reports from the stations of the Meteorological Office, in which a light wind from NE or NNE was generally indicated. At Kew Observatory, Richmond, the wind direction at 1 p.m. was given as NE-NNE, and the velocity as 1–3 miles per hour. At Kensington Palace, the direction was NNE or E, and velocity 4–7 miles per hour, and Greenwich was similar.

Hounslow appears to have been rather exceptional; at 7 a.m. the wind was W., and for the rest of the day SE.

One result, however, is perfectly definite. The electric load diagrams for stations within the area of the dense haze bring to light something of the cost to Londoners of smoke effects of this description, and bear striking testimony to the need for reform with regard to pollution of the air.

Regarding the amount of suspended impurity present near ground level, the following figures were obtained from the records of the automatic filters in operation in Westminster and South Kensington :—

Victoria Street.		South Kensington.	
Time.	Mgs. per cubic metre	Time.	Mgs. per cubic metre.
9.00	1·28	9.05	·64
9.50	2·24	9.55	·48
10.15	1·92	10.40	·48
11.00	1·60	11.25	·48
11.50	1·28	12.10	·64
12.30	0·96	13.00	·64
13.10	1·12	13.50	·64
13.50	·80	14.45	—
14.10	·80	15.30	—
14.50	·80	16.15	·80
15.10	·64	17.10	·80
15.50	·64	18.00	·64

It is worthy of note that during dense smoke hazes in London, 6·4 milligrammes per cubic metre have been indicated on many occasions, and in the usual classification employed during the preparation of curves showing hourly variation of suspended matter a day is not regarded as ranking as "Z" until the amount indicated reaches 1·28 milligrammes per cubic metre.

A record was taken by means of the jet dust counter at 1 p.m., and subsequent counting gave the number of particles per c.c. as 16,250, generally less than 1 micron in diameter. The most general size of the particles so far as could be judged was about ½ micron in diameter, but the smallest ranged down to the limit of resolution of the 1/15-inch oil immersion objective used in the examination.

The record contained many irregular pieces of crystalline material, generally nearly three microns across, and many aggregates or masses of crystals with the appearance of sugar candy. All the crystals were dry, no drops being present on the slip at the time of counting but there were no characteristic shapes to give any indication of the nature of the material of the crystals. Some roughly circular clumps of crystals composed of individuals varying from 1·5 to 3 microns across were as large as 20 to 25 microns in diameter.

In addition to the masses of crystals, there were a few apparently tarry aggregates of black particles, and occasional reddish, glassy spheres from 1·5 microns to 2 microns in diameter, exactly similar to the spheres always found in certain kinds of flue dust, therefore presumably derived from chimneys.

A second record was taken as a check at 1.5 p.m. This gave a similar count to the above, but probably owing to some temperature effect during the mounting, the slip carried a number of drops of liquid of different sizes and shapes, but all apparently colourless. The largest of these drops were 15 microns in diameter, and there was an obvious increase in their number on the actual linear record, pointing to the presence of definitely hygroscopic material collected from the air. These drops usually covered a number of particles which were not loosened from the glass or in any way altered in their distribution, which points to the drops having been formed subsequently to the taking of the record. Some of the drops contained brownish, sugary-looking masses of crystals, and occasionally needles.

The cover slip bearing the above record was removed from the mounting and inverted. Most of the drops evaporated immediately, leaving sugary-looking masses of crystals similar to those obtained in the 1 p.m. record. When the slip was breathed upon, drops condensed on all parts of the slip, but appreciably larger on the dust record, and the sugary masses at once dissolved.

Other apparently crystalline matter was present in the form of flakes similar in appearance to muscovite, which, however, were not visible between crossed nicol prisms. This was not soluble in the condensed water.

It is of interest that when the process of breathing upon the record to dissolve the crystals, and re-evaporation had been carried out several times, the crystals seemed to disappear entirely; this was no doubt due to the fact that the evaporation was very rapid, and the crystals could not form together as before, but remained as independent bodies only two or three microns in diameter, and could not be recognised as crystals.

The slip was re-mounted on a ring coated with Canada Balsam. The few obvious crystals which remained in the record did not become surrounded by drops, and drops did not appear where the masses of crystals were known to have existed before. On the slip, however, there were some small fragments of the original resin adhesive which had become scattered as the slip was removed from its first mounting, and these immediately formed into drops of perfectly regular outline, very similar in appearance to some of the smooth organic cells described under a separate heading. These drops evidently had little or no tendency to spread over the surface of the glass, and were quite different in appearance from those originally present, which had a tendency to spread and were therefore less regular in outline.

The inference is that the original drops were drops of aqueous solution due to the presence of hygroscopic material collected in the record from the air.

SECTION 4.—THE JET DUST COUNTER.

(1) The Double Slot Method.

Many records taken by means of the jet dust counter have been examined in connection with other sections of the research work, and call for no special mention. On two or three occasions, during unusually dense smoke fogs, the instrument with the double slot mentioned in the *Ninth Annual Report* was used.

The double record so produced is more difficult to examine than a single track of particles and the time taken in the counting is greater. The results of the count, however, appear to be reliable and show definitely that in the counting of a heavy record taken by means of the single slot instrument the number of particles is liable to be under-estimated. For instance, on November 26th, the record taken by means of the standard instrument did not appear to be more dense than had been obtained on many occasions previously when the count had not exceeded 52,000 particles per cc. A record taken by means of the instrument with two slots was counted with great care, at least two hours being spent in the counting of one strip of about 360 squares running completely across the double dust trace. The total for the strip was 5,600, representing 82,300 particles per cc.

The single slot fails when the dust particles are so numerous as to be deposited one on top of another, a difficulty easily overcome by increasing the effective length of slot used as described, or by reducing the volume of air drawn through.

(2) An Alternative Method of Reducing the Density.

An alternative method of reducing the density of the record taken by means of the single slot during a heavy smoke haze by a known proportion, by providing a by-pass of known area of cross-section, is also being investigated, and may prove to be as satisfactory as the use of the double slot. In each case the greatest difficulty which presents itself is the maintenance of the required velocity in the air jet to produce a compact record and efficiently retain the whole of the dust particles. The greater the area of the passage for the air to the pump the greater is the difficulty in reaching the extreme velocity required by the principle of the instrument, but any slight loss of efficiency in this direction if present is evidently more than compensated by the advantage gained in the counting. The use of the double slot is, however, only called for during the densest smoke fogs experienced in the winter.

(3) Records from Petersfield and Athens.

Among the interesting records counted in the laboratory may be mentioned a series of twelve taken by Captain Cave at Petersfield, which are dealt with later in this *Report*, and which contained organic particles of definite structure; also a series of twenty-four records taken in Athens and submitted by Professor D. Eginitis, Director of Observatoire National Astronomique et Météorologique, Athens. Although the information gained from these latter slides was not so great as might have been hoped owing to defective manipulation of the instrument when taking the records, some unusual particles almost certainly organic in origin, were found. These were quite different from the mould cells found in English records both in shape and in size. Some cells were from 40 to 70 microns in length; some were most probably epithelial cells, but they were not present in sufficient numbers to allow of any attempt to identify them by chemical means. Occasionally crystals were found, but it is not certain that these were part of the actual record; they may have developed on the cover slip subsequent to mounting, in a manner described in this *Report* under the heading "Deterioration of Records with Keeping."

(4) Organic Particles in the Air.

It was reported on August 25th, 1923, by Dr. H. H. Kimball of the United States Department of Agriculture Weather Bureau that during the whole of August unusual and comparatively large opalescent particles had been encountered in records taken in Washington by means of the jet dust sampling instrument supplied to him through the International Union of Geodesy and Geophysics. These particles had not yet been identified. They were present in large numbers in records taken both on the ground and from an aeroplane.

At the beginning of September, a specimen slide containing some of the particles was received from Dr. Kimball. These particles had the appearance of definitely organic structures, some unicellular and some bicellular; they were unusually clear, turgid and spherical or oval, but sometimes irregular, with as many as nine short but well-defined protuberances. No nuclei could be seen in the cells.

Drawings of the best defined particles were made, and these were exhibited by Dr. Owens at the soirée of the British Association in Liverpool.

Somewhat similar particles of evident organic origin, considered to be pollen grains or spores, had been obtained occasionally by Dr. Owens in records taken in the country. The numbers were, however, always very small and no such particles had ever been noticed in records of suspended matter in London.

On October 10th, 1923, a record of 1,000 cc., taken at South Kensington in the usual way was found to contain two large bodies identical in appearance with some of the opalescent particles in the American record. These were single oval cells filled with finely granular matter, each 6 microns long by 3·75 microns wide, and each with a well-defined papilla at one extremity. The cell wall appeared rough and pitted and was appreciably thinner at the tip of the papilla than at other points. From this date, particles of definite structure were found in a large number of records taken in or near London. On the following day, October 11th, they were present to the extent of about 2 per litre at South Kensington. A record taken at 10.15 a.m. contained a perfectly clear spherical body, 5 microns in diameter, with smooth surface, a similar cell with rough and crinkled wall, and a cigar-shaped body divided in the middle and containing two definite oval cells. The latter was not turgid, but bent over in the middle. The particles were obviously organic cells, but for confirmation, several simple tests were applied.

Water was introduced under the cover slip; the cigar-shaped particle immediately became turgid and apparently split open near one end. The length of the extended particle was 10·8 microns and the centre partition dividing the body into two equal cells was then well-defined.

A small quantity of a solution of Gentian violet was introduced under the cover slip. The cigar-shaped particle and the sphere with the rough wall at once took up the stain and became almost black, but the clear sphere was unaffected.

Further records were found to contain similar oval and spindle shaped particles, which readily took up the stain when mounted in blue glycerin jelly.

A number of records were subsequently taken at different times of the day and night from which it was concluded that the organic particles were not present at all hours in London. For instance, records taken in Bloomsbury on Sunday, October 14th, at 1 a.m. and at 12.15 p.m., contained no definite organic structures, but many square and hexagonal crystals some of which were quite well formed.

Again, at 8.30 a.m., on October 17th, records were taken simultaneously at Cheam and in London, at Bloomsbury. The Cheam record contained at least 20 definitely organic particles per litre, generally oval in shape and up to 12 microns in length, together with approximately 630 smoke particles per cc., whereas the London record contained only 5 or 6 bodies, all less than 5 microns in length. The number of smoke particles shown by the London record was approximately 5,000 per cc. The organic particles from the air of Cheam on this occasion were of particular interest. Three roughly oval cells, each about 4 microns long by 2½ microns wide were found connected together end to end, and the two end cells showed signs of further subdivision by a pronounced thickening of the walls about the middle. Another body took the form of a single oval cell, 10 microns long by 6·7 microns wide, full of clear colourless matter. The cell wall was smooth and at one extremity there was a very well-defined papilla, giving the whole a shape rather like a lemon. Another somewhat cylindrical cell, 12 microns long by 3·3 microns wide bore side markings suggesting points of attachment to other cells, which gave it an appearance resembling a portion of a cabbage stalk stripped of the leaves.

Yet another cell, roughly square with a side of 5·8 microns contained a reddish brown ball of 4 microns diameter with rough surface—possibly a zygospore.

The volume of air passed through the instrument in taking the above records was in each case 500 cc.

A further record taken on the same day in Westminster shortly after 4 p.m. contained one clear oval body, 6·7 microns long by 3·3 microns wide, on which appeared 6 small bud-like protuberances, irregularly spaced on the surface. The record was kept under observation and at 4.20 p.m. five of these buds appeared equal in size, the sixth being much smaller; fifteen minutes later, two of the processes had practically disappeared, while two of the remainder had appreciably increased in size. At 4.50 p.m. four processes remained, one of which had still further increased. Forty minutes later the smallest which had hitherto remained unchanged, was found to have disappeared and its former position was marked by a small black particle not more than half a micron in diameter, just appreciably separated from the main body, suggesting at first sight that the process had now become completely severed. It is, however, more probable that this was a smoke particle at first unnoticed, owing to its being hidden by the process which had now been withdrawn into the main cell. Of the three remaining, the largest process had further appreciably increased since 5 p.m., and took the form, roughly, of a hemisphere of radius somewhat less than 1 micron.

On the next morning, October 18th, the oval body appeared as a single cell with no protuberances, unaltered in size within the limits of accuracy of measurement.

This cell appeared to be not quite turgid and the former positions of two of the processes were marked by the slightest irregularities in its outline. Beyond this no traces remained, but the single smoke particle near the body already referred to was visible. It is thus probable that the rapid change first noted in the appearance of the body may have been due to loss of water by evaporation owing to the focussing upon it of heat rays by the condenser of the microscope.

The slide was gently warmed by placing it under the microscope lamp for four hours, but no change in the appearance of the body was detectable.

Another record containing organic particles was mounted upon a slide face upwards. When the slide was breathed upon, drops condensed round the cells, which swelled up very considerably, and in some cases thin projections were thrown out, only to return to the original condition as the slide dried, thus affording confirmation of the drying theory of the above phenomenon.

The 12 records taken at Petersfield between the end of August and the middle of October, 1923, referred to above, were submitted by Captain Cave for examination. These, again, were found to contain spore-like particles of definite structure, similar in all respects to the organic particles already referred to.

They were generally single, smooth, oval cells, each with a well-defined papilla at one end, varying in overall length from 4·5 to 10·5 microns, but occasional particles of different form were present. In a record taken on October 4th, there was an oval cell 6 microns long by 3 microns wide with a rough surface covered with black markings, and in a record of October 6th there was a cigar-shaped body 15 microns long and 4 microns wide. The record of August 31st contained four smooth oval bodies attached end to end in a string 22·5 microns long, and several strings of smaller particles with the appearance of hyphæ dividing into separate cells were encountered in other records. The record of October 16th contained a large particle 24·75 microns long by 6 microns wide, divided into six well- defined compartments. There is little evidence of variation of the number of particles with the wind velocity at the time of taking the records, as given by Captain Cave. This is shown in the following table :—

Date, 1923.	Wind Force Beaufort No.	Humidity Per Cent.	No. of Organic Particles per 10,000 cc.
Aug. 31 -	3	62	40
Sept. 1 -	2	90	32
5 -	3	81	24
6 -	1	88	36
26 -	3	91	5
27 -	2	85	15
Oct. 4 -	5	85	70
5 -	2	81	13
6 -	2	99	16
9 -	4	99	60
13 -	4	81	20
16 -	4	84	10

The connection between the number of particles and wind force is not very definite, but this may be explainable by the fact that in no case was the volume of air drawn through the instrument greater than 2,500 cc., and these cells could not conceivably be uniformly distributed in the air, but would vary with every eddy and change of direction of wind. Moreover, several of the records contained crystals in various stages of development, which were practically indistinguishable from the smaller organic cells, so that some measure of uncertainty exists in the counts of the organic particles.

No connection is apparent between the number of the bodies and humidity or wind direction. As is shown later, the number would probably be dependent rather upon the humidity of the air some hours previously, and the variation in wind direction is not sufficient to form any basis of comparison.

(5) Origin of Organic Particles.

The occurrence of particles unlike anything previously noted both in America and in England appeared at first sight to suggest a common origin, and it was suggested by several that this might be the severe earthquake which had recently been experienced in Japan. It is known that under suitable circumstances volcanic dust may be carried great distances, as in the case of the Krakatoa eruption of 1883, and it is conceivable that quantities of dust may have been raised from the ground during the earthquake to the high levels in the atmosphere, and carried far. It was noted that the organic bodies were particularly in evidence during wet weather, when rain would be more likely to cause a down draught of air from higher altitudes than to stir up particles from the ground.

This suggested origin of the bodies is, however, improbable; the difference between the number of particles present in London and at Cheam at the same time pointed rather to a local source, the most probable explanation being that they were spores of some fungus, the growth of which was favoured by the wet weather. A portion of a whitish mould—probably mucor or cystopus—found on a fallen apple at Cheam was examined and found to contain a large number of readily stainable globular cells, similar in size to those obtained in the records.

In size and all other respects, the organic bodies correspond with spores of almost any mildew, rust or smut, which, according to one text book "flourish in proportion to the wetness of the season or the dampness of the locality." Spores of corn smut and grass smut, and indeed of most of the Ustilaginaceæ, correspond closely with the particles found, as do also the conidia of white rust.

Many of the spores of the Ustilaginaceæ are coloured; this may possibly account for some of the isolated coloured, spherical particles which have been occasionally found in previous records, although it is known that coloured glassy spheres are also produced in furnaces.

Conidia of white rust (Cystopus candidus) are normally of about 13 or 14 microns in diameter. In the presence of moisture these swell and at one extremity of each there is produced an obtuse papilla. In the process of growth vacuoles are then formed in the contents of each conidium and the protoplasm becomes separated by fine lines of demarcation into 5 to 8 portions, which develop into zoospores in the course of from 1½ to 3 hours. If not immersed in water the conidia of cystopus may remain unchanged for as long as a month.

Thus, every kind of definitely organic particle encountered may be explained on the basis of spores of microfungi, and the recent abnormal increase in their numbers may be the outcome of weather conditions particularly favourable to their development.

It is probably more than a coincidence that these mould cells appeared in the autumn apparently for the first time, at least were detected then for the first time, and one naturally looks for something which occurs in the autumn and not at other times of the year to account for this. The fall of the leaf is one of the most obvious signs of autumn and when the leaves are dead and exposed to continuous damp they are likely to support the growth of moulds of different kinds.

One can easily conceive of threads of mould cells growing up from the surfaces of dead leaves, and the spores produced being swept away by the wind. Also, when the leaves have fallen they are carried about in the wind and rubbed against each other so that any mould on the surface is more than likely to become detached and set free in the air.

To test this hypothesis a number of dead leaves from the trees in the neighbourhood of Cheam were collected by Dr. Owens and on examination under the microscope there was evidence of mould on some of them, but not in any quantity. The leaves were dry at the time and possibly any mould would have become detached, but in the angle between the mid-rib and the lateral ribs of the leaves at the back there were in many cases masses of white thread-like material. A piece of one of these leaves was placed on a drop of water under a watch glass and within 12 hours a plentiful crop of mould had appeared with branched threads of spores.

It appears probable, therefore, that dead leaves were the chief source of the mould cells found in the air.

As a further test, on October 29th, a disc was cut from a leaf of suitable dimensions to fit in the jet dust counter; this was sterilised by boiling and a record was taken on it at 9 a.m. by drawing 1,000 cc. of air through the instrument. The disc of leaf was placed under a glass in a drop of boiled water in a dark place, in the hope that spores collected on the leaf would produce a growth of mould similar to that already found upon the unsterilised leaves. The result was negative, but this may have been due to complete absence of spores in the litre of air drawn through the instrument on this occasion.

A number of the leaves were placed in a box lined with moistened absorbent material, over a microscope slide, though not in actual contact with the slide. After an interval of one day the slide was removed and was found to be densely covered with organic bodies containing specimens identical with every kind previously encountered in the records of the jet instrument, thus affording strong evidence that the latter were actually derived from moulds growing upon the dead leaves, the growth having probably been assisted by the abnormally wet weather which had prevailed for some time.

Many photomicrographs of the organic particles found in various records, and also of the mould cells collected from moist dead leaves were taken, and typical examples are furnished in Figs. 9 and 10. The similarity between the bodies from these two sources is very marked when they are seen actually under the microscope, although the appearance in the photographs is somewhat different. This is due to the fact that in the records of the jet instrument, the cells are projected on to the slips at high velocity and make good contact with the glass, so that they lie in one plane and may be brought into focus more satisfactorily than those which have settled down slowly.

The possibility of fungi growing on the blotting paper lining the walls of the damping chamber of the instrument has not been overlooked. Records were taken for comparison using a damping chamber which had been in use for some months and a chamber freshly prepared with new blotting paper. The result in each case was the same, and no growth whatever could be detected on the old blotting paper after removal from the instrument.

(6) Crystals in the Air.

The occurrence in dust records of crystals of various kinds, sometimes well-defined and sometimes skeletal has been noted on many occasions.* Several records taken in October, 1923, contained abnormally large amounts of crystalline matter. For instance, records on Sunday, October 21st, both in London and at Cheam contained many crystals, some square and undoubtedly consisting of sodium chloride. This is mentioned as being of interest in view of the severe gales just previously experienced, particularly on the south coast, during which quantities of salt were doubtless thrown into the air.

(7) Cleaning of Cover Slips.

Reference was made in the last *Annual Report* to deterioration of records on keeping, due to condensation of drops of liquid on the lower surface of the cover slip. This condensation was apparently independent of the dust record and it appeared possible that it might have been due to hygroscopic material left on the cover slip after cleaning. The most convenient method of cleaning is rubbing by means of a handkerchief, which leaves the surface free from particles, but care must be taken that the handkerchief is not previously handled otherwise very obvious smears of greasy matter may be left on the slip. The risk of contamination of the handkerchief by hygroscopic salts from contact with the hands must be always great and may account for the subsequent condensation of drops on the cover slip. Occasionally instead of drops, perfectly formed dry crystals, or small particles, probably crystals too small to show any characteristic shapes, develop on the slip, apart from the dust record.

The nature of the drops is difficult to determine since they immediately evaporate if the cover slip is raised from the mounting, but they probably consist of :—

(*a*) Something volatilised from the adhesive used,

or (*b*) Water condensed on hygroscopic nuclei.

With regard to the former possibility, Canada balsam or other cement containing a volatile solvent cannot be used for dry mounting the cover slips since the solvent rapidly condenses into drops in the closed cell under the cover slip. For this reason the resinous adhesive now always used was chosen and it should contain no readily volatile constituent. As

* *Ninth Report*, M.O. 260.

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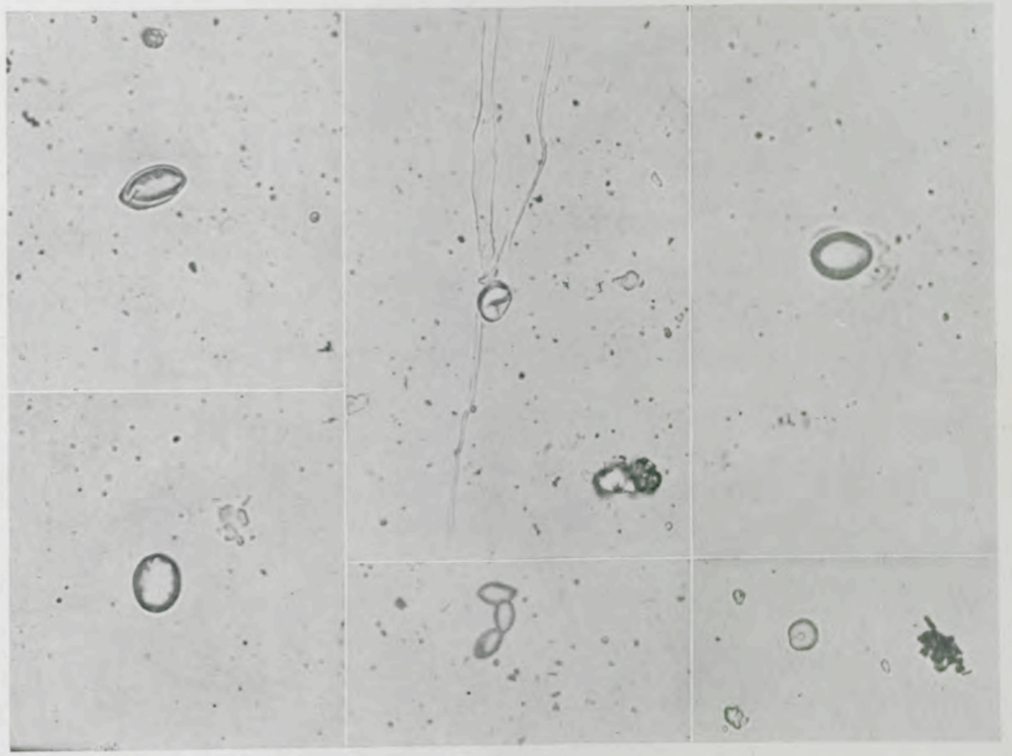


Fig. 9.

Organic Particles collected from the air of Cheam, Surrey. November 19th, 1923. Magnification—1,000 diameters.

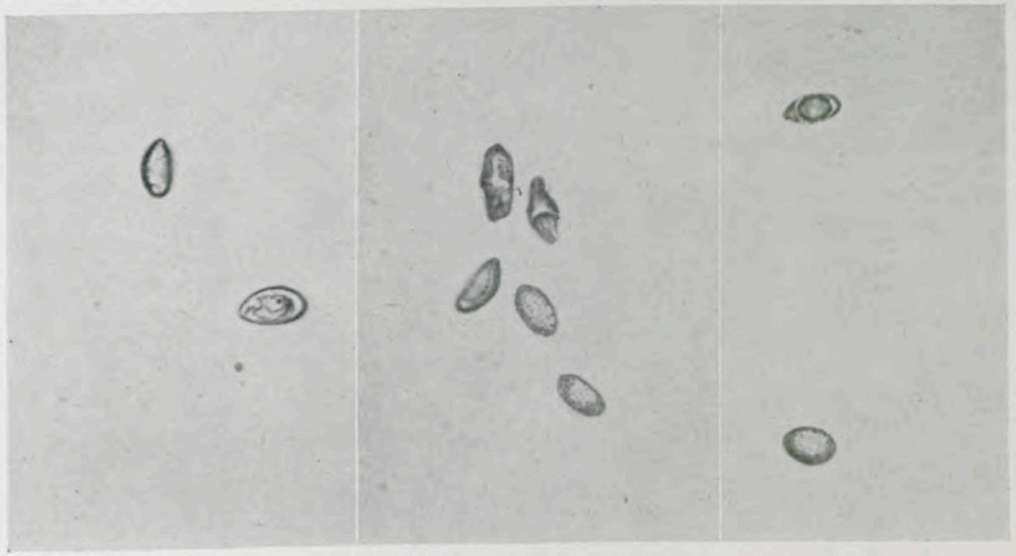


Fig. 10.

Mould Cells, fallen from moist dead Leaves collected at Cheam, Surrey. November, 1923. Magnification—1,000 diameters.

x 23645

already mentioned, the drops under discussion are very readily volatile. It has, however, been noted repeatedly that the drops form most abundantly upon slips which are well sealed down round the edges; if the ring of adhesive is not continuous and communication exists between the cell within the ring and the outside air, the tendency to form drops is definitely retarded.

On the other hand, when a record contains hygroscopic nuclei, such as crystals of sodium chloride—small crystals of which are very hygroscopic—condensation takes place upon these nuclei, which supports the water condensation theory of the origin of the drops. Again, when water is allowed to flow under a clean cover slip, as in experiments on staining of particles from the air, the glass for some distance in front of the advancing edge of the water becomes very densely covered with drops, which often run together and make the actual boundary of the water quite indefinite, thus showing the great tendency for water drops to condense on even carefully cleaned slips.

Strong evidence of the independence of the drops and the dust records on cover slips is given by examples such as the following:—

On April 27th, 1923, records were taken at 10.8 p.m. and at 10.30 p.m., and the cover slips were mounted under identical conditions side by side on the same slide; both cover slips were well sealed down. On May 15th, 1923, the 10.8 p.m. record was as good as when first mounted, the slip being quite clean apart from the linear dust trace, but the cover slip with the 10.30 p.m. record was densely covered with drops. The inference is that the slip used in taking the latter record was cleaned by means of a portion of the handkerchief which had been touched by the hand and become covered with hygroscopic salts.

Four tests slides were therefore prepared to investigate the best methods of cleaning. These may be conveniently referred to as A, B, C, and D.

The slip A was cleaned by means of a soft handkerchief of fine texture which had not been unfolded since washing and was mounted upon a slide which had been kept with its adhesive for three weeks in the case of the dust counting instrument.

The slip B was cleaned by means of a cheaper quality cotton handkerchief which had been carried in the pocket, and was mounted upon the same slide as A.

To eliminate any effects due to volatile matter which may have fallen on to the slide when in the case of the instrument, two other slips, C and D, cleaned in a similar manner to A and B respectively, were mounted upon a slide freshly fitted with tin rings coated with adhesive. The portion of the slide under C was cleaned by means of the soft handkerchief and the portion under D by means of the cheaper cotton handkerchief. All the slips A, B, C and D were practically free from markings and would be regarded as clean enough for use in taking dust records. No drops whatever were present on any of the slips.

Twenty-four days later the slides were examined under the microscope.

On A there were no drops but the slip was densely covered with very small, dry particles. At the edges of the slip, near to the tin ring, the particles were larger and spaced further apart, and very close to the adhesive there was a clear ring entirely free from particles. In the centre the number of particles, all on the limit of resolution of the microscope, per square millimetre of surface was approximately 40,800, and the scattering was apparently indiscriminate. Near the edges, however, the larger particles were definitely formed into symmetrical groups—evidently the beginning of some crystalline structure, and in places the orientation of thread-like crystals which were forming suggested the movements of the handkerchief during the cleaning of the slip.

The slip B was covered with equally distributed particles much larger than those in A, of bluish transparent appearance. The number per square millimetre was approximately 20,400. No drops were present and there was no sign of symmetrical arrangement of the particles or other surface markings.

On C there were neither drops nor particles; the slip was as clean as when first mounted.

D was covered with particles not arranged in any symmetrical pattern, but there were no drops. Each particle took the form of a fine thread about 10 microns long, with a slight knob or thickening at one extremity. The number of these per square millimetre was approximately 3,000.

The slides were then stored for exactly one year, when they were re-examined. The adhesive showed marked deterioration which had evidently begun where exposed to the air. Here it was opalescent and hard and the decay was spreading evenly under the edges of the cover slip.

The bottom of the cell under A had become densely covered with particles, apparently all crystals of two kinds. Some were clear and roughly spherical with a square tendency, generally from 1.7 to 3.5 microns across and others were very fine bluish needles approximately 35 microns long.

The number of large crystals per square millimetre of surface was approximately 3,300 and the number of small needles about 24,500.

The cover slip was densely covered with drops approximately 550 per square millimetre, curiously grouped into clusters, and patches of dry crystals, but there were practically no small black particles. The drops varied in diameter from 3.5 to 8 microns. There were numbers of long threads of colourless crystals up to 5 millimetres long, curled into spirals, and branched in all directions. Other dry, rhomboid crystals were present and one dense circular patch of needle shaped crystals was .57 millimetre in diameter.

The slip B was covered with drops, but no particles or crystals. The drops, up to 20,400 per square millimetre, were generally about 7 microns in diameter, but the largest were up to 14 microns in diameter and the smallest 1.8 microns.

The slip C was also covered with drops of the same size, up to 6,500 per square millimetre, with no particular arrangement except occasional streaks, suggesting the movement of the handkerchief during cleaning, together with a very few small, glassy looking particles about 1 micron in diameter, each surrounded by a drop of liquid.

No drops were present on slip D, except at the extreme edges, where they were evidently derived from the adhesive, but it was densely covered with perfectly formed dry, rhomboid crystals up to 11 microns in length, together with an enormous number of very fine particles on the limit of resolution of the microscope—approximately 44,500 per square millimetre.

It appears to be impossible that the relatively great amount of material present upon the four cover slips could be derived from the handkerchief used in cleaning the slips; the crystalline matter at least probably comes from the adhesive, which is in an obviously unstable chemical condition. The large crystals would be hardly likely to interfere with the counting of any ordinary dust record, and the most serious form of rapid deterioration appears to be due to hygroscopic material left on the slip during cleaning, which emphasises the necessity for keeping a special cloth for the purpose, and the exclusion of dust from the slides before the cover slips are mounted. The best plan would probably be to keep a stock of well-washed cotton slips, each to be used once only, when the records may be expected to remain in good condition for a considerable time. No better adhesive than the resin mixture employed has yet been found and for the present an absolutely permanent method of mounting the records dry cannot be given. They may be mounted permanently and preserved indefinitely immersed in a medium such as Canada balsam, but the disadvantage of this method, such as the complete disappearance of a large proportion of the smallest particles and the difficulty of manipulation outside the laboratory, render it unsuitable for general use.

(8) Specification of Microscope for the Examination of Dust Records

For the convenience of those wishing to undertake a microscopic examination and counting of dust particles in the air obtained by means of the jet instrument for dust sampling, a specification of a microscope suitable for the purpose is given below, together with brief instructions for the use of the dust counter. With such an instrument and accessories the counting of dust records should present no difficulty. This specification has been prepared because many really good microscopes, excellent for other purposes, are not suitable for this particular work.

Microscope Body and Stand.—The microscope itself should be of good, firm design, suitable for the use of high power objectives. It should be provided with a built-in mechanical stage with two movements at least 1 cm. in extent, at right angles to one another, and preferably the top plate above the moving mechanism should be capable of rotation, so that a particular line on the slide to be examined may be set parallel to one of the traversing movements of the stage. Failing the revolving top, large clips permitting the slide to be orientated in practically any direction on the stage may be used, but non-rotatable mechanical stages with special clips for holding the slides in one fixed position, such as are fitted to many microscopes, are unsuitable. Vernier scales are useful, but not really necessary.

It is possible to make use of a microscope with fixed stage for counting dust records by the addition of a small fitting designed by Dr. J. S. Owens,* but this is not nearly so convenient as a built-in mechanical stage, as above recommended.

Below the stage there should be a focussing sub-stage, with centring adjustment, fitted with a condenser of the Abbe type, with stop carrier below the bottom lens.

A double or triple nosepiece—preferably of the dust-proof type—is almost a necessity, and the objectives carried must centre fairly accurately one with another, otherwise difficulty will be experienced in finding the dust record under the higher powers. Other means of changing the objectives are not so convenient as the rotating nosepiece.

Objectives.—Three objectives at least are advisable, the most useful for ordinary work being a $\frac{2}{3}$-inch (16 mm.), $\frac{1}{6}$-inch (4 mm.) and $\frac{1}{12}$-inch (2 mm.) oil immersion. An essential property of all the objectives is flatness of field, which generally entails some sacrifice of numerical aperture. Special research objectives of very high numerical aperture and correspondingly good power of resolution are not suitable for the present purpose, for with them it is impossible to bring into focus at the same time more than a small section of the field of view, while they present in this case no compensating advantage over the more usual and cheaper objectives.

Atmospheric dust records must be mounted and examined dry, that is, not immersed in any mounting medium, otherwise many of the smaller particles near the limit of resolution of the microscope disappear completely, and the difficulty of obtaining a medium sufficiently free from particles not to interfere with the counting is appreciable. Thus an air space is necessarily introduced into the system above the condenser and the high numerical aperture of an oil immersion objective cannot be effectively utilised.

Furthermore, with the low power it is essential to use dark ground illumination, which cannot be easily accomplished under an objective of high numerical aperture, unless the aperture is reduced by the insertion of a special stop.

A 2/3-inch of numerical aperture 0·28 achromatic.
a 1/6 „ „ „ 0·74 semi-apochromatic.
a 1/12 „ „ „ 1·28 achromatic.
and a 1/15 „ „ „ 1·30 semi-apochromatic.

have been used for some time at the laboratory and have given every satisfaction. Objectives of similar make and type can be obtained with mounts of such length that on changing from one to the other by turning the triple nosepiece practically no movement of the tube is necessary for re-focussing, a property which is of the greatest convenience.

* *Ninth Annual Report*, M.O. 260.

Eyepieces.—Eyepieces of magnification × 6 and × 10 are generally sufficient, but a higher power, say × 20 is useful. Two eyepiece reticules, or micrometers, are necessary; one, which is used for counting the particles, ruled in millimetre or half-millimetre squares, and the other bearing an ordinary scale for measuring the dimensions of the particles. A stage micrometer is required for calibrating the reticules. Reticules produced by a grainless photographic process serve quite well and may be obtained comparatively cheaply. It is of importance that the lines, however produced, should be on clear glass; one form of reticule specially designed for use in processes involving counting under the microscope, in which alternate squares are slightly tinted in a chess-board design should be avoided. This form of micrometer may be satisfactory for the counting of relatively large bodies, such as blood corpuscles, but it is unsuitable for counting small dust particles.

The reticules may be used in conjunction with the × 6 eyepiece, if this is of the Huygenian type, supported within the mounting on the usual light stop. This arrangement, however, leaves no satisfactory provision for focussing the scale to suit the sight of different observers, and it is very much preferable to use a special micrometer ocular, in which the top lens is mounted upon a sliding tube for focussing. One such ocular may be used, but to avoid constant changing it is generally worth while providing a separate one for each reticule.

Accessories.—A series of about three stops to fit the carrier in the condenser should be provided for purposes of dark ground illumination, and the smallest which will give a good black background with the $\frac{2}{3}$-inch or 16 mm. should be used. Occasionally, for rapid approximate counting, it is desirable to use dark ground illumination under the $\frac{1}{6}$-inch objective, with numerical aperture suitably reduced. In this case it may be necessary to use a larger stop than is required under the $\frac{2}{3}$-inch.

A polariser and analyser are useful fittings, especially when it is desired to investigate special dust likely to contain mineral matter, for instance, particles from the air of mines or factories.

The interposition of a piece of pale blue glass—not Spitta blue—between the source of light and the microscope often improves the definition appreciably, which is of importance when particles near the limit of visibility are being counted.

For illuminant, an ordinary 60-watt gas-filled lamp with white-opal, or imitation opal bulb, is highly satisfactory, and is recommended in preference to any other light source for general convenience and suitability for dark ground illumination.

Daylight is not suitable.

Where electric light is not available an oil lamp flame or incandescent gas may be used.

(9) Preparation of Slides.

A convenient method was described in the last *Annual Report* for the mounting of dust counter records dry, that is, with the particles not embedded in any solid or liquid medium. This dry mounting is necessary since if mounted in a liquid the larger particles are liable to be swept away and the smallest particles near the limit of resolution of the microscope disappear, no doubt owing to the similarity between their refractive index and that of the mounting medium. For this reason the method of mounting dry, which admittedly has certain small disadvantages, was evolved, in which thin rings of tin coated with a special adhesive are fixed upon microscope slides. The adhesive does not dry, but remains tacky, so that after taking a record all that is necessary is to place the cover glass upon the ring, record downwards, and press gently, when it is at once firmly mounted and cannot be removed without warming. The record is thus mounted in air on the underside of the cover glass.

For the preparation of the slides for use the following procedure has been found convenient :—

Clean the surfaces of the required number of slides and lay out on a level table. Press the tin rings between two flat surfaces, such as two slides, so as to remove bends and make them lie quite flat. Melt the adhesive over a bunsen flame, not allowing to become hot enough to give off visible fumes, and into it dip the tin rings one by one, held in a pair of long, pointed metal forceps slightly warmed in the bunsen flame. This warming prevents the collection of adhesive on the forceps and the formation of strings of adhesive. In removing the ring from the adhesive touch the surface of the liquid with each ring to remove the hanging drop, and then place the ring in the required position on the slide. Once the ring is on the slide its position cannot be easily altered. Place the slides with rings one by one on a flat piece of metal and warm the metal gently until the adhesive just melts and flows into an even coating on the rings. Remove the slides and place in a level position to cool.

The rings will then be cemented all round to the slides and will have a coating of adhesive also on their free surfaces. The slides should be placed in a box free from dust until required for use.

Slides thus prepared should remain suitable for use for several weeks, after which the adhesive becomes opalescent and hard. The rings may then be conveniently removed from the slides by immersing them in a tall narrow beaker of benzene, after which they may be re-coated with adhesive. It is advisable to prepare sufficient slides to last for about three weeks only owing to the hardening referred to.

(10) Taking the Dust Samples.

Fix the pump to the body of the instrument, remove the plug and place on a bench with the three-claw spring upwards. Then clean a microscope cover glass by wiping with a rag moistened with benzene or xylol, if necessary, and finally by breathing on the glass and polishing it with a clean, soft cambric handkerchief reserved for the purpose, rubbing the slip enclosed in the handkerchief between the finger and thumb. After a little practice it is possible to tell by the "feel" of the slip when all dirt is removed. On examination under the microscope, with a low power objective and dark ground illumination described below, the slip should be free both from dust and from smears of grease. A silk handkerchief is not recommended as it is not suitable for taking off fine smears of grease, which are the most troublesome markings to remove.

Take up the clean slip by the edges between the finger and thumb and place upon the spring of the plug, when it will be supported free from contamination, with the lower surface protected from falling dust.

If in the open, where it is too windy to place the cover glass down, or where there is no convenient place to do so, it will be found easy to hold the clean cover glass by the edges between the finger and thumb of the left hand, taking care not to touch its surfaces.

Having ensured that the blotting paper in the damping chamber is wet, take up the apparatus by the pump, avoiding touching the damping chamber, and close the hole for the plug by pressing against it the base of the thumb. Withdraw the pump handle six or eight times to fill the damping chamber with air to be tested, pick up the cover slip by the edges and place in position in the cell, with the lower protected surface downwards. Screw in the plug and pull out the pump plunger smartly so as to draw one or more volumes of air through the jet, allowing an interval of about 10 seconds between each stroke.

Remove the plug and drop out the cover slip on to the hand. The record is now on the upper surface of the glass, therefore pick up the slip by the edges without delay and invert. By holding in a bright light and examining against a black background, it is usually possible, in cities, to see the direction of the linear deposit of dust.

Place the slip, suitably orientated, upon the tin ring of a prepared slide with the record downwards. Hold the slip in position for a few seconds under the thumb, when it should be firmly sealed down all round the ring. The top of the slip may now be cleaned.

The slides should be labelled with the following particulars:—

1. Number.
2. Place of taking record.
3. Time of taking record.
4. Volume of air drawn through jet.
5. Date.

It will generally be more convenient to number the slides and to enter full particulars in a notebook, where a record of prevailing weather conditions, wind direction, visibility, &c., may also be kept.

(11) Examination of Records.

There is generally difficulty in finding the dust records under the microscope unless dark ground illumination is employed. When using a low-power objective, such as a 1 inch or $\frac{2}{3}$ inch, and a centre stop of suitable diameter is placed in position in the carrier under the condenser, the iris diaphragm being opened to its fullest extent, the centre rays which would normally pass directly through the objective to the eyepiece are cut out, with the result that the object viewed is strongly illuminated from all sides, but the background appears black. This is termed "dark-ground illumination." The stop used should be the smallest compatible with the production of a dark background, when with an illuminant such as already specified above, the smoke particles stand out vividly as bright spots, and the dust record is easily visible, even when containing comparatively few particles.

For accurate counting and measurement of particles it is essential that an oil immersion objective should be used. A rough count may be made under a $\frac{1}{6}$ inch (4 mm.) objective and dark ground illumination, but this furnishes no information as to the size of the particles, the majority appearing as spurious diffraction discs, and further the number of particles seen depends upon the strength of the illumination employed. The smallest particles generally cannot be detected by this means. Dark ground illumination of particles mounted dry is possible under a $\frac{1}{6}$ inch when a special stop is inserted in the objective to reduce its numerical aperture. Special condensers for the production of dark ground illumination with objectives of high numerical aperture are not suitable for use with dry-mounted specimens.

(12) Arranging Slides for Examination.

The slide should be placed in position on the stage and arranged, either by sliding it about under the holding-down clips or by means of a rotating plate, so that the record runs parallel to one of the movements of the mechanical stage and at right angles to the other. Thus by turning one milled head the record can be examined from end to end, and by turning the other it is moved across the field. The $\frac{2}{3}$-inch objective and dark ground illumination should be used at this stage.

During counting it is necessary to move the record laterally by means of the mechanical stage, keeping some part in view all the time. Consequently, the movement of the stage must be very steady. In most microscopes the to-and-fro movement is effected by means of a rack and pinion, and the left to right movement by means of a screw. The latter is more easily controlled than the former, and should be reserved for the above lateral movement of the record for counting. It is thus desirable that the dust trace should be arranged at right angles, and not parallel, to the length of the microscope slide, if a stage of this type is used. Should both movements be operated by screws, the record may be arranged longitudinally on the slide, if desired.

The net-ruled micrometer eyepiece should then be inserted and placed so that one set of rulings runs parallel to the length of the record. Without moving the eyepiece or slide, the high-power objective should be brought into operation. It is assumed that the various objectives are correctly centred with regard to one another and to the substage condenser. The stop must be removed or definition will be bad. The light should be adjusted by means of the iris diaphragm to give the best resolution. A piece of pale blue glass interposed between the source of light and condenser will often improve the definition. The width of the record will now more than fill the field of vision, hence the necessity for setting the record parallel to the direction of movement of the stage under the low power.

If it is desired to employ a microscope without built-in mechanical stage, by utilising the small special fitting to which reference has already been made, it is best to mount the records with the linear deposit in the long axis of the slide; also, as the attachment raises the microscope slide a few millimetres above the stage, it will be necessary to adjust the height of the condenser to suit the level of the slide.

(13) Counting.

It is required to count the particles in a strip one square wide, running completely across the record at right angles to its length. Since the record is in the form of a line of known length and of uniform width and scatter, simply multiplying the count of one strip by a factor, depending upon the magnification of the microscope, will give the total number of particles in the record. To ascertain the factor, the number of such strips in the length of the record may first be counted under the low power. Supposing a $\frac{2}{3}$-inch objective is used for counting the number of strips, and there are fifty strips in the length of the record; then, if the $\frac{1}{6}$-inch magnifies four times as much as the $\frac{2}{3}$-inch, the number of strips when using the $\frac{1}{6}$-inch will be 200. If the $\frac{1}{12}$-inch magnifies ten times as much as the $\frac{2}{3}$-inch, the number of strips will be 500, when examined under the $\frac{1}{12}$-inch. If the magnification produced by the various objectives is not known, it may be ascertained once for all by the use of a stage micrometer, that is, a glass slide on which is ruled a series of fine lines at known distance, say, 0·001 cm. apart. Care must be taken that the draw tube of the microscope is in its correct position for the objective used, and the same position must be adhered to in making counts. Supposing that in a particular case 300 particles are found in a strip across the record when examined under the $\frac{1}{12}$-inch, and that 50 c.c. of air have been drawn through the jet, the number of particles per c.c. will be:—

$$\frac{300 \times 500}{50} = 3000$$

Generally, if:—

S represents the number of strips in the length of the record,
N represents the number of particles per strip,
C represents the number of c.c. drawn through the jet in taking the record,

then:—

$$\text{Number of particles per c.c. of air} = \frac{N \times S}{C}$$

To simplify matters it will be advisable to use the same volume of air for each record as far as possible, and to count under the same eyepiece and objective.

Thus the factor $\frac{S}{C}$ will remain constant.

By turning the milled head of the mechanical stage shift the slide so that the record moves just off the right hand side of the field of vision. Select a row of squares near the middle of the reticule to define the strip to be counted and slowly move the record into view, counting the isolated outlying particles as they cross a convenient vertical line. When the thinly scattered outlying particles are passed, the rest of the record should be counted square by square. Bring the last of these scattered particles to the edge of the left hand square of the selected strip and write down the number of particles visible in each successive square to the other end of the row. Then, by means of the mechanical stage, bring the last particle counted back to the starting square and continue with the counting. This may be repeated until the opposite side of the record is reached, when the few isolated scattered particles on that side may be counted as before while moving the stage.

The image produced by the objective may not be sufficiently good to permit of counting the particles in the squares at the edge of the reticule. With one particular objective it has been found best to use only the middle four squares in the eyepiece and to move the stage several times in the counting of each strip across the record.

It is advisable to count two or three transverse strips at different parts of the linear record and to take an average of the results, which should agree to within 10 per cent.

It is easiest to obtain a reliable count of a record when the maximum number of particles per square of the reticule is about 20 to 30, which, after a little practice, can be fairly accurately estimated at a glance. A record of this density is just conveniently visible to the naked eye and permits of easy mounting in the correct orientation on the slide.

During an ordinary winter day in London, it is sufficient to take only one stroke of the pump; on a clear summer day in the country as many as 40 strokes (2 litres) may be necessary. On the other hand, in a dense smoke fog 50 cc. may give too dense a record, as already referred to under "Double Slot," Section 4, *Ninth Report*.

If a record is wavy or broken this is due to the presence of dust in the slot of the instrument which should be cleaned by means of a slip of thin paper pushed through from below, moistened with xylol if found necessary.

(14) Size and Nature of Particles.

In addition to the number of particles counted a note should be kept of their dimensions, shape and other characteristics. The sizes may be measured by means of the eyepiece scale, previously standardized by comparison with a stage micrometer. The record may consist of minute black smoke particles, crystals, spheres—transparent or opaque, and aggregates of numbers of particles.

It will generally be found that smoke particles tend to be of a uniform size, which should be noted, together with the maximum diameters of isolated particles, aggregates, etc. The smallest generally grade down to the limit of resolution of the microscope; particles below a critical dimension appear as spurious discs due to diffraction, this dimension depending upon the objective used.

(15) Method of Obtaining Crystals from the Deposit

An alternative method of using the instrument, which provides additional information as to the nature of the dust was referred to in the *Eighth Annual Report*. This is briefly as follows:

In taking a record for the purpose of counting the instrument is held in the hand by the pump barrel and the volume drawn through is adjusted so as not to get too heavy a deposit. In the method now referred to the instrument is held with the damping chamber in the left hand; this slightly warms the damping chamber and more water is given to the air drawn through the jet. A sufficient volume is then drawn through to give a heavy deposit, say 20 times the volume required for counting. The effect obtained under these conditions is that a comparatively large quantity of water is condensed upon the record and filters through it, being blown out laterally as the air flows away along the surface of the cover glass. As the water evaporates the soluble salts contained in the dust, which have been dissolved in the water, crystallise out upon the cover glass, and the form of record obtained shows dried-up stream beds flowing out on each side of the dust deposit. In the beds of these streams, at the ends, crystals may often be observed and these can be examined in the usual manner.

(16) Examining Dust for Acidity or Alkalinity.

By taking a heavy record, as described above for crystals, upon a cover glass on which two half discs of thin neutral filter paper are stuck, one made red with acid methyl orange solution, and the other yellow with alkaline solution, the characteristic colour change due to acid or alkaline dust can be obtained. In this case the record should be taken across the junction of the two half discs so that one half shall be on the red, and one on the yellow paper.

SECTION 5.—SPECTROGRAPHIC ANALYSIS OF SUSPENDED IMPURITIES.

A preliminary experiment was made on December 21st, 1923, to test the practicability of a spectrographic analysis of matter collected from the air. The impurity was collected on a glass cover slip by means of the standard jet instrument connected to a filter pump, from which the discharge of air was passed through a gas meter, and measured at atmospheric pressure.

The pump was maintained in operation for two hours, 19 cubic feet of air being drawn through the instrument, when a heavy deposit was collected upon the cover glass.

Several photographs of the spectrum of an arc passing between electrodes of pure copper were taken by means of the quartz spectrograph, different exposures being given. The electrodes were then thoroughly cleaned and the collected dirt transferred as completely as possible to the flat end of the lower one. The other electrode, which was pointed, was pushed through the dirt and made to touch the lower electrode. The whole was then arranged in front of the slit of the spectrograph and the current was switched on. The copper poles were just separated and the deposit of dirt volatilised in the arc.

The result was not satisfactory, no lines due to the volatilised matter being visible, but the method presented no obvious difficulties, and after further experiments regarding the necessary exposure of the photographic film definite results should be obtainable. It is proposed to deposit the dust directly on to platinum foil in a special form of collecting apparatus, and to volatilise in an arc between this foil and a platinum wire, thus eliminating all danger of contamination of the deposit during transference to a separate electrode.

SECTION 6.—THE SETTLEMENT DUST COUNTER.

The object of this instrument is to enable a true count to be obtained of the number of dust particles or bacteria contained in the air, even when such dust particles are very coarse. The ordinary method of exposure of a plate or dish for a given time, while giving a roughly comparative result, has little value as a quantitative method, since the amount of dust deposited upon a plate exposed in the open depends upon many variable factors, such as size of dust particles, their density, temperature of air, degree of turbulence of the air; while, in addition, the deposit is obtained from an unknown volume of air. The present instrument is designed to eliminate these sources of uncertainty.

The instrument depends upon the principle of enclosing a definite volume of air to be tested in a small vessel with suitable precautions, the height of the vessel being known. The dust in a column of air of this height is allowed to settle upon the surface of a cover glass, where it is subsequently counted. Thus, the area of the base and the height of the column being known, the amount of dust per unit volume of air can be calculated.

To permit the measurement of bacteria, the instrument is of such design that it admits of being easily sterilised by heating.

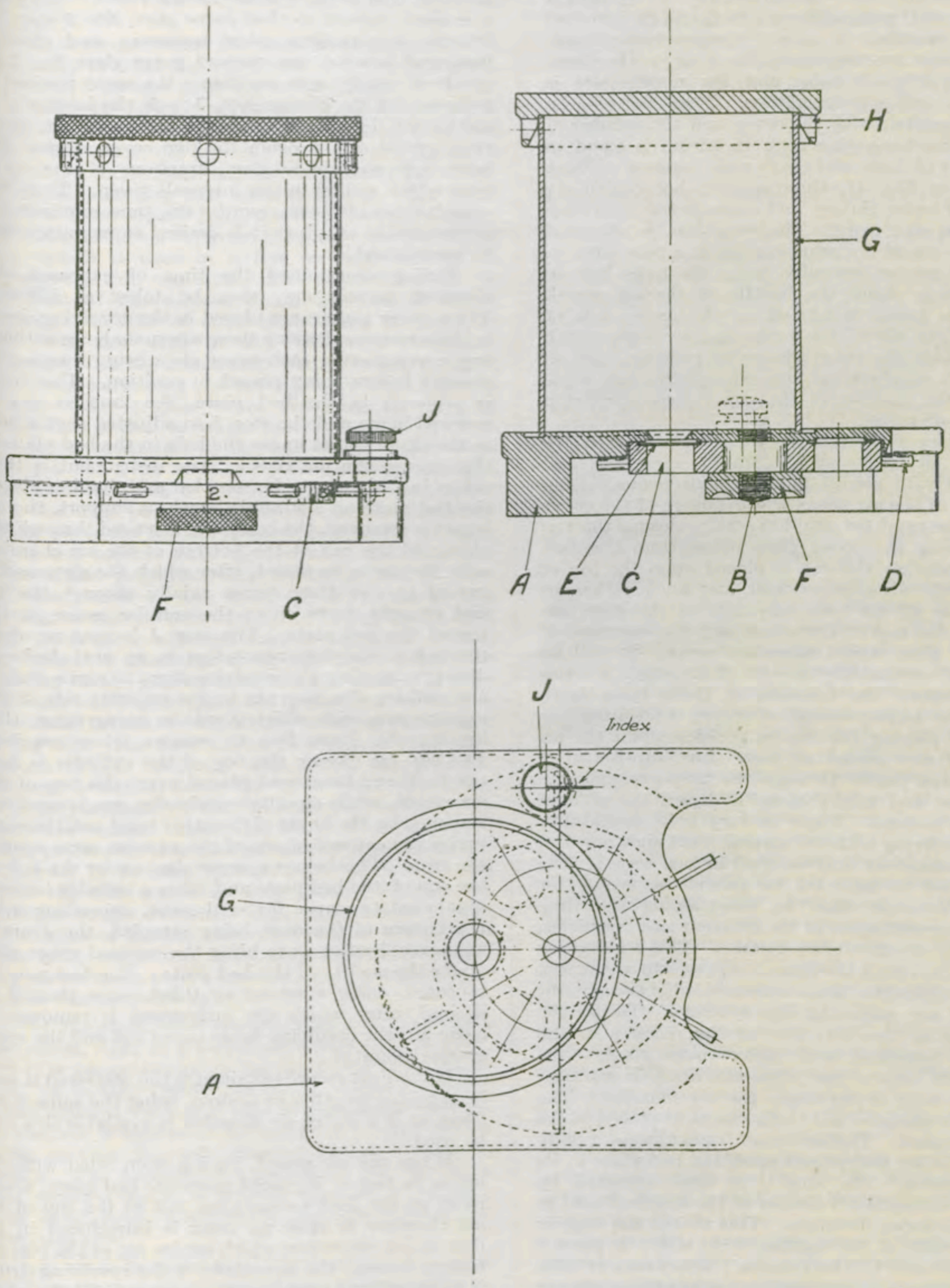
Referring to Fig. 11, the instrument consists of a heavy platform, or bed plate A, on the upper surface of which a cylindrical air vessel G, open at both ends, is placed. An annular ring is formed in the upper surface of this bed plate to receive the lower end of the cylindrical air vessel. A loose cap H is also provided for closing the upper end of the air vessel.

Referring to the air chamber G, it will be observed that this is a plain, open-ended metal tube. It is made in this form intentionally to permit it to be easily filled with the air to be tested by sweeping it axially through such air, and also in order that vessels of different height may be used if desired.

The diameter of the air chamber is made very large compared with that of the cover glass, with the object of eliminating any effect which might be produced by the sides of the vessel.

Situated centrally under the axis of the air vessel is a circular hole penetrating the bed plate, which permits dust settling from the air to pass through it and on to a microscope cover glass placed beneath the hole, as subsequently described. The under surface of the bed plate has a circular recess formed therein, eccentric to the axial hole, the recess receives a drum C pivotted at its centre to the bed

Owens's Settlement Dust Counter.



Scale: Half size.

Fig. 11.

plate by a pivot B, and held in position by a knurled nut F. Around the circumference of the drum capstan arms D project, by which it can be revolved round its spindle. A stop J is provided, which serves to limit the rotation of the drum. The drum has six equidistant holes and the upper part is recessed to receive cover glasses. These holes lie on a circle concentric with the drum and the number of capstan arms projecting from the drum is equal to the number of holes and cover glass recesses. Thus, as shown in Fig. 11, there are six holes with six recesses for cover glasses, and consequently there are also six capstan arms. The stop J is so disposed that when one of the arms engages it a hole with its recess will appear centrally under the axial hole in the bed plate under the middle of the air vessel. An annular recess is formed on the under side of the bed plate above the holes and recesses, which serves to hold the cover glasses in position, and an index with numbers on the side of the bed plate indicates the number of the cover glass appearing under the air vessel.

The object of the design is to enable a representative sample of air to be enclosed in the air vessel and subsequently to permit of the simultaneous closing of the top of the air vessel and exposure of the cover glass. The need for simultaneously closing the top and exposing the cover glass arises from the fact that immediately the cap is placed upon the top of the vessel the air is imprisoned, and since settlement is going on all the time any interval between the closing of the top of the vessel and the exposure of the cover glass would introduce error. It will be noted that surrounding the rim of the cap is a series of open holes; the function of these holes is to prevent the imprisonment of excess air during the process of placing the cap in position upon the air vessel. If any excess air were thus imprisoned it would escape partly through the hole exposing the cover glass and might cause a deposition of dust during its passage. There is very little probability of such occurring with the arrangement shown.

The instrument may be used in two ways:—The first method is intended to provide a means for grading the dust, that is, ascertaining the time required for settlement of the different sized particles, and also the numbers of each grade. This is necessary in order to ascertain the time of exposure to settlement which is required to obtain a true record of the amount of dust of any particular size or shape. To use the instrument in this way five of the recesses in the drum are provided with clean cover glasses, the sixth is left empty, and when the drum is replaced the empty hole is put under the air chamber. The air vessel is removed and the instrument placed in the air to be tested. The air vessel is next swept axially through the air and placed upon the bed plate in its annular recess. The stop J is next adjusted by making a complete revolution of the knurled head in an anti-clockwise direction. This moves the stop to the other side of the capstan arm, which is pushed slightly forward in the process. The drum is then free to revolve when required, so as to expose a cover glass; the cap H, which has been placed mouth downwards to prevent contamination with dust, is now placed upon the top of the air vessel, while simultaneously the drum is revolved to bring cover glass No. 1 in position under the air vessel. The stop J is again moved so that cover glass No. 2 may be brought into position when necessary, and after a measured interval has elapsed cover glass No. 2 is revolved rapidly into position; the same process is repeated for the glasses Nos. 3 to 5, the interval for settlement depending upon the nature of the dust. On removal of the drum the five cover glasses will have deposited upon them fractions of the total dust which settled in the intervals given. Thus, by examination of these records, the time required for settlement of the dust it is desired to examine may be ascertained.

Having ascertained the time of exposure the required records may then be taken as follows: Three cover glasses are placed in the revolving drum in their recesses, leaving three alternate holes without any cover glasses, each cover glass being thoroughly cleaned before being placed in position. The drum is replaced in the bed plate, the knurled nut F screwed home and the stop J so adjusted that a hole in the drum comes under the hole in the bed plate in the axis of the air vessel. The instrument is then taken into the air to be sampled and, having placed the bed plate on a suitable bench or support, the air vessel is removed, the bed plate is waved through the air to fill the cell at the bottom of the air chamber with the air to be tested, after which the air vessel is passed two or three times axially through the air and brought down on to the annular recess on the top of the bed plate. The stop J is next revolved through a complete revolution in an anti-clockwise direction causing the revolving drum to move slightly and shifting the stop pin to the opposite side of the capstan arm with which it was in engagement, thus leaving the drum free to revolve when required. The cap for closing the top of the cylinder is next taken in one hand and placed upon the top of the air vessel, while simultaneously the revolving drum is moved by the finger of the other hand until brought up by the contact of one of the capstan arms against the stop. This brings a cover glass under the hole in the top of the bed plate and, after a suitable interval is allowed to elapse for settlement, depending upon the nature of the dust being sampled, the drum is again revolved so as to bring the exposed cover glass under the shelter of the bed plate. The test may be repeated, using a second or third cover glass if so desired, after which the instrument is removed to clean air, the revolving drum taken out and the cover glasses mounted.

If the dust record obtained is too scattered it may be repeated as often as desired, using the same cover glass, or if a higher air chamber is available this may be used.

When the air vessel, having been filled with the air to be tested, is placed upon the bed plate, settlement of the dust commences, but as the top of the air chamber is open no error is introduced in the dust count, since dust which settles out at the bottom, falling through the open hole in the revolving drum, is replaced by a corresponding amount of dust, which settles into the open upper end of the air vessel. It is only when the vessel is closed by the cap H that settlement inside becomes important and to avoid

error then, as already pointed out, the closing of the vessel and the exposure of the cover glass must be simultaneous.

In order to make the records permanent it is necessary to treat the cover glass before exposure so that the deposited dust will adhere thereto. To do this a dilute solution of Canada balsam in xylol is prepared, containing 15–20 per cent. of Canada balsam. The cover glass, having been thoroughly cleaned, is taken in a forceps and one-half is dipped in the solution, the remaining half being kept dry. The cover glass is lifted slowly from the liquid so as to allow all excess to flow away from the glass, and allowed to dry, which it does in a few seconds, leaving an excessively thin continuous film of hard balsam on the part of the surface which was immersed. A sufficient number of cover glasses are prepared in this way and kept in the dust-proof receptacle provided with the instrument. After taking a record the drum containing the cover glass is removed and placed under a glass cover provided, the roof of which has a disc of white blotting paper which is previously moistened by the addition of a few drops of xylol. In a few seconds the film of Canada balsam on the cover glass is softened by the xylol vapour and the dust particles adhere firmly. On removal of the cover the balsam re-hardens in a few seconds, when the records may be removed and mounted upon slides prepared with tin rings coated with adhesive, such as are employed in mounting the records of the jet dust counter. It has been found that cover slips on which dust is deposited without any adhesive discharge their dust very easily, the cleaning of the glasses electrifies the surface and on touching the cover glass to mount it the dust is sometimes driven off and all deposited on the bottom of the cell. The dust cannot be mounted in Canada balsam in the ordinary way, since the particles become detached from the glass and lose their relative positions, so that it becomes impossible to count the record. Moreover, many of the particles, being practically transparent, almost disappear when immersed in Canada balsam. The portion of the cover slip left uncoated with balsam permits the particles to be examined dry, if so desired. The cover glasses, having been mounted in position on their cells, the film of balsam on the upper surface may be removed before examination, by wiping with a cloth damped with xylol.

For examination of the particles and counting a low power, such as a ⅔-inch objective, may be used, and it is advantageous to use dark ground illumination. A square ruled micrometer eyepiece, having ½ mm. squares, such as is used in connection with the jet records, is calibrated by means of a stage micrometer so that the area covered by the squares is known. The number of particles on the record is then counted inside a definite number of squares, from which figure the number per unit volume can be ascertained.

Care must be taken that the instrument is kept free from dust, that is, it must be cleaned carefully. It is intended for use in dusty air where coarse dust particles are settling rapidly and therefore it will soon become coated with dust and it should be carefully cleaned after use and before replacing in its box.

The cover glasses which have been previously prepared with balsam must be protected from dust while placing in the instrument; should dust settle upon them it may be removed by using a clean camel's hair brush or blowing upon the surface, but it is preferable never to attempt to place clean cover glasses in position in very dusty air.

SECTION 7.—DUST IN THE UPPER AIR.

(1) Progress of Attempt to get Aeroplane Records.

Reference was made in the last *Report* to observations which were being carried out in the United States of America and Belgium on the distribution of dust in the vertical, and the hope was expressed that data might be obtained in England also in time for publication in this *Report*. Unfortunately, it has not been possible to obtain any records from aeroplanes or balloons in England so far, but the arrangements referred to last year are now nearing completion and there is a possibility that something may be available in time for the *Eleventh Report*.

(2) United States' Weather Bureau Report on Dust in the Upper Air.

Valuable results have been obtained by Dr. Kimball of the United States Weather Bureau. He commenced observations in April, 1923, using the jet dust counter and taking the records from aeroplanes. A number of difficulties were encountered, some of a nature hardly to be anticipated without trial, but these are now overcome and periodic tables of results are sent by Dr. Kimball to the Committee.

As illustrating the type of difficulty met with in taking dust observations from aeroplanes, Dr. Kimball found that while it was possible to take a series of records at different heights during the ascent of the aeroplane it was not possible to do so during the descent. The reason was ascertained to be that at high altitudes where the air temperature was comparatively low the instrument attained the temperature of the air or approached it, and when descending rapidly there was a lag in the warming so that it remained sufficiently cooler than the air drawn through to promote serious condensation of water upon the cover glass.

Dr. Kimball has taken over 100 records from aeroplanes, while 45 records have been taken from a balloon. The records were taken at different heights and under different conditions from the ground level to a maximum height of 14,000 feet from aeroplanes and 7,000 feet from the balloon.

The results of these observations are published in a valuable article by Dr. H. H. Kimball and Dr. Irving F. Hand in the United States *Monthly Weather Review* for March 1924.

Tables and curves are given bringing out the relation of number of dust particles to visibility, seasonal variation in quantity of dust, and variation of dust content with height. It was found that with a clear sky in the morning there is more dust near the ground and less between 2,000 and 7,000 feet than in the afternoon. Often with clear skies there was a marked increase in the dust content with elevation up to about 2,000 to 5,000 feet and then a gradual decrease as the height increased. The means of the October–November series gave the following figures :—

Altitudes in feet	0	1000	2000	3000	4000	5000
No. of particles per cc.—Means	357	308	282	235	157	104

Altitudes in feet	6000	7000	8000	9000	10,000
No. of particles per cc.—Means	94	86	63	55	43

It is, however, shown also that the average diameter of the particles collected at the surface was about four times that at 10,000 feet, and since the volume varies as the cube of the diameter the average volume of each particle at the surface was 64 times that at 10,000 feet, so that the total weight or volume at the surface as compared with the 10,000 feet level was about as 530 to 1.

SECTION 8.—RESEARCHES INTO THE EFFECT OF ATMOSPHERIC POLLUTION UPON VISIBILITY.

The research on the obstruction of light by suspended matter in the atmosphere has been continued during the current year by the two methods adopted at the beginning of the investigation, *i.e.*, by the use of a surface brightness photometer in conjunction with an illuminated hollow cube, and a " contrast " photometer in conjunction with a specially modified searchlight.

During the preliminary experiments last year several minor defects were discovered in the contrast photometer and these were first corrected. The prism in the eyepiece was moved to a position so that it could not offer any obstruction to light passing through the telescope tube and the iris diaphragm in front of the object lens was fitted with a new scale and pointer permitting easy reading. The iris diaphragm was calibrated for the new scale. The setting of the instrument during observations could generally be made consistently to within one half of a millimetre division.

The services of a technical assistant were provided by the Meteorological Office for two hours four times a week, and systematic observations by the two photometric methods were commenced early in November 1923. At each observation records of the suspended matter in the air were taken by means of the automatic filter and the jet dust counter, and in addition the humidity was measured by means of an Assmann psychrometer.

It appeared certain that the results from the contrast photometer were more trustworthy than those from the surface brightness photometer, and attention was therefore concentrated upon observations with the former instrument.

Moreover, the contrast photometer could be used during daylight, when observations were of more value than after dark.

Readings were obtained on most of the abnormally foggy days during the winter, but it was not thought necessary to multiply observations on non-foggy days in view of other work in hand.

(1) Illumination Photometer.

A number of experimental difficulties not inherent in the method have been experienced in the application of this method during the current year, and since the number of reliable observations secured is small these have been omitted for the present, and will be embodied in a future report. The possibilities of the method have not been fully investigated, but results obtained justify the belief that with small modifications its application will present little difficulty in the future.

(2) Contrast Photometer.

(a) *Discussion of use.*—The results obtained by means of this instrument appear to be reliable and no difficulty of any magnitude has been experienced. It was expected that following the removal of the eyepiece prism from the path of the light in the tube, the results could have been worked out by the method outlined in the *Ninth Annual Report, i.e.*, in a similar manner to those of the lumeter. It was found, however, that this led to erratic results, and it often appeared that the opening of the iris diaphragm when the instrument was adjusted at 250 feet from the searchlight was smaller than would have been anticipated if this method of interpretation were applicable. The explanation of this phenomenon may lie in the complicated nature of the images of the illuminant produced by the parabolic mirror of the searchlight. Since the fullolite lamp used as light source was of considerable dimensions, and was situated only a little nearer to the mirror than the principal focus, there is probability of the formation of a complicated system of images, real and virtual, with the result that in addition to the conditions assumed in the first consideration of the principle of the method, light may be concentrated into caustics or into definite points of focus along the path of the main divergent beam. This may account for an abnormal amount of light falling upon the object lens of the photometer when set up in position for working at 250 feet.

These objections, however, are of no great importance since all the readings obtained at each distance are strictly comparable among themselves, and no objection can be made to their interpretation by the method involving the use of clear air standards.

In taking observations by means of the contrast photometer the usual procedure adopted was as follows :—Readings were taken at 100 feet, followed as quickly as possible by others at 200 feet and 250 feet, the number of settings at each distance depending upon their agreement among themselves, but generally being about ten. The photometer was then brought back to 100 feet and readings taken to check with the first series in order to detect any variation in conditions during the progress of the experiments.

(b) *Clear Air Standards.*—This method of interpretation, already described in a previous Report, involves the knowledge of what the photometer reading would be at each distance in clear air.

Fig. 12.

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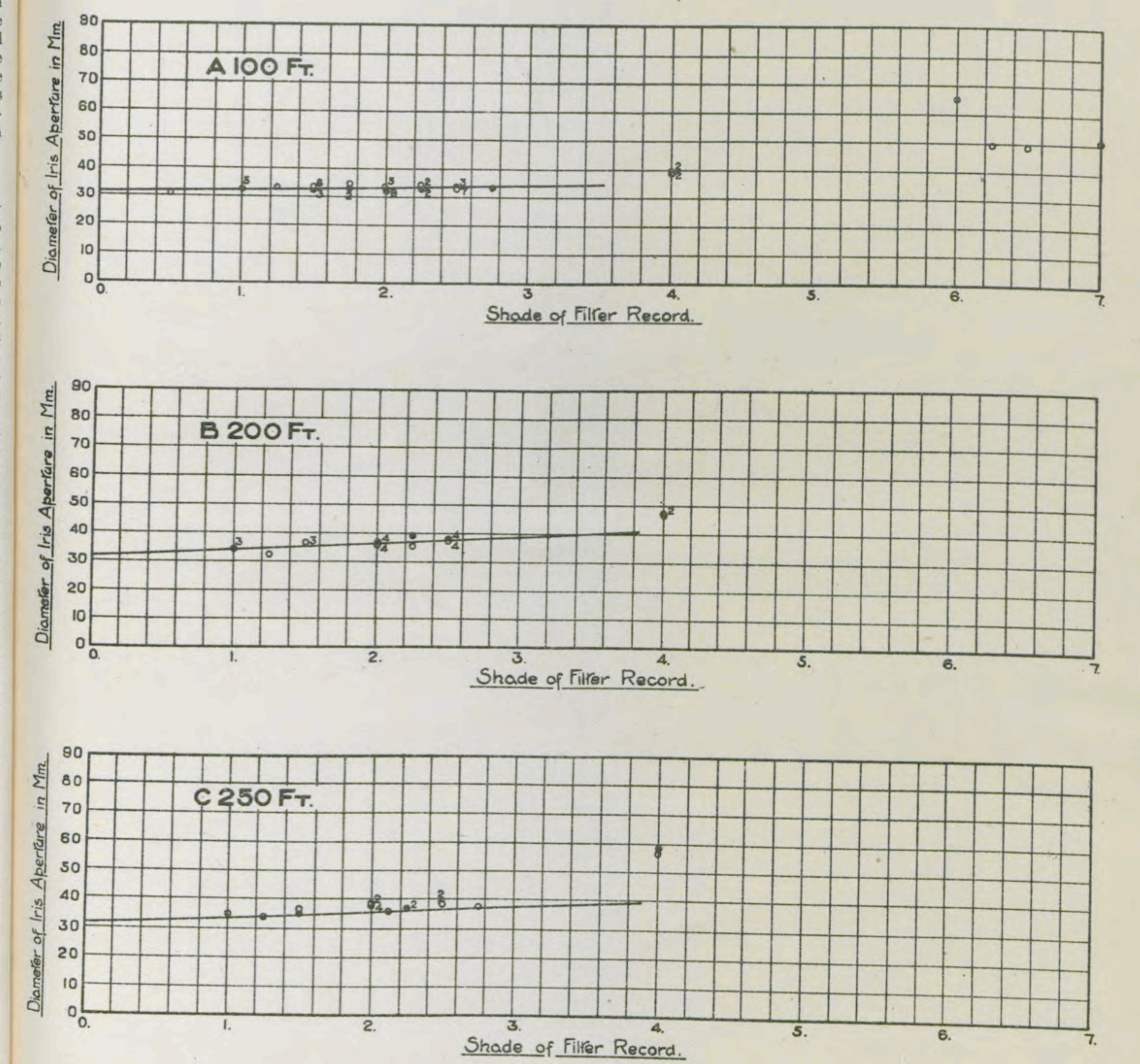
Contrast Photometer Results Plotted Against Automatic Filter Results.



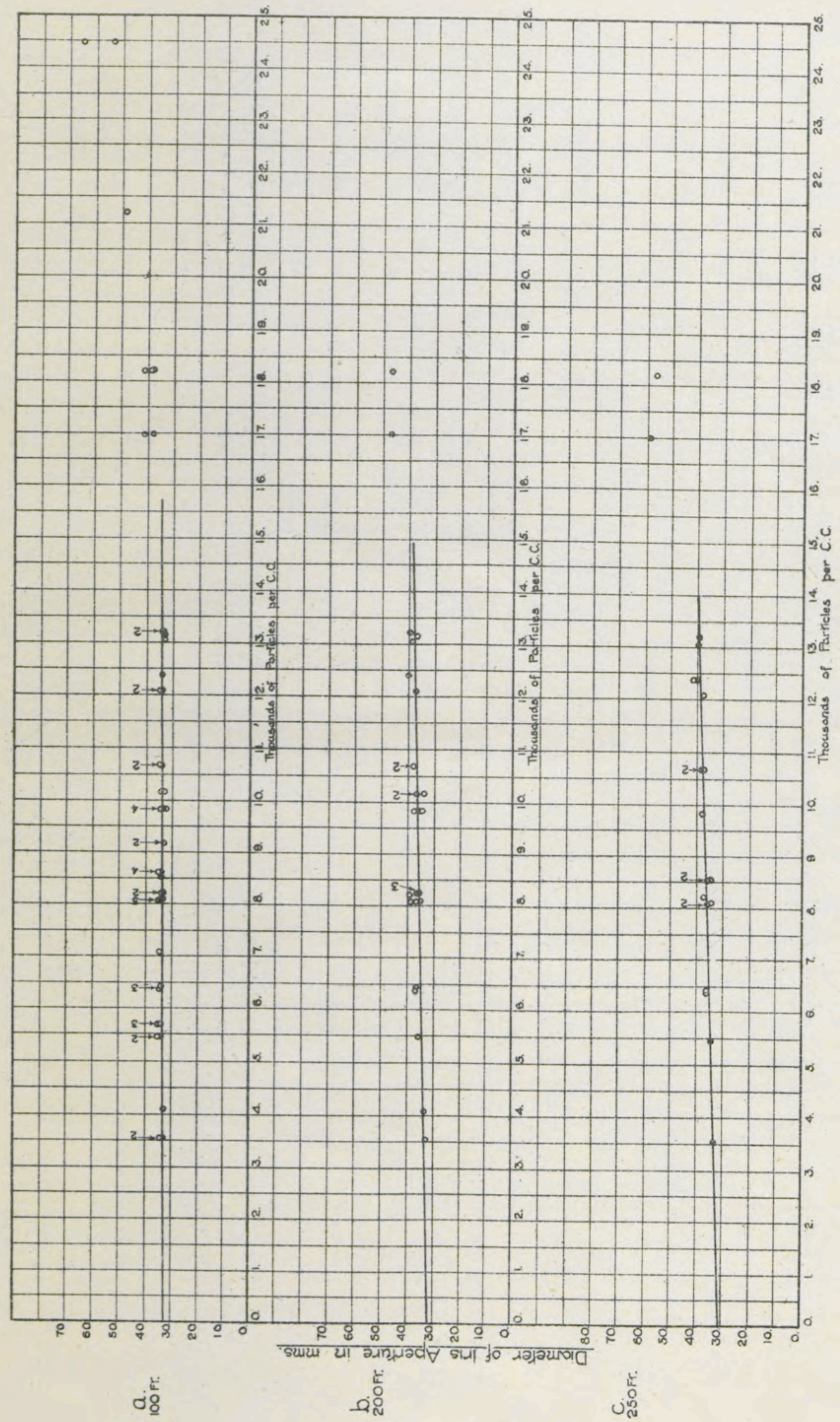


Fig. 13. Contrast Photometer Results Plotted Against Dust Counter Results.

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If, as should theoretically be the case, the light from the searchlight entering the object glass of the photometer varied proportionally with the area of the image formed on the screen, the reading in clear air would be independent of the distance (Annual Report, 1922–23). This condition, however, apparently does not quite obtain, probably owing to the complicated beam from the searchlight. A slight variation of the readings in clear air is also indicated by the numerical ratio between them, obtainable by calculation from observations at the three distances during steady conditions.

The clear air readings may be obtained by several methods :—

(i) By comparison of contrast photometer results with those of the illumination photometer obtained on occasions when atmospheric conditions were apparently steady.

(ii) By plotting for a number of observations the diameter of the iris opening against the corresponding figure for the amount of suspended impurity in the air, obtained by means of the dust counter or automatic filter and extrapolating to find the aperture corresponding with clear air.

(iii) By direct measurement in clear air on suitable occasions.

Method (i).—With reference to the first method, the number of reliable illumination photometer results available in the present instance is small. The evening observations by means of the lumeter were made chiefly with a view to furnishing an absolute measurement or datum from which the results of the contrast photometer could be standardised, and therefore the comparable observations with the latter instrument were generally made at one distance only, namely, 100 feet in order to save time and avoid errors due to alteration of the prevailing conditions. The method involves the use of the following formulæ. Suppose—

d_{100} = diameter of aperture of the iris diaphragm of the contrast photometer when matched.

C_{100} = corresponding diameter in clear air.

y = percentage transmission through 50 feet.

I_0 = intensity of the searchlight as would be measured by the photometer in clear air at 100 feet.

I_{100} = the intensity as actually observed.

Then :—

$$I_{100} = \frac{I_0 y^2}{100^2}$$

but :—

$$\frac{I_0}{I_{100}} = \frac{(d_{100})^2}{(C_{100})^2}$$

Therefore :—

$$C_{100} = \frac{y d_{100}}{100}$$

The aperture C_{100} is termed the clear air standard for 100 feet.

The average from five sets of lumeter observations by one observer gave C_{100} = 29·75 mms., and the average from four sets of observations by three other observers gave C_{100} = 30·18 mms.

Method (ii).—The results obtained by method (ii) appeared to be satisfactory. In Figs. 12A, B and C the diameters of the iris apertures when the instrument was set at 100 ft., 200 ft. and 250 ft., respectively, are plotted against corresponding shades of the automatic filter records.

Owing to the large number of points which would otherwise be involved, average values of the diaphragm diameters were used in plotting these graphs. The number of observations for each point is shown by the adjacent figure. The results obtained by different observers were treated separately.

The points in Fig. 12 may be raised on the vertical axis by the presence of water fog, but no corresponding factor can operate to lower them : the curve, therefore, should be made to pass rather through the lowest points than through the average of them all.

In Fig. 13a, b and c the corresponding iris diameters are plotted against the number of particles as determined by means of the dust counter.

The larger particles during dense smoke haze would place the points higher on the vertical axis than if the dimensions of the particles were always the same. For this reason, the graphs in Fig. 13 must be expected to curve upwards as the dense smoke haze portion is reached. Since this portion of the curve, though instructive, is of no consequence in the present instance, the points to the right in Fig. 13 were not taken into account in drawing the curves.

A regular relationship between the amount of suspended impurity in the air and the obstruction to light is shown in both Figs. 12 and 13. It is therefore justifiable to apply the method of extrapolation to find the clear air standards.

The clear air standards obtained in this way from the filter records are :—

For 250 feet - - -	31·5 mms.
For 200 ,, - - -	31·5 ,,
For 100 ,, - - -	31·0 ,,

From the dust counter records they are :—

For 250 feet - - -	31·5 mms.
For 200 ,, - - -	31·5 ,,
For 100 ,, - - -	32·0 ,,

Method (iii).—During June the air appeared to be perfectly clear on many occasions late at night, and clear air standards were determined then by direct measurement. On June 21st, observations were taken from 11.22 p.m. to midnight in the usual manner, readings being taken at 100 ft., 200 ft., and 250 ft. The small stop was used in the photometer. The diameters of the openings of the iris obtained on this occasion, reduced to the basis of the large light stop, were :—

d_{100} = 31·8
d_{200} = 31·7
d_{250} = 32·2

A dust counter record taken shortly after midnight showed the presence of only 210 particles per c.c., all extremely small, and the automatic filter recorded

TABLE 8.

Table showing the effect of suspended impurity on light transmission as measured by means of the contrast photometer at different distances from the searchlight.

d refers to the diameter of the iris diaphragm aperture in millimetres. Y is the % of light transmitted through 50 ft. of air.

Date.	Results obtained at— 100 Feet.			200 Feet.			250 Feet.			Dust Counter Records.		Auto Filter Records.			Relative Humidity.	
	Time.	d 100.	Y.	Time.	d 200.	Y.	Time.	d 250.	Y.	Time.	No. of Particles/CC	Time.	Shade.	Mgms/Cub. Metre.	Time.	%
Nov. 6th, 1923	10.31 a.m. 10.45 a.m.	36·5 34·5	84·76 87·64	10.36 a.m.	43·0	85·49	10.40 a.m.	43·0	88·35	11.0 a.m.	19,050	11 a.m.	4	1·28	10.40 a.m. 10.50 a.m. 10.54 a.m. 11.0 a.m.	80 78 80 75·6
Nov. 8th, 1923	10.22 a.m. 10.37 a.m. 11.5 a.m.	35·5 34·1 31·4	85·17 88·65 96·29	10.10 a.m.	68	67·98				10.5 a.m. 10.30 a.m. 11.10 a.m.	41,520 20,330 11,290	10.5 a.m. 10.30 a.m. 11.10 a.m.	11 6 2·5	3·52 1·92 0·80	10.15 a.m. 10.23 a.m. 10.43 a.m. 10.56 a.m 11.8 a.m.	75 76 75 70 66
Nov. 17th, 1923	10.48 a.m. 11.5 a.m.	33·4 32·3	93·53 96·7	10.50 a.m.	32·6	98·24	10.56 a.m.	33·9	97·03	11 a.m.	3,535	10.48 a.m. 10.56 a.m. 11.5 a.m.	1·25 1·25 1	0·40 0·40 0·32		77
Nov. 20th, 1923	10.7 a.m. 10.35 a.m.	*34·4* 32·8	90·78 95·21	10.15 a.m. 10.30 a.m.	*38·2* 36·6	90.76 92·72	10.20 a.m.	*39·9*	90·9	10.11 a.m. 10.37 a.m.	13,050 13,130	10.7 a.m. — 10.35 a.m.	2·5	0·80	10.0 a.m. 10.35 a.m.	82·5 82
Nov. 22nd, 1923	9.41 a.m. 10.14 a.m. 10.16 a.m. 5.15 p.m. 7.0 p.m.	*33·15* *33·4* 34·2 33·2 33·25	94·23 93·53 91·33 94·08 93·96	9.51 a.m. 9.53 a.m.	*38·2* 36·4	90·76 92·98	10.5 a.m. 10.5 a.m.	*36·8* 36·8	93·89	9.42 a.m.	8,080	9.41 a.m. 9.51 a.m. 10.5 a.m. 5.15 p.m. —7.0 p.m.	1·75 1·5 1·5	0·56 0·48 0·48	10.0 a.m.	85·4
Nov. 23rd, 1923				1.18 p.m. 4,25 p.m. 4.33 p.m.	35·6 36·0 35·2	94·01 93·5 94·56				1.17 p.m.	8,260	1.18 p.m. 4.25 p.m. 4.33 p.m.	2 2 2·25	0·64 0·64 0·72		
Nov. 24th, 1923	10.0 a.m. 10.15 a.m. 10.42 a.m. 10.45 a.m.	*33·9* 33·6 32·5 32·15	92·12 92·96 96·1 97·14	10.20 a.m. 10.23 a.m.	*37·4* 37·5	91·73 91·6	10.26 a.m. 10.34 a.m.	*38·6* 38·2	92·1 92·49	10.10 a.m. 10.30 a.m.	10,670 9,170	10. 0 a.m. 10.45 a.m.	2·5+ 2·5—	0·80+ 0·80—	10.10 a.m. 10.30 a.m.	87 89
Nov. 26th, 1923	11.0–11.11 a.m. 11.15–11.30 a.m. 11.36–11.42 a.m. 11.50 a.m. 12.56 p.m. 3.35 p.m. 6. 5 p.m. 6.10 p.m. 6.13 p.m. 6.15 p.m.	*128·9* *128·4* *125·2* *137·6* 65·0 53·9 *50·9* 49·4 *51·9* 48·6	24·23 24·32 24·95 22·7 48·05 57·94 61·37 63·23 60·17 64·27							11.29 a.m. 12. 0 p.m. 3·40 p.m. 6·50 p.m.	82,300 65,600 24,260 21,180	11.0–11.11 a.m. 11.15 a.m. 11.36 a.m. 11.45–11.56 a.m. 12.56 p.m. 3.35 p.m. 6.5–6.13p.m. 6.30 p.m. 6.50 p.m.	7·5 8 10 12·5 6 8 7 6 6	2·40 2·56 3·20 4·00 1·92 2·56 2·24 1·92 1·92	11. 4 a.m.	91
Nov. 29th, 1923	10.12 a.m. 10.27 a.m. 10.45 a.m. 10.55 a.m. 5.50 p.m.	32·8 33·9 *32·6* 32·4 32·6	95·21 92·12 95·81 96·4 95·81	10.15 a.m. 10.47 a.m. 10.48 a.m. 5.57 p.m.	37·1 *35·2* 34·0 33·7	92·09 94·56 96·2 96·63	10.20 a.m.	38·1	92·61	11.0 a.m. 6.15 p.m.	9,820 4,080	10.15–10.47 a.m. 10.50–11.0 a.m. 5.57 p.m.	2 2— 1	0·64 0·64— 0·32	10.26 a.m. 5.50 p.m.	91 82
Dec. 5th, 1923	5.58 p.m. 6.0 p.m.	31·9 31·2	97·9 100									5.58 p.m.	1·5	0·48		
Dec. 8th, 1923	10.1 a.m. 11.0 a.m.	32·1 33·7 *33·25*	97·29 92·68 93·96	10.7 a.m. 10.10 a.m. 10.50 a.m. 10.56 a.m.	*36·2* 36·1 *34·6* 36·0	93·24 93·37 95·37 93·5				11.0 a.m.	10,150	10.0–11.0 a.m.	2	0·64	10.0 a.m. 11.0 a.m.	89 80
Dec. 11th, 1923	9.50 a.m. 10.11 a.m.	32·8 *33·6*	95·21 92·96	9.53 a.m.	*39·0*	89·82	10.3 a.m.	37·6	93·09	10.10 a.m.	8,220	9.50 a.m. 10.11 a.m.	2·25 2	0·72 0·64	10.0 a.m.	94
Dec. 13th, 1923	9.53 a.m. 10.15 a.m. 10.24 a.m.	*33·4* *33·1* 33·9	93·53 94·36 92·12	9.58 a.m.	*36·8*	92·5	10.4 a.m. 10.30 a.m. 10.40 a.m.	37·8 *36·0* 35·6	92·9 94·73 95·15	10.0 a.m. 10.30 a.m.	12,080 8,520	9.53 a.m. 10.15 a.m. 10.30 a.m. 10.40 a.m.	2·5 2·75 2·25 2+	0·80 0·88 0·72 0·64+	10.0 a.m.	89
Dec. 14th, 1923	6.45 p.m. 6.48 p.m. 7.14 p.m. 7.15 p.m.	34·0 33·25 34·0 33·4	91·85 93·96 91·85 93·53							7.18 p.m.	8,630	6.45 — 7.15 p.m.	2	0·64		
Dec. 15th, 1923	9.52 a.m. 10.18 a.m. 10.0 a.m. 10.50 a.m.	*33·6* *33·6* 34·0 33·6	92·96 92·96 91·85 92·96	10.4 a.m. 10.5 a.m.	*36·0* 36·3	93·5 93·11	10.10 a.m. 10.15 a.m.	*36·6* 36·6	94·10 94·10	10.51 a.m. 11.0 a.m.	6,425 6,370	9.52 a.m. 10.0 a.m. 10. 20 a.m. 10.51 a.m.	2·5 2·25 2·25 1·75	0·80 0·72 0·72 0·56	10.0 a.m. 11.0 a.m.	78 73
Dec. 18th, 1923	9.58 a.m. 10.17 a.m. 10.24 a.m. 5.55 p.m. 6.0 p.m. 6.33 p.m.	*33·4* *34·1* 34·1 33·1 *33·1* 34·2	93·53 91·58 91·58 94·36 94·36 91·33	10.7 a.m.	*35·1*	94·69	10.12 a.m.	*35·0*	95·79	10.13 a.m. 10.34 a.m. 6.35 p.m.	5,470 7,090 5,690	9.58 a.m. 10.7–10.24 a.m. 10.34 a.m. 5.5 p.m. 6.35 p.m.	1·75 1·5 1·75 1·5 1·5+	0·56 0·48 0·56 0·48 0·48+	10.0 a.m. 10.24 a.m.	93 74
Jan. 30th, 1924	12.7 p.m. 12.10 p.m. 12.40 p.m.	*37·7* 38·13 40·9 39·0	82·85 81·93 76·37 80·07	12.17 p.m. 12.20 p.m.	*46·22* 46·43	82·51 82·32	12.30 p.m. 12.35 p.m.	*58·57* 56·45	77·96 79·12	12.12 p.m. 12.40 p.m.	16,990 18,200	12.7 12.40 p.m.	4	1·28	12.10 p.m. 12.40 p.m.	95·4 93·4
Feb. 11th, 1924	4.3 p.m. 4.16 p.m. 5.42 p.m.	32·38 32·69 32·48	96·45 95·54 96·16	4.7 p.m. 5.37 p.m.	34·93 34·08	94·92 96·10	4.12 p.m.	34·93	95·88	4.24 p.m.	8,100	4.3 p.m. 4.16 p.m. 4.24 p.m. 5.42 p.m.	1+ 1 1 1—	0·32 0·32 0·32 0·32—	4.16 p.m.	77·4
Feb. 12th, 1924	11.54 a.m. 12.26 p.m. 2.45 p.m.	33·44 33·01 *33·23*	93·42 94·62 93·99	12.8 p.m. 2.52 p.m.	39·00 39·4	89·82 89·37	12.20 p.m. 2.54 p.m. 2. 55 p.m.	39·62 41·32 40·68	91·16 89·64 90·2	12.5p.m. 3.0 p.m.	13,200 12,380	11.30 a.m. 11.54 p.m. 12·26 p.m. 2.45 p.m. 2.54 p.m.	2·5 2 2·5 2 2	0·80 0·64 0·80 0·64 0·64	12.0 a.m. 2.45 p.m.	89 89·6
June 21st, 1924	11.22 p.m.	31·8	99·66	11.40 p.m.	31·70	99·63	11.50 p.m.	32·22	99·02	12.6 Midnight	210	11.12 p.m.	0	0·00		
June 22nd, 1924	10.2 p.m. 10.25 p.m.	30·09 31·8	100 99·66	9.46 p.m. 10.42 p.m.	30·62 32·1	100 99·02	9.36 p.m. 10.56 p.m. 11.6 p.m.	30·09 32·0 32·6	100 99·28 98·56	11.16 p.m.	2,200	Till 10 p.m. from 10.15 onwards.	0 Trace	0·00		

no impurity whatever. The searchlight beam was practically invisible showing that the air was very nearly free from suspended impurity.

On June 22nd, conditions were not so favourable, but no impurity was recorded by the automatic filter until after a set of observations had been completed.

The values of the clear air standards obtained were:—

$$C_{100} = 30 \cdot 09$$
$$C_{200} = 30 \cdot 62$$
$$C_{250} = 30 \cdot 09$$

The averages of results obtained by all the different methods are:—

$$C_{100} = 31 \cdot 23$$
$$C_{200} = 31 \cdot 47$$
$$C_{250} = 31 \cdot 44$$

These were accepted as being correct and used in working out the whole of the results of the investigation.

(c) *Results obtained.*—The results obtained with the contrast photometer at 100 ft., 200 ft., and 250 ft. are given in Table 8, the time, diameter of iris opening d, and percentage of transmission in 50 ft. y being given under each distance. In parallel columns, for comparison with the transmission are given the number of suspended particles in the air and the time of taking the record, and under the heading "filter records" are given time and amount of impurity present in milligrammes per cubic metre.

Each light transmission entry in this table was prepared from the average of about ten readings so that the total number of readings represented is approximately 1,200.

The results of November 6th, 8th and 13th, respectively, although included in Table 8, were obtained under slightly different conditions from the rest, and for this reason they are marked distinctively in Fig. 15.

On November 6th, observations were taken from 10.31 to 10.45 a.m. in the usual order, 100 ft., 200 ft. and 250 ft., and then again at 100 ft. for confirmation. The filter record showed that the air was clearing at the time; the results of the photometer observations are as follows:—

From 100 ft. result at 10.31 a.m. transmission $y = 84 \cdot 76$ per cent.

From 200 ft. result at 10.36 a.m. transmission $y = 85 \cdot 49$ per cent.

From 250 ft. result at 10.40 a.m. transmission $y = 88 \cdot 35$ per cent.

From 100 ft. result at 10.45 a.m. transmission $y = 87 \cdot 64$ per cent.

The clearing from 10.31 to 10.40 a.m., followed by loss of transmission at 10.45 a.m., is probably a genuine effect of the fluctuations of the haze. It was noted repeatedly that following a gust of wind there was an appreciable momentary alteration in the reading of the instrument.

The results of November 8th are of interest in view of the very rapid clearing of the smoke haze as shown by the filter and dust counter records, and the simultaneous falling of the relative humidity, with the corresponding increase in the percentage of light transmission through 50 ft. of air.

In Fig. 14, A, B and C, the percentages of obstruction of light are plotted against the corresponding records of the automatic filter. In these graphs the results obtained by certain different observers are marked differently in order to indicate any personal factor in the observations. The results do not show very great regularity, but it is to be remembered that no allowance has yet been made for the presence of water fog, and the four outlying points representing an obstruction of approximately 76 per cent. were all obtained on November 26th, 1923, during a particularly dense fog, when the effect of suspended water drops may have been considerable.

In Fig. 15 the percentage obstruction of light, irrespective of the distance at which the readings were taken, is plotted against the number of particles per cc. as obtained by means of tne jet dust counter, the interval between the taking of the dust record and the photometric measurement being in no case more than a few minutes, unless otherwise stated. This graph suggests that the greater the number of particles the greater the obstruction of light per unit. This may be due to the fact that the conditions favourable for the formation of a dense smoke haze also tend to produce a water fog, and also because the size of the particles during a heavy smoke haze is generally abnormally great.

(d) *Theoretical Obstruction by Suspended Particles.*—To investigate the probable effect of variation of size of the particles, the obstruction was worked out theoretically assuming ideal conditions,* that is, simple obstruction by the projected area of the particles, and making due allowance for the probability of particles falling one behind another. In general:—

If I_0 represents the intensity of light entering a column of air;

I represents the intensity of light emerging from the column;

n represents the number of particles present per cc.;

l represents the length of column of air in cms.;

A represents mean area of diametral plane of the particles;

Then:—

$$\frac{I}{I_0} = e^{-Anl}.$$

In the present case:—

If I_0 is taken as 100 arbitrary units and $l = 50$ ft. $= 1{,}520$ cms.;

Then:—

I becomes the percentage transmission of light through 50 ft. and compares with that measured by means of the contrast photometer.

The obstruction as indicated by the above formula was worked out taking a number of different values of n, for particles of mean diameter $1 \cdot 20$ microns and $0 \cdot 5$ micron respectively. These results are also plotted in Fig. 15 and they show the considerable variation in light obstruction produced by the difference of size of the particles. It is noteworthy

* L. F. Richardson, *Proc. Roy. Soc.*, Vol. 96, 1919.

FIG: 14. CURVE SHEWING EFFECT OF SUSPENDED IMPURITY ON LIGHT TRANSMISSION AS MEASURED BY MEANS OF THE CONTRAST PHOTOMETER.

To Face Page 52.

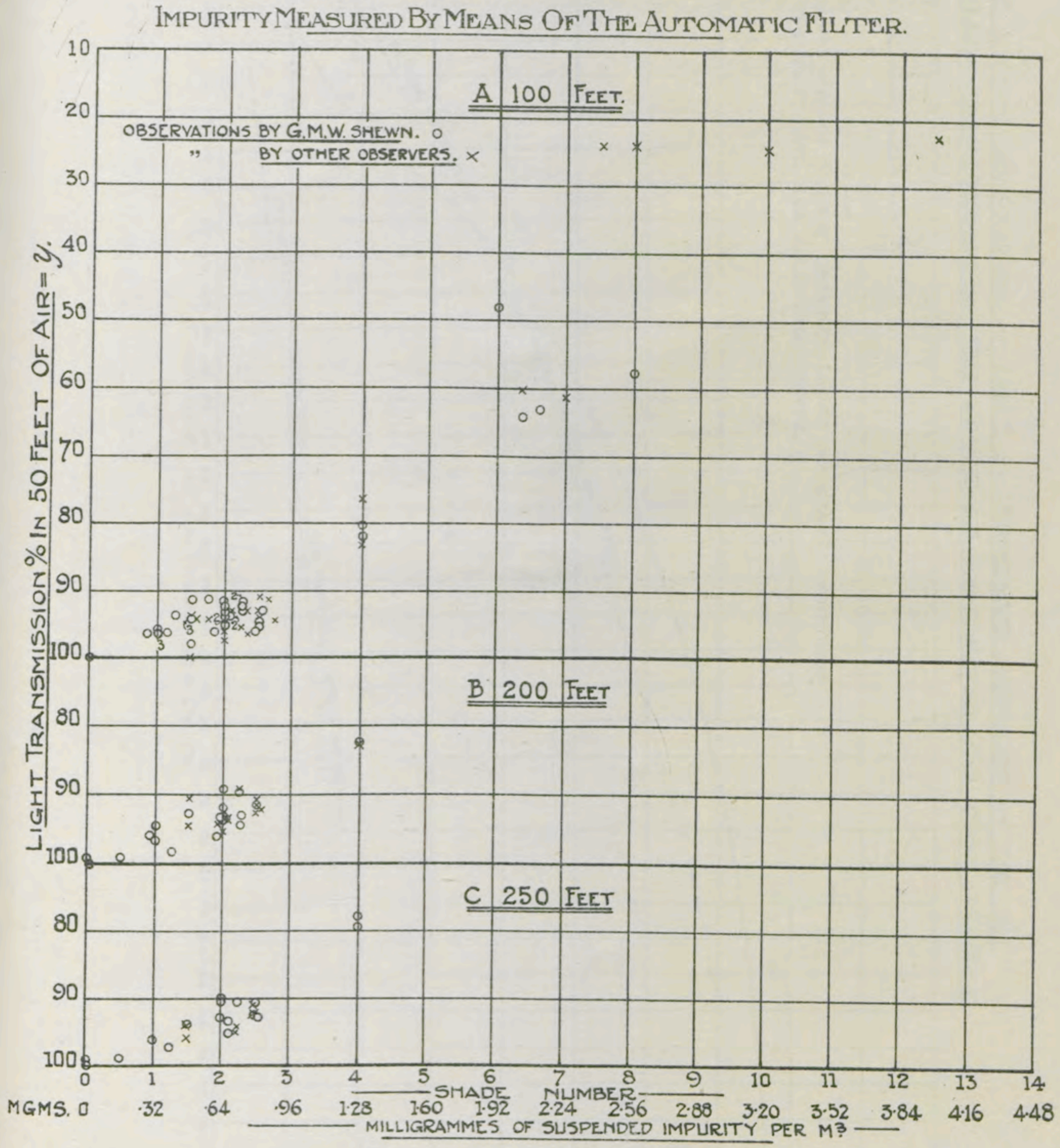


FIG: 15. CURVE SHEWING OBSTRUCTION OF LIGHT BY SUSPENDED PARTICLES IN THE AIR PREPARED FROM RECORDS OF THE CONTRAST PHOTOMETER AND DUST COUNTER.

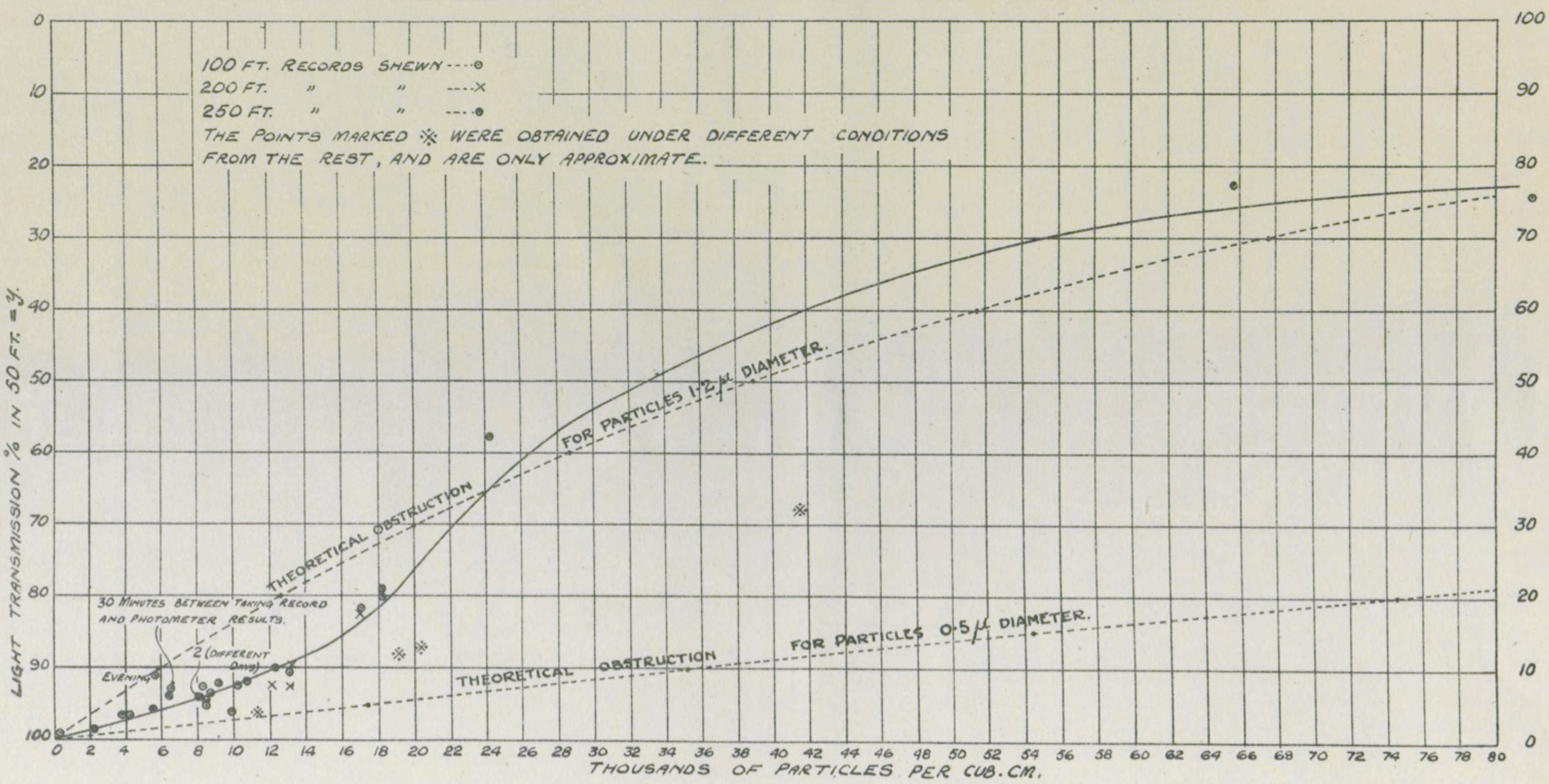
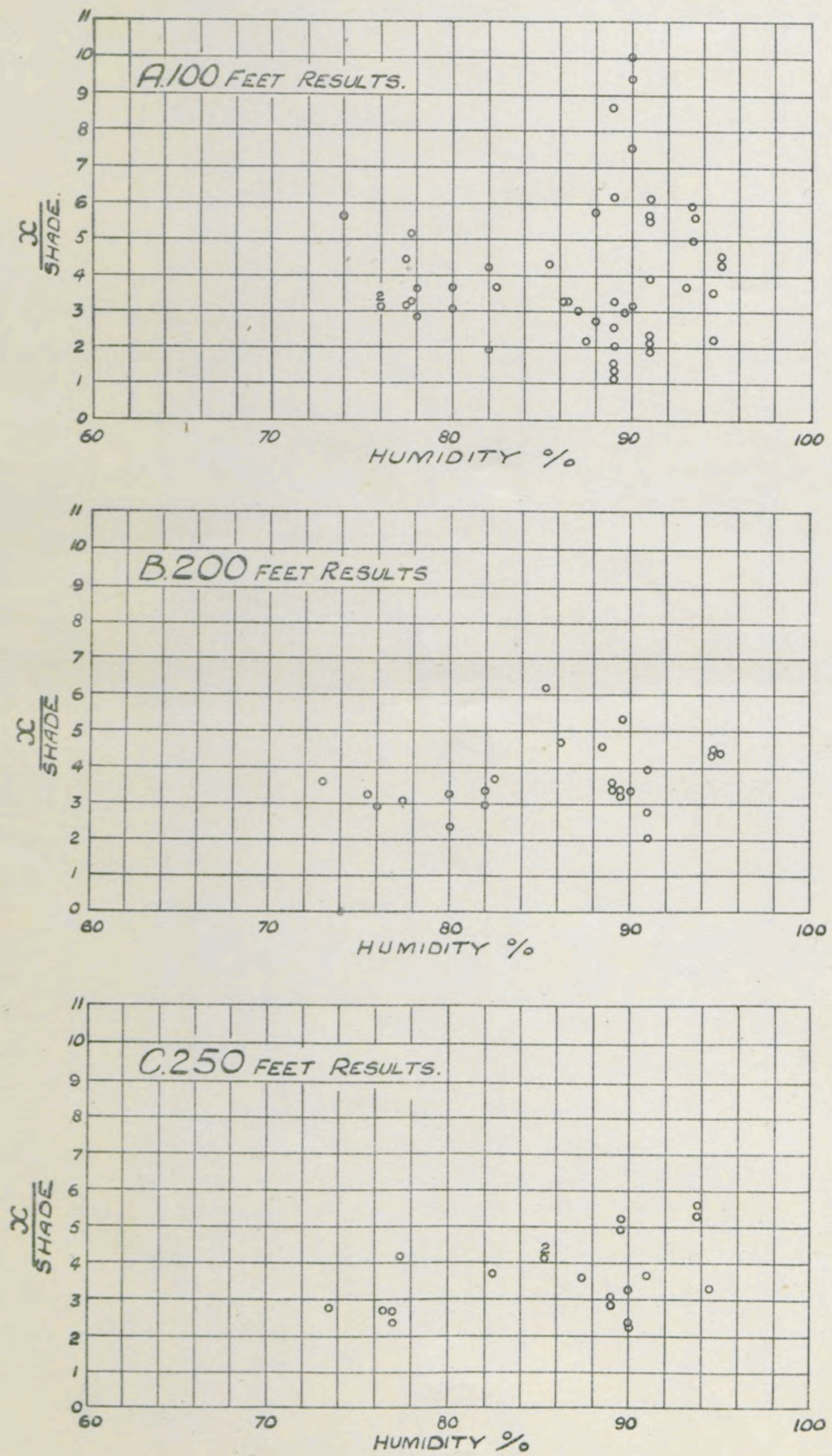


FIG. 16. To Face Page 53.

RATIO % OBSTRUCTION IN 50 FEET. (x) / SHADE NUMBER. PLOTTED AGAINST THE RELATIVE HUMIDITY AT THE TIME OF THE EXPERIMENTS.



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that with two exceptions the experimentally determined points fall between the two theoretical curves, thus, apart from all other disturbing influences all irregularity in the results may be accounted for by variation of size of the particles.

The point which represents the obstruction for 65,600 particles per cc., gives, by the application of the exponential formula above, an average diameter of 1·219 microns.

Referring to Fig. 15 the curve must be asymptotic to the line representing 100 per cent. obstruction, since when the whole of the light is cut off, the further addition of particles can produce no effect, that is it must eventually become concave to the number of particles axis. The initial curving upwards of the graph for numbers of particles from 0 to 24,000 may well be due to the increasing diameter of the particles as the heavier smoke hazes are reached and the subsequent flattening out towards the horizontal, to the fact that the particles were here approaching their maximum size, and the other factor was becoming predominant.

The curves in Fig. 14 do not show so marked a tendency to being concave to the particles axis, which is probably due to the fact that in the method of interpretation of the filter records some account is taken of the size of the particles and the result represents rather the total weight of the suspended matter than the number of particles.

(e) *Suspended Water.*—As a preliminary investigation of the effect of suspended water upon the results, the obstruction of light on each occasion was divided by the shade of the corresponding automatic filter record and the result was plotted against relative humidity at the time of the experiment (Fig. 16), as determined by means of the Assmann psychrometer. Though the psychrometer gives no indication of the amount of water suspended in the form of drops, it shows when drops are likely to be present. The results shown in Fig. 16 were not definite but gave some indication of a water effect.

The results for 100 ft., 200 ft. and 250 ft., are plotted separately, since during dense fogs, when the most definite indication of the effect of water drops might be expected, the photometer could not conveniently be used at greater distances than 100 ft. from the searchlight. In the 100 ft. results, the ratio of light obstruction to weight of impurity became much more erratic when the humidity was about 90 per cent., and this may be due to the presence of water drops.

On drier occasions it is possible that the obstruction of light may be influenced by condensation taking place upon hygroscopic nuclei before the air is nearly saturated, but such an effect could hardly make itself obvious in 100 ft. The need for an independent instrument for measuring the amount of water present in the air in the form of drops is obvious, and it is anticipated that in observations in the near future such an instrument, the vapour pressure hygrometer referred to in the *Ninth Annual Report*, may be brought into use.

It appears that roughly a loss of 50 per cent. in 50 ft. is caused by the presence of 32,000 particles per cc., or by 2·6 milligrammes per cubic metre, which shows satisfactory agreement with the corresponding results obtained in last year's investigation.

It is anticipated that during the coming winter, this research may be concluded, and that a complete statement of the results obtained may be available for the next Annual Report.

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