CIRCULAR No. 54.

LONDON FOG INQUIRY.

DEFINITIONS.

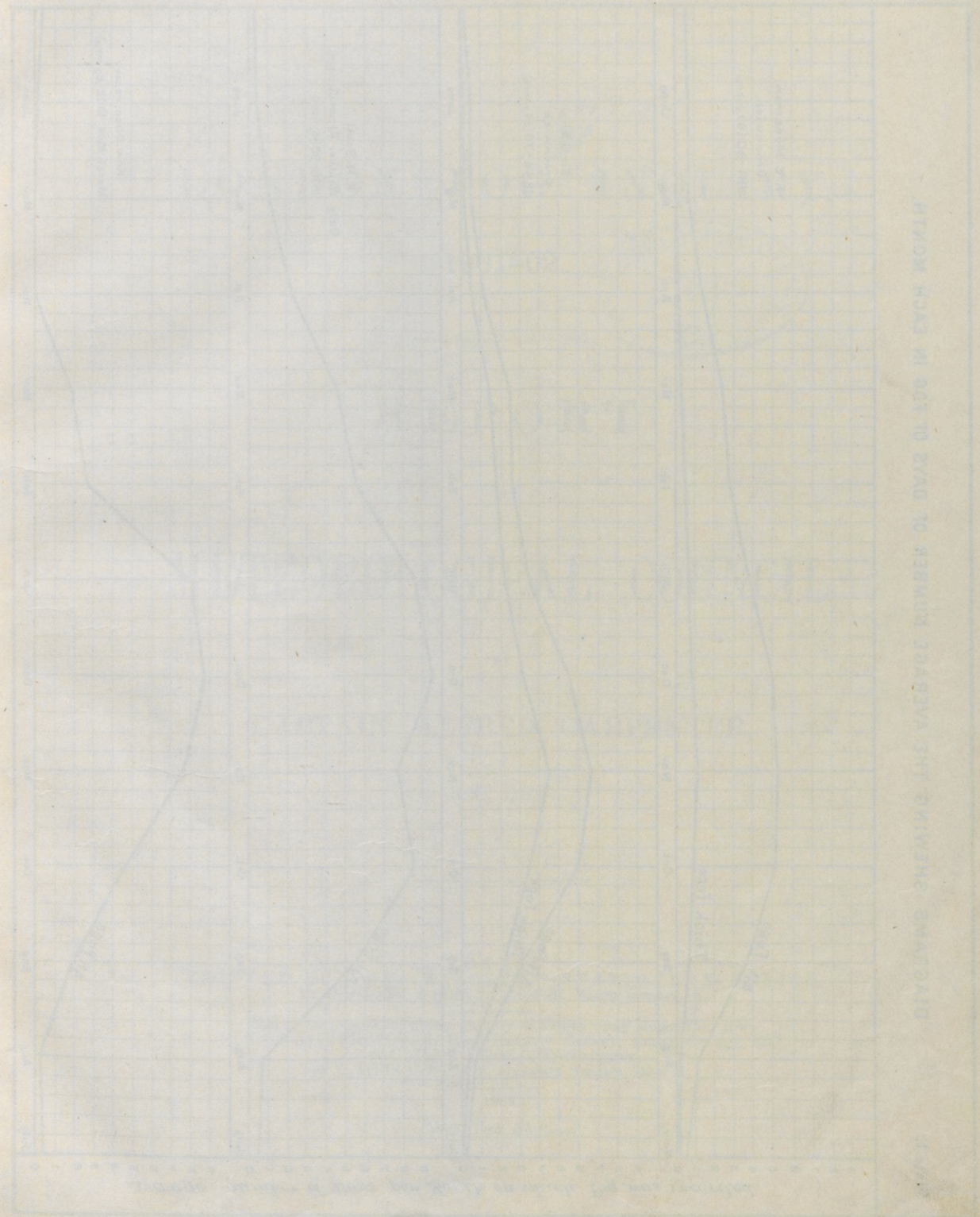
To bring the two forms Nos. 55 and 58 together on similar lines it would be well to use the following abbreviations:—

L., Light; M., Moderate; T., Thick; W., White; S., Smoky.

The definitions would thus read—

L.W., Thin Fog or Mist. Slightly hinders rail and river traffic but not road traffic, objects visible 200 yards or more.

M.W. or M.S., Moderately Thick Fog. Hinders all traffic. Cannot discern



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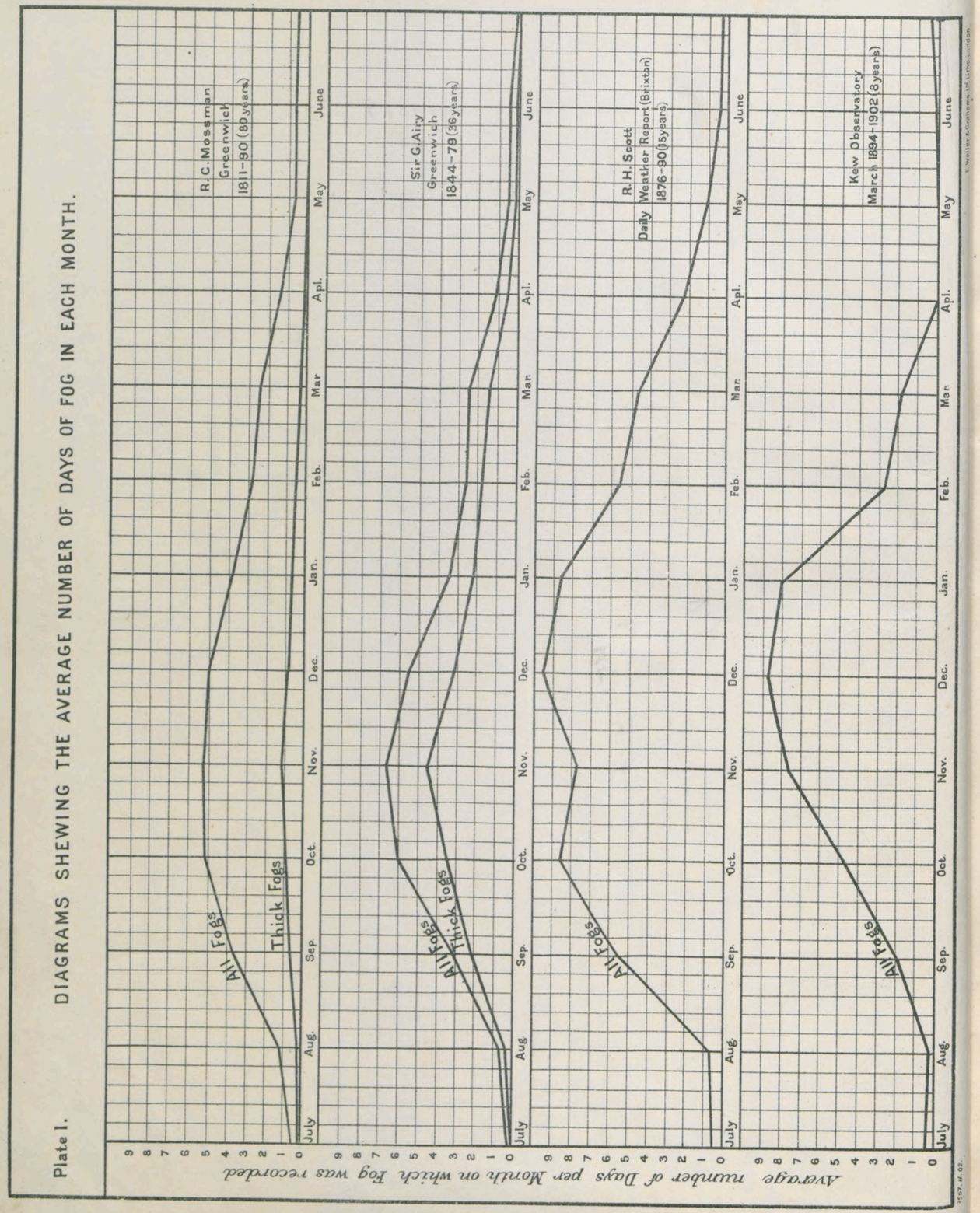

June 4, 1902.

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LONDON FOG INQUIRY,

1901–02.

REPORT

TO

METEOROLOGICAL COUNCIL,

BY

CAPTAIN ALFRED CARPENTER,

R.N., D.S.O.

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LIST OF PLATES.

LONDON FOG INQUIRY.

WINTER 1901–02,

BY

CAPTAIN ALFRED CARPENTER, R.N., D.S.O.

Observations incomplete.

In placing on record the results of the inquiry into London fogs during the winter of 1901–2, it is necessary at the outset to say that the observations were very incomplete, partly owing to the inquiry not being instituted until the very middle of the fog season, and partly owing to the novelty of the inquiry precluding the investigations being at once carried out on the lines which would ensure the best results. It was not until 22nd October, 1901, that the London County Council came to a decision upon the suggestion put forward by the Meteorological Council. In accepting the report upon the matter by the General Purposes Committee, the County Council authorised the various fire brigade stations and men under Captain L. Wells, R.N., to afford assistance in the inquiry by making such observations as the Council might desire to have taken. Without such assistance, an inquiry embracing all parts of the London area was impossible.

Captain Carpenter selected to conduct inquiry.

On the 10th November, the Meteorological Council did me the honour of selecting me to conduct the inquiry, and a suitable office and the services of an assistant were provided at the Meteorological Office. I wish at once to acknowledge the kindly advice and very great assistance I have received from Mr. W. N. Shaw and the officers of the different departments of the Meteorological Office.

Previous Observations.

Former observers.

On looking up previous records, I found that the late Sir George Airy had kept a continuous record of fog at Greenwich during the years 1844 to 1879, a copy of which was supplied by the courtesy of the Astronomer Royal ; that Mr. R. C. Mossman* had made a collection of fog records from various sources extending over 167 years, which is given in the Quarterly Journal of the Royal Meteorological Society, Vols. XXIII. and XXIV. ; that Mr. R. H. Scott had discussed fogs in London between 1876 and 1890, in a paper published in the Quarterly Journal of the Royal Meteorological Society, Vol. XIX. ; and that Mr. F. J. Brodie had written on fogs in London during the 20 years 1871 to 1890 in Vols. XVII. and XVIII. of the same Journal. In Plate I. I have shown the monthly frequency of fog as given by several of the above discussions, and to these has been added the fog frequency at Kew during the past eight years derived

* Only that portion of the record which includes the years 1811–1900, and for which the observing station was Greenwich, has been used in preparing Plate I. The previous records, being taken from various sources, were considered less trustworthy, and were consequently not included.

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from observations supplied by the Kew Observatory. It will be seen in Plate I. that the occurrence of fog in London increases rapidly from the 15th August, and reaches a maximum about the middle or end of November. To obtain results for a whole season it is obvious that an inquiry of this nature should commence early in August.

The Hon. Rollo Russell*, has written several papers on haze and mist; and in the "Nineteenth Century" for January, 1902, has gone closely into the various forms of fog and the effect of their occurrence in London.

Dr. W. J. Russell,† has written two important papers on the chemical analysis of London fogs, which show the accumulation of products of combustion, and the consequent vitiation of the air during the prevalence of fog.

Arrangements for Observations.

Observing stations.

At the time of my appointment the season for fogs was well advanced, and it was necessary to commence observations at once, and after conferring with Captain Wells, a form for the record of fog occurrence was forthwith issued to 30 fire stations of the Metropolitan Fire Brigade.

To get records from open spaces, observations were asked for from Kew Observatory (National Physical Laboratory), Regents Park (Royal Botanic Society), Battersea Park (London County Council), Hyde Park (Metropolitan Police). The Commissioner of Metropolitan Police also kindly caused observations to be taken at four police stations outside the London County area, viz.: Barking, Plaistow, Harlesden, and Kingston. The Lords Commissioners of the Admiralty consented to observations being made at the following coast guard stations in the Thames estuary, Tilbury, Gravesend, Cliffe Creek, Haven Hole, and Sheerness. Regular observations of fog were also taken by the Staff of the Poplar Borough Electricity Works at Bromley-by-Bow, aboard the training ship "Worcester" off Greenhithe, and by Mr. J. T. Smith at Forest Gate. There were in all 46 observing stations, a complete list of which, with the exception of the coast guard stations, with the names of the observers, is given on page 16.

Form of fog record.

The form supplied to the various observing stations is reproduced in Plate II. This form distinguishes between high fog and surface fog, it is ruled for ten minutes' intervals throughout the 24 hours, and gives certain definitions as to intensity and colour.

High fog.

The term high fog refers to darkness caused by fog that lies over the tops of the houses either in the forms of heavy smoke drifts, or of condensation overhead mingling with the smoke, and sometimes coming down in the form of drizzle or snow. This fog is now of common occurrence over London. It was observed on 14 days, on four of which there was ordinary fog locally as well. It is probably formed by a change of air current overhead which causes condensation, possibly also electrical action, and rolls back the smoke floating in the air. The consequence is darkness, and a descent of either thick smoky fog, locally in smoky districts, or of fine smutty rain or snow. The appearance of high fog is black, but that of ordinary fog, yellow. When the high smoke fog descends it often comes down quite thick without any preliminary light fog.

Classification of ordinary fog.

Ordinary fog is divided into three intensities, light, L; moderate, M; and thick, T; and into two types, white, W, or smoky, S.

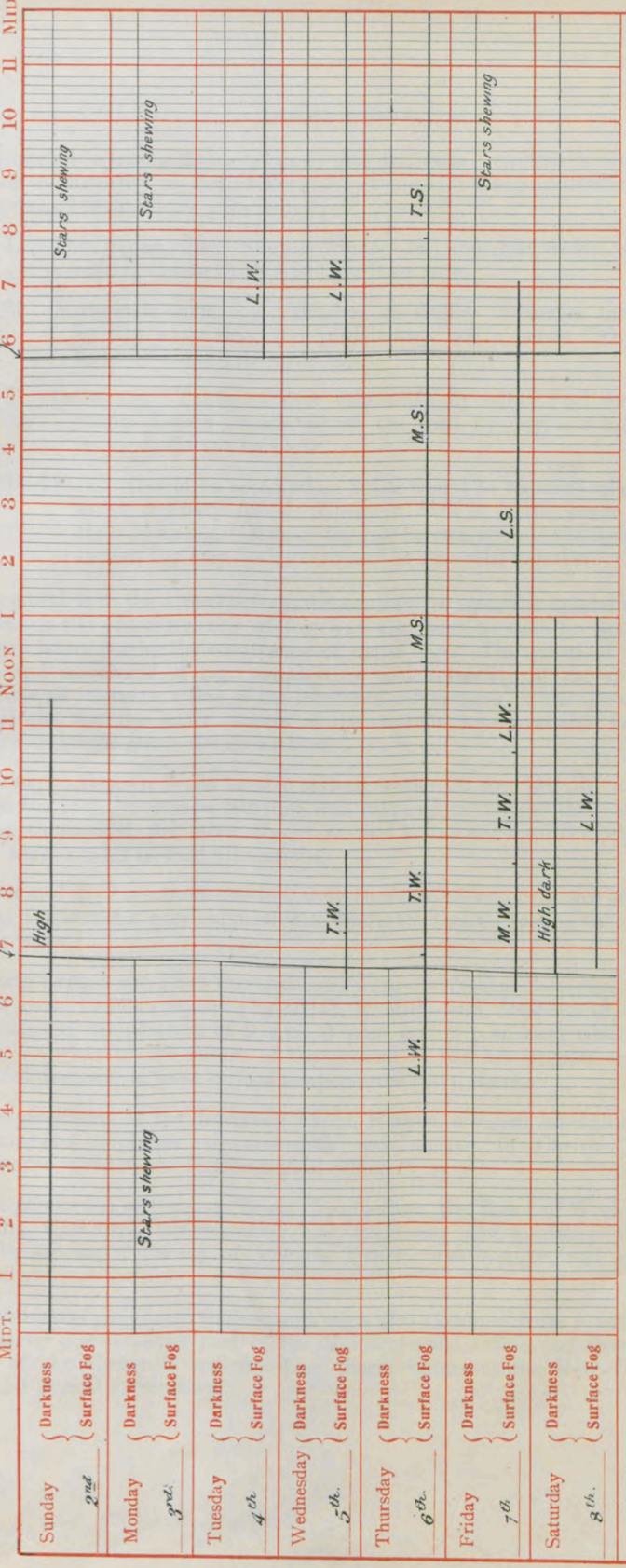
* Quarterly Journal, Royal Met. Soc., Vol. 23, p. 16, Vol. 24, p. 267.
† Monthly Weather Report, April 1884, App. II., and August 1885.

To face page 4.

Meteorological Office. Form No. 55.

Record of DARKNESS and SURFACE FOG kept at *Electricity Works, Bromley-by-Bow.* by *Superintendent*

during the week ending *8th March* 1902.



SYMBOLS.

L Light, thin
M Moderate
T Thick
W White
S Smoke laden, Yellow

INSTRUCTIONS.

In the above Diagram six spaces, to indicate each 10 minutes, are inserted in the space devoted to each hour of the day.
Distinction is drawn between **Darkness** (without surface fog), which may be due to heavy clouds, high fog, or merely the fact that the sun is not above the horizon, and true **Surface Fog**, when the cloud of fog itself surrounds the Observer and renders bright objects invisible horizontally at comparatively short distances.
A **dark line** should be drawn through the time spaces during which the darkness or fog prevailed.
The **Surface Fogs** may be again distinguished by writing on the line W (white fog); or S (smoke laden fogs); and their intensity sub-divided into L (light fogs), not sufficient to require artificial light in the daytime; M (moderate fog), when ordinary gas lamps, though visible at 60 yards, are invisible at 440 yards (¼-mile); and T (thick fog), in which street gas lamps are invisible at 60 yards or less.
The temperature in degrees Fahrenheit where observed may be written in the corresponding space.
If fog shows indications of drifting, a note may be also inserted to that effect.

E. Weller & Graham, Ltd. Chiswick, London

In actual working it was found that the form required some amendment, the definition of intensity at foot of Form 55 (Plate II.) being insufficient. The following definitions and instructions were issued :—

L. Thin fog or mist. Slightly hinders rail and river traffic, but not road traffic, objects visible by day 200 yards or more.

M. Moderately thick fog. Hinders all traffic. Observer cannot discern a man by day more than 100 yards away, nor a house 200 yards, nor a street light by night 440 yards.

T. Dense fog. Traffic on river impossible, by rail or road very slow. Observer cannot discern objects across the road by day, nor lights of street lamps 60 yards distant by night.

Darkness. Should be noted when lights would be required night or day for work in an ordinary office. However dark it is the street lamps are bright if there is no fog. Mist or fog can be seen against the lights. Darkness and surface fog may both occur and be recorded together.

Special fog observations.

In addition to the common form for continuous record a special form containing 23 questions on the characteristics of fog was also sent to each fire station to be filled up every two hours during the occurrence of dense fogs. The questions referred to density, height, and movement of fog, temperature and humidity of the air and drift of any perceptible air currents. One of the incidental advantages of the use of the Fire Brigade stations, was, that the watch towers of the stations were available for observation at a considerable height above the street level.

Record commenced on 18th November.

Owing to Captain Wells' kindly assistance the 30 fire brigade stations commenced work on the 18th November, but time was required to obtain the necessary permission for, and to instruct the other observers, and it was not until the 5th January that full reports were coming in from all stations.

Temperature.

Wet and dry bulb thermometers were issued to seven of the fire stations, and two of the river fire stations were supplied with thermometers for testing the temperature of the Thames water.

Earth surface and grass thermometers were observed at Battersea Park, Hyde Park, Regents Park, Camden Square (by Dr. H. R. Mill), and Sanderstead, near Croydon, and observations of temperature at 9 a.m., 3 p.m., and 9 p.m. were contributed from these stations. Owing to the nature of the ground at the fire brigade stations, it was not considered desirable to have surface temperatures taken there.

By permission of the Reverend Canon Henson, a screen containing wet and dry and maximum and minimum thermometers was erected in Christ Church graveyard, Westminster, close to the Meteorological Office.

By permission of the Lord Great Chamberlain, the Board of Works, and the Dean of St. Paul's Cathedral, self-recording and maximum and minimum thermometers were placed in screens at the top of Victoria Tower, Westminster, and above the dome of St. Paul's.

Continuous records of temperature were also obtained from a self-recording electric thermometer placed on the roof of the Meteorological Office, and from the photographic records of the Council's self-recording thermometers at the Kew Observatory of the National Physical Laboratory.

Mr. David Mair, of Banstead, Surrey, took thermograph observations specially for the inquiry.

Humidity. The only observations available for the determination of the humidity of the air were readings of dry and wet bulb thermometers at the Meteorological Office, Kew Observatory, Camden Square, Regents Park, Battersea Park, and occasionally at some of the Fire Brigade Stations. Unfortunately, the atmospheric conditions during fog are not at all favourable for the accurate determination of humidity by this method, especially when the air temperature is below the freezing point, and in consequence some uncertainty attaches to the results.

Barometric pressure. No special observations on pressure were made. Readings of the barometer are regularly taken at Brixton or at the Meteorological Office for incorporation in the Daily Weather Report or the working charts of the office, and these were sufficient for the purposes of the inquiry.

Wind. Besides the special observations of light airs at the Fire Brigade Stations, the regular observations of wind at other stations, the daily reports from Greenwich Observatory, and the anemograms of the Robinson and Dines anemometers at Kew Observatory were available.

Summary of Observations.

It is not proposed to give a detailed account of all the records of the occurrence of fog which appear in the returns received from the observers.

Light fogs are permanent. It was soon found that light fogs largely attributable to smoke were permanent, or at least of daily occurrence in some parts of London in the winter. From the summit of St. Paul's Cathedral or of Westminster Tower for instance, the average limit of visibility between 20th December and 17th March in 25 ascents, made as a rule between 2 p.m. and 3 p.m., was only ½ mile, and the maximum limit of vision 1½ miles. It was not until

Smoke. 3rd March that one of these elevated points was dimly visible from the other. The obscurity was most certainly due chiefly to smoke, for out of the 25 days on which ascents were made only nine can be legitimately classed as days of fog. This conclusion is corroborated by an inspection of the records from the parks which seldom fail to shew the presence of thin fog. The view in most streets being limited to 100 yards or so, there is no great depth of mist to impress itself on our vision, and we believe the air to be tolerably clear. It was found necessary to change one or two stations thus shut in, as they could form no satisfactory estimate of thickness except in the very densest fogs.

Light fogs not dealt with. Having regard to the difficulty of obtaining comparable records in the case of light fogs, I have only dealt with days on which fog of thick or moderate intensity was recorded at two or more stations in London, the term "moderate" being defined as a fog that: "hinders all traffic, and through which one cannot discern a man more than 100 yards away, nor a house 200 yards, nor, at night, a street light 440 yards." The evidence recorded shows that by the time moderate fog was recorded in two or three places, the whole of London was more or less enveloped in light fog.

"Moderate" fog as thus defined was recorded on 52 days between November 2 and March 14.* A summary of the observations on these 52 days is given in Table A.

* 54 days are mentioned in the table. Two occasions when fog commenced before midnight and continued for less than 24 hours are only counted as one day each.

Discussion of Observations.

General line of inquiry. It must be borne in mind that the object of the inquiry was not to free London for ever from fog but to collect information as to the best mode of attacking the purely meteorological question of local forecasts. Attention was therefore directed chiefly towards the following considerations:—

(1.) What were the specific meteorological conditions under which fog might be expected in London?

(2.) Which part of London would be the first to experience it, and why?

(3.) Will it spread regularly from one part to another so as to admit of warning being sent in advance?

(4.) Will it become a dense fog inconveniencing traffic? If so, in what part of London will it be most dense?

(5.) Will it lift regularly, and what are the meteorological conditions causing it to lift?

System of discussion. The system of discussion was as follows:—An outline map of the London district was coloured to shew both the surface geological formation, and the topographical contours of height above mean river level. From the Daily Weather reports the barometrical conditions over the south of England were considered, special attention being paid to the readings at Yarmouth, Oxford, Dungeness, and Loughborough as compared with that of London. The probable movement of air according to the isobaric gradients, on the assumption that the movement of the air is nearly tangential to the isobars, was compared with the recorded wind at Brixton, the London station of the Meteorological Office for the purpose of the daily weather report. The time of high water at London Bridge was also noted, as from it could be inferred the state of ebb or flow of a large body of water of a temperature different from that of the air. With these probable influences borne in mind the distribution of fog was plotted from hour to hour on the outline map by placing over the positions of the various stations white wool of several thicknesses representing light, moderate, or thick fog. For this idea of using wool of different thicknesses to represent fog and for other suggestions as to the characteristics of fogs that might be recorded, I am indebted to Captain Lionel Wells, R.N., Chief Officer, Metropolitan Fire Brigade.

By this means it was seen:—

Data to be obtained from records.

Where the fogs began.
The time of first appearance.
The direction of spread.
The increase or diminution of density.
The localities specially favoured.
The time of lifting.
The places where the fogs lingered.
Whether the geological conditions affected any of these points.
Whether the elevation above river had any effect on them.
Whether the ebb and flow of the Thames water affected any of these points.

TABLE

RECORD of FOGS of MODERATE DENSITY that occurred between 2nd

Date.	Between what times.		Character of fog.	Whether most on river, in parks, or smoky districts.	Whether fogs on S. or E. coast that day.	State of sky outside fog.	Isobaric gradient.
1901. November.							
S. 3rd	2nd Midt.	Midt.	T. W.	General	Yes, general	Clear	Open isobar, shallow.
M. 4th	3rd Midt.	Midt.	T. or M. Yellow. Country white.	General	Yes, general	Clear	Open isobar, shallow.
T. 5th	4th Midt.	Midt.	T. or M. Yellow. Damp in a.m.	General	Yes, general	Clear	High ridge, shallow
W. 6th	5th Midt.	Midt.	M. Smoky. Wet in country	General	Yes, general	Clear	High ridge, shallow
Th. 7th	6th Midt.	4 p.m.	M. to T. Smoky. Wet in country.	General	Yes, general	Clear	Anticyclone ..
Sat. 16th	15th 10 p.m.	16th Midt.	T. White	General	No	Clear	High ridge .. ..
S. 17th	16th Midt.	4 p.m.	T. Smoky lasting from 16th.	General	Yes	Clear	Excentric anticyclone.
F. 22nd	8 a.m.	1 p.m.	Rain cloud, smoky travelling.	General	No	Cloudy	Low trough between two highs.
Sat. 23rd	7.30 a.m.	Noon	L. to M. Low lying stations.	River	No	Clear	Excentric anticyclone.
S. 24th	5 a.m.	7 p.m.	T. Smoky in places ..	Lingered longest at S.W. stations.	No	Clear	Excentric anticyclone.
M. 25th	6 a.m.	11 a.m.	M. Lifted noon to 4 p.m.	Local and changeable.	East Coast	Clear	Anticyclonic ..
T. 26th	1 a.m.	Noon	M. Smoky in places ..	General	No	Gloomy	Excentric anticyclone.
F. 29th	7.30 a.m.	3 p.m.	M. Smoky. High in places	Local. River ..	No	Detached cloud.	Parallel isobars, open.
December.							
W. 4th	7.30 a.m.	8 p.m.	T. Smoky. High fog as well.	General	Yarmouth	Overcast	Anticyclonic ..
Th. 5th	7 a.m.	Noon	M. White. Mostly L. ..	Local	No	Overcast	Open isobar. Ridge
F. 6th	7 a.m.	Noon	M. White	General	Yarmouth	Detached cloud.	Open isobars ..
16th-17th	16th, 7 p.m.	17th, 1 p.m.	T. Smoky in places ..	Very general, but mostly N. of river.	No	Clear	High col. .. ..
Th. 19th	8 a.m.	8 p.m.	T. Smoky	Very general ..	No	Clear	Low trough between two highs.
F. 20th	7.30 a.m.	3 p.m.	M. White	General. River ..	Yes	Detached cloud.	Open parallel isobars.
Sat. 21st	7 a.m.	4 p.m.	M. & High fog	Less at Western Stations.	Yes	?	High ridge, shallow
S. 22nd	21st Midt.	Midt.	M. Some high fog. Smoky in p.m.	General	Yarmouth, Spurn Head.	Detached cloud, mist.	Open parallel isobars.
M. 23rd	22nd Midt.	1 p.m.	M. White	General	Yarmouth, Spurn Head.	Overcast, some snow.	High ridge .. ..
F. 27th	8 a.m.	2 p.m.	L. to M.	Open spaces. Local.	No	Clear	Open parallel isobars.
1902. January.							
F. 3rd	7 a.m.	3 p.m.	L. to M. Some rain in p.m. Smoky in p.m.	Began in parks and open spaces.	Sheerness, T. Dover.	Detached cloud.	High ridge upset by a low passing.
Sat. 11th	8 a.m.	6 p.m.	Darkness and rain and smoke giving L. to M.	General	No	Cloudy	High ridge. Low pushing in.
W. 15th	7 a.m.	Noon	L. to M. White	General	No	Clear	Anticyclonic ..
F. 17th	7 a.m.	6 p.m	T. Smoky in p.m. Some high fog.	General. T. on river and round Deptford.	Yes	Overcast	Anticyclonic ..
Sat. 18th	7 a.m.	19th 2 a.m.	M. Smoky in places ..	General	Yes	Clear	Anticyclonic ..
S. 19th	8 a.m.	1 p.m.	L. to M.	Local	Yes	Detached cloud.	Excentric anticyclonic.

A.

November, 1901, and 14th March, 1902.

Wind.				Remarks on general temperatures in and around London—Frost, &c.	Relative humidity.		Remarks.
By barometer gradient.	Direction and Force—Brixton. 8 A.M.	Direction and Force—Brixton. 6 P.M.	Velocity—Maximum in miles per hour at Kew.		At Kew, 9 a.m.	At Camden Square, 9 a.m.	
East	Calm	Calm	Nil	From 1½° above normal on 1st it fell to 12½° below normal on 3rd. Min. 33°.	Bulb frozen.	100%	
E.S.E.	Calm	Calm	Nil	Min. 32°	93%	100	
East	Calm	Calm	Nil	Temperature rose in p.m. to 39°	96	100	
E.S.E.	W.S.W. 1	Calm	4 to Nil	Temperature steady 32°	100	100	
Westerly	W.S.W. 1	Calm	Nil to 4	Temperature rose 11° in p.m. ..	98	100	
N.N.W.	Calm	Calm	Nil	Hard frost. Temperature 21° below normal. Very cold in places. Min. 24°.	(95 p.m.)*	100	Railway accidents.
W. by N.	Calm	S.W. 1	6 at Noon	Hard frost. 21½° below normal. Min. 20°.	92	100	Collisions of ships.
W.N.W. variable.	W.N.W. 1	N.N.E. 3	Sudden increase to 17 at 0·30.	Sharp fall of 11° from high temperature.	93	94	Change of wind.
Northerly	E.N.E. 1	N.E. 1	—	Temperature falling. Min. 32°..	86	82	
N.N.W.	Calm	E.S.E. 1	3 at 1 p.m.	Temperature 12° below normal. Min. 24°.	83	90	
?	N.E. 1	N.E. 1	Nil	Temperature rising to 36° in p.m. Min. 25°.	79	80	
N.W.	N.W. 1	N.N.E. 2	?	Rising temperature. Min. 30°..	78	77	
N.N.W	N.W. 1	W. 1	9 at 4 p.m.	Temperature fell and rose again. Min. 31°.	76	82	Combined river fog and smoke.
N.W.	South 1	Calm	Nil	Temperature falling. Min. 35°	91	81	Very dark. A high fog and a low fog together. Dry.
South	S.S.E. 2	S.W. 2	12 at Noon	Temperature steady. 15° below normal. Min. 32°.	86	82	Thick in the City.
N.Wly.	W. 1	S.W. 3	12 at Noon	Temperature rose in p.m. to 45°. Min. 33°.	93	100	Cold surface fog.
?	Calm	S.W. 1	—	Isotherms irregular. Fall of temperature to 25° at 7 a.m. and quick rise to 2 p.m.	(81 p.m.)*	85	
Westerly	W. 1	Calm	Nil	Slight fall to 28°	—	100	
N.N.W.	N.N.W. 1	N.W. 1	17 at 1 p.m.	Slight fall. 14½° below normal. Min. 25°.	89	96	Smoke lay heavily over houses.
? S.W.	N.W. 1	W. 1	8 in p.m.	Temperature slightly risen. Min. 26°.	89	92	
? S.E.	Calm	Calm	11 at 9 a.m.	Temperature steady. Min. 29°..	88	99	Lifted and fell a good deal.
S. by W.	Calm	S. 4	Sudden increase 10 at 1 p.m.	Slight fall to 27°	92	100	Lifted to southerly wind.
W.S.W.	S.W. 1	W. 1	Puffs 13 at 2 p.m.	Slight fall to 31°. Min. 30° ..	88	100	
S.S.W.	W.S.W.	S.W. 2	12 ?	8 a.m., grass bulb, Regents Park, 31°. 8 a.m., top of Victoria Tower, 43°. Temperature above normal and falling.	93	98	Cold surface fog.
West	W. 2	S.W. 1	15 at 5 p.m.	Slight fall, but above normal. Min. 49°.	97	99	
W.S.W.	W.S.W. 1	W.S.W. 2	10 at 11 a.m.	Considerable fall in last day or two. 14½° below normal. Min. 24°.	88	90	
W. by N.	S.W. 1	S.S.W. 1	—	Considerable rise since 15th above normal. Regular. Min. 39°.	93	95	Eastern stations full of smoke.
?	18th p.m. N. 1	19th a.m. W. 1	Nil	Sharp fall of 10° in evening. Irregular in p.m. Min. 27°	84	86	The cold wave came from S.W.
S.W.	S.W. 1	W.S.W. 2	Nil	Further fall. 12° below normal. Irregular in a.m.	91	98	

TABLE

Date.	Between what times.	Character of fog.	Whether most on river, in parks, or smoky districts.	Whether fogs on S. or E. coast that day.	State of sky outside fog.	Isobaric gradient.
1902. February.						
W. 5th	6 a.m. & 3 p.m.	M. Smoky. High fog and darkness.	General	Yarmouth, Sheerness.	Overcast	High ridge, but shallow.
Th. 6th	8 a.m. & 11 a.m.	L. to M. Smoky. High ..	General. Low levels.	Yarmouth, Loughboro'.	Overcast	High ridge, shallow
F. 7th	6 p.m. & Midt.	L. to M.	General	Jersey	Clear	No gradient, large shallow depression.
Sat. 8th	8 a.m. & 5 p.m.	L. to M. Smoky. High fog and darkness.	General	Jersey, Sheerness.	Overcast, snow.	Low secondary, shallow.
T. 11th	8 a.m. & 11 a.m.	L. to M. White	Open ground ..	No	Clear	High ridge .. ..
W. 12th	6 a.m. & 6 p.m.	L. to M. Yellow	General	Sheerness	Clear	High col. .. ..
Th. 13th	6 a.m. to 10 a.m.	M. Wisps of fog. At some places lingering from yesterday.	General	Sheerness, Yarmouth.	Detached cloud.	Open isobars. High, almost a col.
F. 14th	9 a.m. to 4 p.m.	High fog in p.m. and darkness.	Partial to south stations.	Sheerness	Overcast	High ridge .. ..
S. 16th	6 a.m. to 2 p.m.	M. to T. White	Near river	Sheerness	Clear	High ridge. Open isobars.
M. 17th	7 a.m. to Noon	L. to M. White	General	No	Clear	Open isobars ..
T. 18th	7.30 a.m. to 6 p.m.	T. High, dark	General	Sheerness	Overcast	A low pushing in over a high col.
Th. 20th	10 a.m. to Noon	High, some rain	General	Sheerness, Jersey.	Overcast	Open isobars ..
F. 21st	0.30 a.m. to Noon	T. White	General	Sheerness, Jersey.	Cloudy	Open isobars ..
T. 25th	6 a.m. to Noon	M. White	General	Channel	Cloudy	Open isobars. Low advancing.
March.						
S. 1st	1 a.m. to 10 p.m.	T. White. Cleared from noon to 6 p.m.	General	Yarmouth, Spurn Head.	Clear	Open isobars. Low advancing.
M. 3rd-4th	10 p.m. to 3 a.m.	Smoky. Local, Willesden and Kingston, and Greenhithe.	F. B. stations not observing.	Yarmouth and Channel.	Cloudy	Open isobars ..
T. 4th	6 p.m. to 5th 6 a.m.	T. Wet	River and country	Yes, general	Detached cloud.	High ridge .. ..
W. 5th	6 a.m. to Midt.	T. Wet	General	Yes, general	Clear	High ridge .. ..
Th. 6th	Midt. to Midt.	T. Wet in suburbs ..	General	No	Clear	High ridge .. ..
F. 7th	Midt. to Noon	Smoky	General	Yes, general	Clear	High col. .. ..
M. 10th	8 a.m. 2 p.m.	Smoky. Local	General	No	Overcast	Open isobars. Shallow.
T. 11th	7 a.m. 4 p.m.	White a.m., smoky and high p.m.	General	Yes, general	Overcast	High col. Shallow
W. 12th	11th 8 p.m. 12th 2 a.m.	High, smoky	General	Continuation of previous afternoon.		

EXPLANATION OF TABLE A.

Character of fog.—L. Light. M. Moderate. T. Thick.
Fogs on Coast, refers to sea fogs on East or South Coast of England.
The thick margin refers to continuous fogs lasting more than one day.
Normal temperature refers to Normal Mean temperature at Kew.

A—*continued.*

Wind. By barometer gradient.	Wind. Direction and Force—Brixton. 8 A.M.	Wind. Direction and Force—Brixton. 6 P.M.	Wind. Velocity—Maximum in miles per hour at Kew.	Remarks on general temperatures in and around London—Frost, &c.	Relative humidity. At Kew, 9 a.m.	Relative humidity. At Camden Square, 9 a.m.	Remarks.
S.S.E.	S.S.E. 1.	East 1.	13 at 4 p.m.	Freezing in country	82%	90%	
East.	N.E. 1.	East 3.	—	Regular, 34°	84	90	
?	N.N.E. 2.	Calm 0.	Nil.	Regular, 33°	(80 p.m.)*	79	
S.S.W.	S.S.W. 1.	W. 1.	19 at 3.30 p.m.	Colder in country. Some rain a.m.	89	92	Probably snow above causing darkness, falling as rain in places. Variable airs and damp. Smoke rolled up.
W.S.W.	W.S.W. 1.	W. 1.	10 at 10 a.m.	Regular. Colder, 29°	80	90	
N.W.	N.W. 1.	N.N.E. 1.	9 at 4 p.m.	Very irregular, 28°	89	98	Varying in density all day.
North.	North 1.	N.N.E. 1.	—	Very cold in country, 22° ..	76	90	
North.	N. 1.	N. 2.	13 at Noon.	A little warmer, 29°	87	96	Fresh white frost.
E.N.E.	N.E. 1.	N.E. 1.	16 at 1 p.m.	Very cold in country, 21° ..	83	91	
S.E.	S.S.E. 1.	N.E. 1.	10 at Noon.	A little warmer, 26°	80	100	
N.E.	N.E. 1.	N.N.E 1.	7 at 10 a.m.	Much warmer, 34°. Regular ..	82	86	No fog at Eastern stations.
E.N.E.	E.N.E. 3.	E. 1.	—	Some rain. Regular	89	96	
East.	E. 1.	South 2.	10 at Noon.	Slightly irregular, 35°	92	99	Warm South wind over cold E. wind.
S.E.	E. 1.	E. 2.	19 at Noon.	Regular, above normal	99	100	
S E.	Calm.	S.E. 1.	Nil.	Colder, but above normal ..	98	97	Very fine day in country.
S.E.	3rd p.m. S.S.W. 3.	4th a.m. S.E. 2.	—	Regular, 42°	(94 p.m.)*	90	
S.E.	4th p.m. E. 2.	5th a.m. N.E. 1.	16 at 8 p.m.	Slightly irregular. Country warmer.	(94 p.m.)*	100	Afternoon of 4th very warm and sunny.
S.E.	N.E. 1.	E.S.E. 1.	5 at 1 p.m.	Earth temperature highest. Frost. Irregular.	95	100	This may have been started by a wet sea fog blown in from the channel. It began very wet and white, lifted under a very warm sun in p.m. of 5th, and then settled down again thick and smoky. Winds were noted from trend of smoke and were mainly from N.E. in the Eastern districts and from West in the Western districts all day on the 6th.
?	Calm.	Calm.	15. 8 p.m.	On 6th temperature very irregular, especially in p.m., when hot currents of air experienced. Warmer at higher than at lower altitudes.	94	100	
N.N.W.	W.S.W. 2.	N.N.W. 1.	8 at Noon.	—	?	97	
West.	N.N.E. 1.	S.W. 1.	13 at Noon.	Colder, but above normal, 41° ..	96	98	Night of 9th-10th very warm. Light drizzle 7.30 a.m. of 10th.
?	W. 1.	S. 1.	3 at 9 a.m.	Regular, 45°	93	95	
—	—	—	14 at Midnight.	Regular, 48°	(94 p.m.)*	95	

EXPLANATION OF TABLE A.

Gradients :—*High ridge.* A V shaped isobar projecting from Anticyclonic centre.
(*See* Plates.) *High Col.* A neck or saddle of High Pressure between two areas of Low Pressure.
Open Isobars. Parallel isobars of very slight gradient.
Low Secondary. A secondary depression.
Excentric Anticyclonic. When the locality of highest pressure was some distance from London.
Low Trough. A neck of Low Pressure between two areas of High Pressure.
* On these occasions the fog commenced in the evening ; the relative humidity at Kew at 9 p.m. instead of 9 a.m. has consequently been given.

For each serious fog a summary was prepared of all available information bearing upon the questions indicated above.

As examples the following summaries for two of the most noteworthy periods of fog, namely, I. from 2nd to 7th November, 1901, and II. from 5th to 7th March, 1902, may be quoted :—

I. The Fog from 2nd to 7th November, 1901.

[The fog inquiry was not yet started when this fog occurred, but a few notes can be put together from records kept at the electricity works at Bromley-by-Bow, and by Captain Wilson Barker, H.M.S. *Worcester*, off Greenhithe ; by the Kew and Greenwich reports on Clouds, from the Daily Weather reports, and also from newspaper cuttings.]

Radiation. From the 31st October to the 7th November the sky was almost continuously free from cloud outside the fog area. The radiation from the earth was therefore great. Fog was pretty general over the south of England, the Midlands, the English Channel, and the North Sea.

Barometer. An anticyclone of considerable dimensions lay with its centre over Denmark from the 2nd till the 5th, and spread over England on the 4th. On the 5th it moved slowly southward in response to a "Low" forming over the north of Norway, and on the 7th moved to the westward over France, again spreading over the south of England. A "Low" lay to the S.W. of England, over the Atlantic, until the 6th, when it passed southward, another "High" forming over Ireland. *See* diagram for 5th November, Plate III.

Temperature. The mean temperature at Kew was 1½° above normal on the 1st, and fell to 12½° below normal by the 3rd. The normal temperature for the day is computed from the Kew records, 1871–1900. (*See* Meteorological Office Publications, *Temperature Tables for the British Isles*, 1901.)

The minimum temperature at Brixton was 44° on morning of the 1st, 36° on the 2nd, and 33° on the 3rd. It remained low until the 8th.

Wind. There was practically no wind from p.m. of 2nd till p.m. of 7th November.

Fog record, 3rd November. The record commences at 10 p.m. on the 2nd, when there was fog at Kew. On the 3rd November it was T. W. all the morning until noon, when it lifted in places. The S.E. districts remained comparatively clear. It began again everywhere at 6 p.m., and became so thick that all navigation on the river came to a standstill, and in the streets omnibuses and cabs could only go at a walking pace.

4th November. On the 4th November (Monday) it was thick and yellow all day in some places ; at others it lifted somewhat or thinned from 2 to 3 p.m. At Sanderstead village, 530 feet above the sea, two miles south of Croydon, the fog was thick till 11 a.m. It then fell below the village, the sun shining till 4 p.m., but it again crept up at 6 p.m. and blotted out everything. At Captain Carpenter's house, 320 feet above the sea, the fog, at 2.30 p.m., fell to a level 20 feet below the house until 6 p.m., when it again rose. In London all traffic was hindered and on the river completely stopped. Trains were delayed very much ; cabs refused to take fares. Link boys with torches drove a roaring trade, and there were many accidents.

A correspondent reported :—"At 2.30 a.m. it was quite clear as I walked from Blackfriars to King's Cross ; then I found moderate fog as far as Maiden Lane Station (which, it may be noted, is the north end of a long line of railway depôt) ; then it cleared again, but on reaching Camden Road I found a river of fog, six feet high, flowing towards Holloway." This shows how variable it was in density. In the southern suburbs it cleared slightly at night.

5th November. On the 5th it was worse, if possible. White and damp in the early morning, it became smoky later, the particles coated with soot being dry and pungent to inhale. There was a complete block of street traffic at some crossings. Omnibuses were abandoned, and several goods trains were taken off. Perishable cargoes on the river suffered beyond redemption. The Dover to Calais boats were much delayed, and there was a very bad fog in the Bristol Channel. Sanderstead village, 530 feet, was covered all day.

6th November. On the 6th the fog seemed to be whiter, but it remained M. until noon, when it thinned in some parts of London, and in the country lifted altogether until about midnight. Early railway traffic and Channel steamers much delayed. Thick fog in Paris.

7th November. On the morning of the 7th it was M. again, and was a wet fog in the country. The temperature, however, began to rise, and went up 10° by the morning of the 8th. The fog cleared off generally about 4 p.m. Traffic still disorganised in early part of day. Several collisions occurred and large vessels were much delayed in the Channel.

II.—The Fog from 5th to 7th March, 1902.

From the 4th to 7th the sky seems to have been free from cloud outside the fog area. It was, however, difficult to judge, as fog was general over England. In the Dover Straits it was very dense from 3rd to 7th, and at the mouth of the Thames traffic stopped on the 6th. On the night of the 5th the Irish Mail Steamer ran ashore, and an American liner was sunk off Holyhead by collision in a thick fog. Liverpool was under a pall and the river traffic stopped. At Queenstown the harbour was under dense fog all the 6th.

Barometer. On the 3rd March pressure was high over the Gulf of Finland and also over the south of France, with a "Low," travelling N.E., off the west of Ireland. On the 5th the centre of the high pressure area was over N.E. Germany, with a wedge stretching over south of England, separating the "Low" over the Shetland Islands from another over the Bay of Biscay. (*See* diagram 5th March, Plate III.)

On the 6th the condition was much the same, but the northern "Low" was travelling up the coast of Norway. On the 7th a fresh "High" appeared over the west of Ireland.

Thermometer. The minimum temperature at Brixton on morning of 4th was 38° ; on 5th, 34° ; on 6th, 32° ; and on 7th, 30°. The 40° isotherm for 8 a.m., ranging due N. and S., crossed the east of England on 3rd, and on 4th, 5th, and 6th it advanced westward right over England, on the latter day a cold patch of 30° was shown over the Midlands and Bristol. On the 8th the 40° isotherm withdrew over the North Sea.

Fog. 4th March. 5th March. A wet fog commenced round London about 7 p.m. on the 4th, after a fine sunny afternoon ; it cleared away from 10 a.m. till 6 p.m. on the 5th, and came on again at 7 p.m., thick. A frost came on during the night, and by morning of 6th white rime was deposited on everything.

6th March. By 8 a.m. on 6th the fog was moderate to thick on the river, thick at the Park stations, and smoky in places. By noon it was lifting at Kew, Tilbury, Hammersmith, and one or two other places, but there was fog at 36 stations—lightest in the west, densest in the centre and east. (*See* Plate VII.)

The distribution of fog at 3 p.m. is shown on the map (Plate VIII). It was still thinner at 4 p.m., but at 6 p.m. it began to thicken again, and by 8 p.m. was general over London, except places of high altitude, such as Hampstead, Shooters Hill, Dulwich, being reported T. at nine stations, mainly in E. and N.E.

7th March. On the 7th fog was recorded at 6 a.m. at 23 stations, mostly central and eastern, and had been prevalent during the night. Fresh L.W. fog came on about 7 a.m. at stations which had been clear in the night; and at 8 a.m. there were 30 stations under fog, though only T. at four stations. At Plaistow, Shadwell, Wandsworth, and Harlesden it lifted finally about 5.45 a.m. By 10 a.m. fog was thinning generally and lifting, but still T. at Hyde Park and Bromley-by-Bow. By noon the fog was dispersing before a W.S.W. wind, and a rising temperature, and very little was left.

Wind. 6th March. The *air movement* over London on 6th was taken at all fire stations, by watching trend of smoke from high chimneys. *See* wind arrow charts. Plates VII. and VIII.

10 a.m.—Winds mainly from N.E., but an indraught towards Broad Street.

At North Kensington, Wandsworth, Tooting and Woolwich the air trended outward from London. Calms at seven stations. From the Kew Anemograph, Mr. Shaw thinks that the wind changed from E. to N.W. about 11.45 a.m.

Noon.—From E. direction in N.E. and S.E. quadrants of London, and from W. to S.W. in the N.W. and S.W. quadrants. Calms on a line from Camden Square to Camberwell. (*See* Map, Plate VII.)

2 p.m.—N.E. in the N.E. and S.E. districts, and from W. in the N.W., S.W., and central districts, blowing towards a line drawn from Kentish Town to South Bermondsey.

At North Kensington, Wandsworth, Tooting, Isle of Dogs, and Woolwich, the wind trended outward from London. (*See* Map, Plate VIII.)

4 p.m.—Wind mainly N.E., but a W. and N.W. current pushing in from the west district. Calms between Fulham and Camberwell.

6 p.m.—Winds mainly from N.E., but a wedge of W. and S.W. wind pushing in from Hammersmith to Broad Street.

7th March. The air movements on the 7th were :—

8 a.m.—General trend from W.S.W., but at a few places, from N. or N.E. very light airs. Wandsworth, S.E. ; Tooting, E. 10 a.m.—Main current from W.S.W., with a tendency to blow along the river. At five stations wind reported from N. or N.E. From the Kew Anemograph, Mr. Shaw gathers that the wind changed from N.W. to W. at 9 a.m. on the 7th, but probably the air was too light to move the vane.

The maps (Plate VII. and VIII.) show the distribution of temperature and fog at noon and 3 p.m. respectively on the 6th (the wind arrows are for noon and 2 p.m.).

Two interesting points should be mentioned ; they will be more fully discussed in considering the general results of the inquiry (*see* pp. 20 and 22).

Temperatures. Firstly, the temperatures were considerably higher on the tops of St. Paul's Cathedral, the Victoria Tower, and the roof of the Meteorological Office than in the streets below.

Secondly, the fog was thickest in the central and N.E. districts and showed a tendency to clear in the W. and S.W. In the N.E. the temperatures were low (Islington 39°), and the air currents were mainly from the N.E., whereas in the W. and S.W. the temperatures were distinctly higher than the average (Kew and Banstead 54°), and the wind was from a westerly direction. The main features of the distribution of fog, temperatures, and air currents appear to have remained constant as long as the fog lasted.

Some further remarkable temperatures which occurred during the days of fog are here given.

March 6th, at 9 a.m.—Dry bulb at Sanderstead (37°·5) was 6°·5 above the earth's temperature, the sun was, however, on the screen ; the temperature on St. Paul's was 3°·5, above that at Regent's Park.

At 10 a.m—Bethnal Green (37°) was 6° below Great Marlborough Street.

Warm air currents were experienced in the streets between 5 and 6 p.m., notably so at 5.15 at Waterloo Place, also in Ebury Street, Hyde Park, and King's Road, Chelsea.

At 6 p.m.—On roof of Meteorological Office, 53°. At Brixton, Rushey Green, and Islington, which were under fog, temperature, 39°. At Banstead, Kew, Hammersmith, 50° to 53°. At 8 p.m.—Hammersmith, 45° L.W. Rushey Green, 35° T.S.

At 9 p.m.—Victoria Tower, St. Paul's, Meterological Office roof, about 48°·5.
Camden Square and Battersea Park, 37°.

On March 7th—

8 a.m.—Temperature, Banstead, 43° ; Brixton, 32° ; general temperature, 38°·5 ; Brixton under T. fog.

9 a.m.—Temperature, Banstead, 45° ; Kew, 36° ; general temperature, 39°·5 ; Kew under M. fog.

10 a.m.—Temperature, Banstead, 48° ; Islington, 39° ; general temperature, 43° ; Islington under fog.

Noon.—Temperature, Islington, 42° ; general temperature, 44° to 50°, fog practically dispersed.

At outlying stations the fog was reported as being wet all day on the 6th, but inner stations recorded it dry.

General Results of Inquiry.

Fog frequency. It is hardly correct to take the record of fog occurrence at one place as a record of days of fog for the whole area, for instance, the Daily Weather Reports give the weather at Brixton daily for 8 a.m. and for 6 p.m., and fog is there recorded if it exceeds the usual very thin fog called mist. During the period under discussion fog was only recorded as having occurred on 37 occasions within the 24 hours previous to the 8 a.m. observations. But by the figures already given it will be seen that there were really 52 days of fog of a density reaching at least moderate at more than two places ; and, if we were to include lesser densities we should probably arrive at a figure of some 80 days of fog occurrence in London out of a period of 132 days.

But, perhaps, a better estimate of local liability to fog can be made by taking the number of days of fog occurrence at each station using fogs of all densities that lasted at least $2\frac{1}{2}$ hours, so as not to include mere wisps of smoke fog. In Table B a list of all the stations in the immediate vicinity of London is given, with the number of days on which such fogs were observed during the period of 90 days between 15th December, 1901, when all the stations were in operation, and 14th March, 1902, when the season practically concluded. The names of the observers and the heights of the stations above mean river level have been included.

TABLE B.—ORDER of STATIONS in FOG FREQUENCY—WINTER 1901–2; FOGS of all DENSITIES INCLUDED.

Name of Station.	Observer.	Height above River.	Number of days on which fog occurred between 15th December and 14th March.
Botanical Gardens, Regents Park *	J. Wilson, R. Bot. Soc. ...	104	59
Kingsland Road, N.E.	G. L. Frankham, M.F.B. ...	64	59
Cherry Garden Pier, Bermondsey Wall	W. Gill, M.F.B.	4	42
Electricity Works, Bromley-by-Bow	Superintendent...	25	41
Upper Street, Islington	T. Hore, M.F.B.	122	35
Deptford Victualling Yard Pier	L. George, M.F.B.	18	32
Barking Police Station	Metropolitan Police	20	31
Hyde Park Centre	Metropolitan Police	60	30
Paddington, Edgware Road	S. Sharp, M.F.B.	107	30
85, Fulham Road	P. C. Shead, M.F.B.	26	30
Wandsworth, West Hill	W. Deacon, M.F.B.	60	28
Battersea Bridge	S. J. Jeanes, M.F.B.	22	27
Camberwell, Peckham Road	F. Stickland, M.F.B.	24	26
Clerkenwell, Roseberry Avenue	E. Williams, M.F.B.	70	26
Great Marlborough Street, Regent Street	T. J. Grievson, M.F.B.... ...	78	26
Harlesden Police Station, Willesden	Metropolitan Police	150	25
Tooting, Balham Hill Road	W. P. N. Mundy, M.F.B ...	95	25
Kingston, Police Station	Metropolitan Police	32	25
Blackfriars, River Side	F. J. F. Allshorn, M.F.B. ...	14	23
Stoke Newington, Leswin Road	J. F. Spencer, M.F.B.	80	23
Sydenham, Crystal Palace	W. Mitchley, M.F.B.	325	22
Forest Gate	J. T. Smith	38	21
Shadwell, Glamis Road	G. S. Morris, M F.B.	28	21
Hampstead, Heath Street	J. Smith, M.F.B.	375	19
Blackheath, Tranquil Vale	J. Parsons, M.F.B.	125	19
Bethnal Green, 51, Green Street	H. T. Dawson, M.F.B.... ...	47	18
Kew Observatory (National Physical Laboratory) ...	The Staff	23	17
Brixton, Ferndale Road	F. Coates, M.F.B.	50	17
Woolwich	W. E. Tozer, M.F.B.	50	16
Rushey Green	E. J. Blampied, M.F.B. ...	60	16
Watling Street	S. Taylor, M.F.B.	50	16
Shooters Hill, South End of Woolwich Common	L. Davis, M.F.B.	250	13
Southwark, Southwark Bridge Road	Officer of Watch, M.F.B. ...	18	13
Isle of Dogs, Junction of Ferry Roads	C. T. Stubbings, M.F.B. ...	16	12
Poplar, West India Dock Road	G. A. Rothwell, M.F.B. ...	20	10
Plaistow Police Station	Metropolitan Police	21	9
North Kensington, Faraday Road	C. A. J. Ccok, M.F.B.	77	7
Hammersmith, near the Stations	H. C. D. Thoburn, M.F.B. ...	18	7
Dulwich, East Side of Dulwich Park	C. R. Couch, M.F.B.	185	1

* Observations were not taken at Kew throughout the night.

Only fogs lasting at least two-and-a-half hours have been included. The Observatory at Greenwich reports 15 fogs in the same period. Coast guard stations have not been included, being too distant to be properly compared.
Battersea Park (Superintendent F. J. Coppin) is not included, as fog observations were discontinued there early in January on account of its proximity to the Fire Brigade Station at Battersea Bridge. Temperature observations were taken regularly till the inquiry ceased.

All the observers have been treated as estimating equally; but as such a desirable result is hardly possible this table cannot be considered final. It, however, forms a basis for further investigation. I would here warn the reader against taking these figures as in any way final for any part of London. A very short distance frequently makes a great difference in the descent of the fog or in its duration. The stations Bromley-by-Bow and Poplar are only three-quarters of a mile apart, yet the figures are 41 and 10.

Days of the week.

The order of fog frequency on days of the week during the past winter works out in the following order :—

Friday	163	Tuesday	115
Saturday	143	Thursday	112
Sunday	143	Monday	87
Wednesday	139		

Light fogs have been included.

Hours that fog begins.

The time of commencement of fog generally appeared to be simultaneous over London although it slightly favoured low-lying stations. The following were the hours of commencing to form :—

Midnight to 1 a.m.	3	occasions.
5 a.m. to 6 a.m.	8	,,
7 a.m. to 8 a.m.	23	,,
9 a.m. to 10 a.m.	2	,,
5 p.m. to 10 p.m.	7	,,
Total	43	,,

Probably light fog at night was not recorded with very great accuracy.

Greatest density.

The worst time of the day for the occurrence of dense fogs hindering traffic was from 6 a.m. until Noon. As the Traffic Manager of one of our great southern railway systems remarked,—

> "The fogs of overnight frequently die down and the stars come out and all seems to be "favourable for the early morning city trains, then the sun rises and the fog thickens between "8 and 10.30 a.m. just when the traffic is greatest."

After dusk, when the streets are full, a moderate fog causes all the inconvenience of a thick fog by daylight.

Spreading of fog.

Fog appeared to spread on no regular system. This fact will perhaps come as a surprise to many, but it seems to be clearly borne out by the evidence. There were several instances of fog first occurring in one district of London before another, but there was apparently no regular onward spread from any one locality to another. Many fogs formed high overhead and descended, many formed in low streaks, and there were days on which fog seemed to grow out of the air everywhere simultaneously.

Thames estuary.

Fogs do not travel up the River Thames and thus invade London. The sea fogs of the estuary are very different in character from the smoky fogs nearer London. The fact that fog occurred at Sheerness on 72 per cent. of the days that it occurred in London would appear to shew that town fogs and sea fogs originate from nearly similar causes.

Geology.

The geological formation on which the various stations are located does not seem to sensibly affect the occurrence of fog, and this is not surprising when we consider that the surface layer over the greater part of Central London is composed of made ground covered by concrete, asphalte, cobble stones or wood pavement. The high places in the

order of frequency, taken by Regent's Park and Hyde Park, point to the probable influence of a moist grass surface on the formation of fog, but an allowance must also be made for the greater range of view conducing to a higher record of fog occurrence.

Relative humidity.

The relative humidity of the atmosphere four feet above the ground on days of occurrence of fog is recorded in Table A. for 9 a.m. both at Kew and at Camden Square. As the hour of nine in the morning is a time when fogs are most dense, and the sun in the winter months has but little heating power, the Tables probably give a good idea of the state of humidity of the atmosphere when fogs arise. The average relative humidity was 89 per cent. at Kew on days of occurrence of fog, and 93¾ per cent. at Camden Square. It must be borne in mind, however, that there was not necessarily a fog at either Kew or Camden Square on each of these days.

It will be seen that the relative humidity reached,—

At Kew,—				At Camden Square,—			
100 per	cent.	on 1	occasion.	100 per	cent.	on 16	occasions.
95–99	,,	8	,,	95–99	,,	15	,,
90–94	,,	16	,,	90–94	,,	10	,,
85–89	,,	12	,,	85–89	,,	4	,,
80–84	,,	8	,,	80–84	,,	5	,,
75–79	,,	5	,,	75–79	,,	2	,,
70–74	,,	1	,,				

The mean relative humidity for 8 a.m. at Brixton from November to March was 86·8.

The months of November and January were unusually dry in the South-east of England.

Effect of previous rain.

The occurrence of fog was not increased by previous rainfall. Probably as regards evaporation, the ground surface of London must be regarded as damp throughout the winter.

Change of density with height

With regard to observations above the ground level, it may be remarked that only on one or two occasions were we able to get above a London fog. It seemed to be very rare that a moderate or thick fog showed any evidence of being thinner near its upper surface with any of the moderate variations of height available. The density was much the same throughout its depth. Observations made from the watch towers of the Fire Brigade stations, and from Westminster Tower and St. Paul's, shewed little or no difference in visibility from observations taken at street level. Balloonists and mountaineers find a similarly uniform density of cloud and abrupt transition from cloud to clear atmosphere.

Elevation.

The effect of elevation is undoubtedly to decrease the record of fog occurrence, as it is well known that many fogs lie in valleys and hollows when the heights above are clear. This is not very evident from the list of frequency, but it is a fact that a thick fog was of rare occurrence at Hampstead, Sydenham, Shooters Hill, or Dulwich, the four highest stations.

Dispersal.

Fogs in London were dispersed when the record of wind at Kew reached a velocity of 13 miles per hour, except the very smoky fogs accompanying the damp air of advancing

depressions, and these seemed to require a force of about 17 miles an hour to dislodge them. Further observations on this point are very desirable, as the record is too short.

Fogs lifted or dispersed much more irregularly than they began, still there were distinct simultaneous dispersals frequently at several stations, leaving the denser patches to dissolve later. The most common time for a preliminary lift, and sometimes for a complete dispersal, was the hour of noon.

Besides the sun's power being greatest at this time, we found that on 23 days out of the 52, light breezes sprung up between 10.30 a.m. and noon, and gradually increased. Taking the Dines pressure-tube record at Kew for the force of wind during the hours of fog, the most common description of wind force would read somewhat as follows :—

> "Calm from 9.15 p.m. last night to 11 a.m. this morning, then a light air sprung up, and by noon had attained a velocity of 13 miles per hour."

A further lift frequently took place about 4 p.m., the denser patches giving way by that hour to sun's heat or increasing wind.

Fog lingered.

The following are some of the stations at which fog lingered later than at others :—

Deptford River Side,
Camberwell,
Bromley-by-Bow,
Islington,
Paddington,
Kingsland Road,
Tooting,
Bermondsey Wall River Side (Cherry Garden),
Battersea Bridge,
Woolwich.

The direction of wind generally caused the leeward stations to be the last to lift.

Sun's heat.

The fogs in November and December and January lifted less in the middle of the day than those in February and March, and also, as far as scanty records go, less than those in September and October. The sun's altitude in London on the shortest day at noon is only 15°, whereas on the longest day it is 62°. Striking the earth's atmosphere thus obliquely the solar rays have to penetrate on the shortest day an atmosphere more than three times as thick, and a great deal more smoky, than on the longest day. The reduced heat rays that get through, therefore, even on days of clear sky, have little effect on a dense body of fog. On the other hand, when the sun's altitude is higher its heat induces convection currents that help to disperse fog.

Meteorological conditions.

The number of distinctly separate fogs between the 2nd November, 1901, and 14th March, 1902, in which a density of at least M. was recorded at more than two stations, was 43, extending over 52 days as shown in table A.

In this period the most continuous fog was from the night of 2nd November till 4 p.m. on 7th November, or for 4 days 18 hours. Out of 52 days of fog, a cloudless blue sky prevailed outside the limits of fog on 23 days, and there was fog on the East, or on the South Coast of England, on 35 days.

Barometric distribution.

The Daily Weather Reports show that on these 52 days the London area was under one or other of the following barometrical systems, which will be understood from the diagrams which follow :—

A High ridge	on 16	occasions.	
A High Col	on 6	„	
Anticyclonic	on 6	„	
Excentric Anticyclonic ...	on 5	„	
Open parallel isobars	on 15	„	
A Low trough	on 4	„	

These may be reduced to—

Anticyclonic conditions	33
Open parallel isobars	15
Low trough	4
Cyclonic conditions	Nil.

Plates III., IV., and V. give diagrams of barometrical distribution on days of fog. They are taken from the Daily Weather Reports of the Meteorological Office.

Gradients.

Open parallel isobars signify low gradients. The mean gradient on the 15 occasions mentioned was ·0067 inch per 15 nautical miles, and it ranged from ·004 inch to ·011 inch. This represents a rise or fall of one tenth of an inch in 224 nautical miles, corresponding to a pressure difference of ·078 inch between say London and Plymouth.

Wind.

The Barometrical conditions over the South of England during fog would have led one to expect a probable movement of air over London from—

North-Westerly quadrant	on 15	occasions.	
South-Westerly	„	„ 9	„
South-Easterly	„	„ 14	„
North-Easterly	„	„ 6	„

Not allowing for probability of calm.

The recorded Winds at Brixton gave at commencement of fog—

Calms	on	7	occasions.
North-Westerly quadrant	„	11	„
South-Westerly	„	„ 8	„
South-Easterly	„	„ 6	„
North-Easterly	„	„ 10	„

Movement of air over London on calm days.

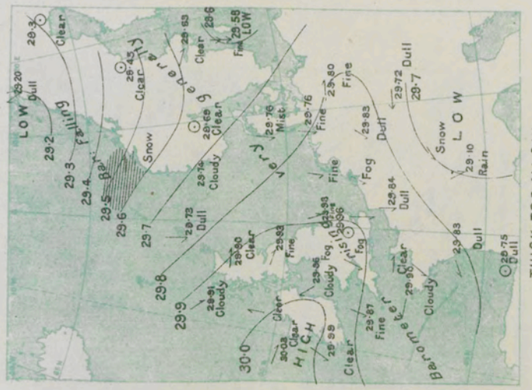
The two hourly observations by the Fire Brigade, taken specially on days of very light airs, show that a record of the direction of light airs at any one place in the London area is of no assistance towards forming an estimate of the general drift of wind. When, on such days, the wind records from the 30 stations are plotted, it is found that there is generally a distinct in-draught deflecting the wind arrows from parallel courses, and on days of the very lightest airs, the wind arrows point from all quarters direct towards the centre of London causing central calms. *See* Plates VII., VIII., IX., X., for 12th February and 6th March, 1902.

To face page 20.

Plate III.a.

Fog Occurrence. Barometric Distribution.

A High Ridge. 16 November 1901. 8 A.M.



A High Ridge. 5 November 1901. 8 A.M.

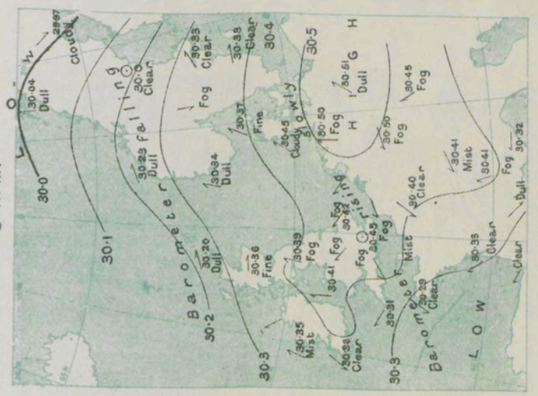
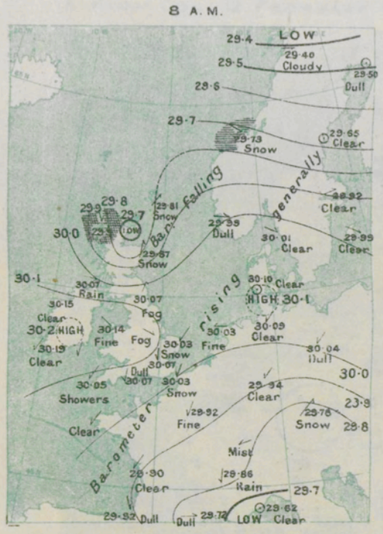


Plate III[b]

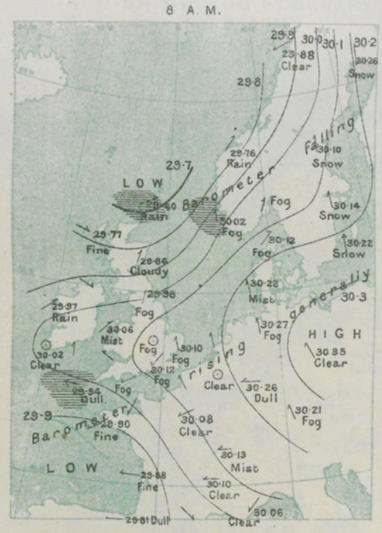
FOG OCCURRENCE. BAROMETRIC DISTRIBUTION.

A HIGH RIDGE. 14 FEBRUARY 1902.
8 A.M.



MODERATE FOG 9 A.M. – 4 P.M. HIGH FOG IN P.M.
TEMPERATURE AT BRIXTON AT 8 A.M. 29°.

A HIGH RIDGE. 5 MARCH 1902.
8 A.M.



THICK FOG 6 A.M. – MIDNIGHT.
TEMPERATURE AT BRIXTON AT 8 A.M. 34°

3557.11.02.

E. Weller & Grahams, Ltd Litho. London.

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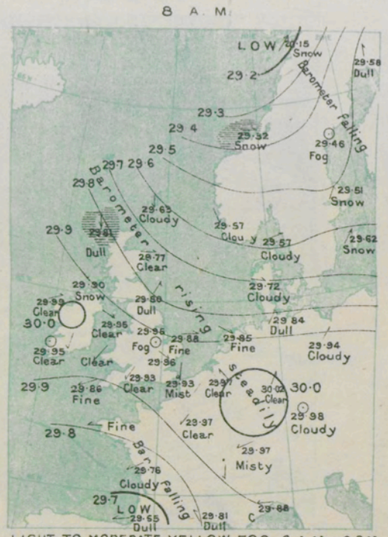
Plate IV.a

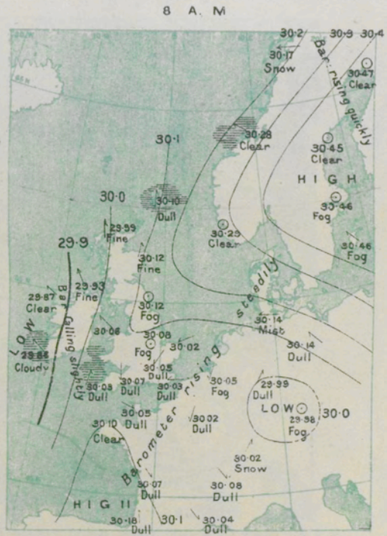
Fog Occurrence Barometric Distribution.

A High Col. 12 February 1902.
8 A.M.



LIGHT TO MODERATE YELLOW FOG 6 A.M.–6 P.M.
TEMPERATURE AT BRIXTON AT 8 A.M. 24°

A High Col. 18 February 1902.
8 A.M.



THICK HIGH FOG 7.30 A.M.–6 P.M.
TEMPERATURE AT BRIXTON AT 8 A.M. 33°

3557 11 02

E. Weller & Graham's L.th Litho London

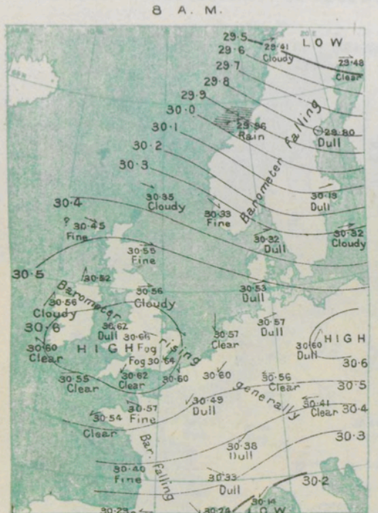
To face page 20.

Plate IV[b]

FOG OCCURRENCE BAROMETRIC DISTRIBUTION.

ANTICYCLONIC. 25 NOVEMBER 1901.

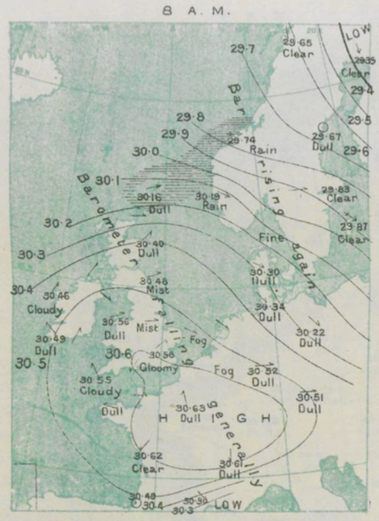
8 A. M.



MODERATE FOG 6 A.M. TO NOON AND 4 P.M. – 11 P.M.
TEMPERATURE AT BRIXTON AT 8 A.M. 30°

ANTICYCLONIC. 17 JANUARY 1902.

8 A. M.



THICK FOG, SMOKY IN P.M., SOME HIGH FOG, 7 A.M. – 6 P.M.
TEMPERATURE AT BRIXTON AT 8 A.M. 41°

3557. 11.02

E. Weller & Graham, Ltd Litho London.

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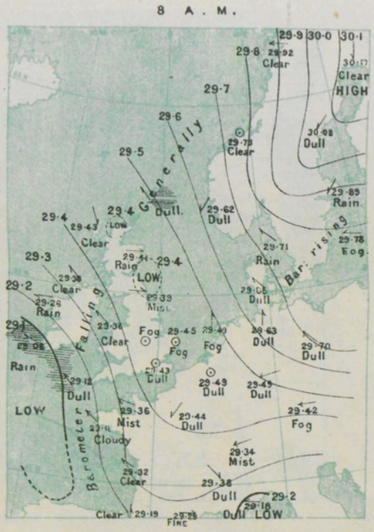
Plate V.ª

Fog Occurrence. Barometric Distribution.

Open parallel isobars. 22 December 1901.

8 A.M.

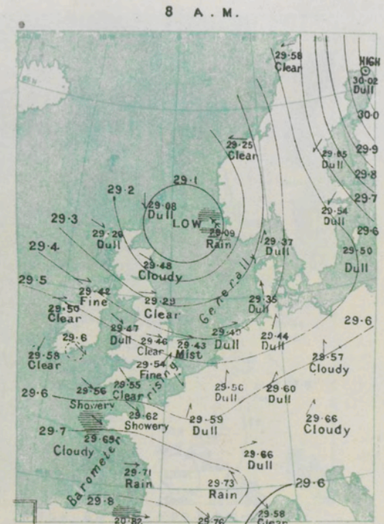


MODERATE FOG ALL DAY; SMOKY IN P.M, SOME HIGH FOG

TEMPERATURE AT BRIXTON AT 8 A.M. 31°

Open parallel isobars. 27 December 1901.

8 A.M.



MODERATE TO LIGHT FOG 8 A.M.— 2 P.M.

TEMPERATURE AT BRIXTON AT 8 A.M. 31°

352.17.22.

E. Weller & Grahams. Ltd Litho London

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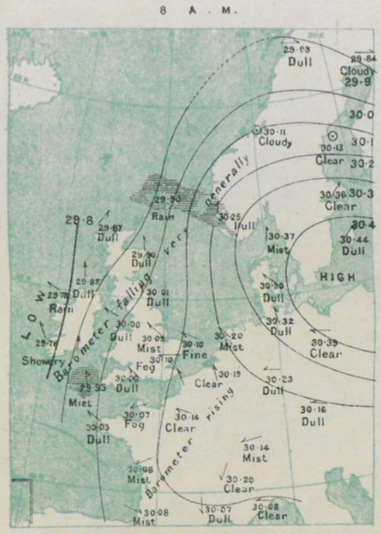
Plate V^b

Fog Occurrence. Barometric Distribution.

Open parallel isobars 21 February 1902.

8 A.M.

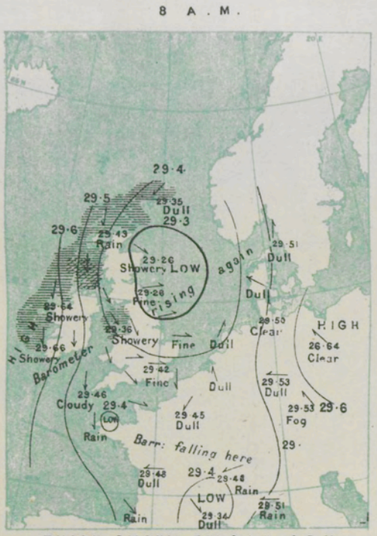


THICK FOG MIDNIGHT TO NOON

TEMPERATURE AT BRIXTON AT 8 A.M. 34°

Low trough. 19 December 1901.

8 A.M.



THICK SMOKY FOG 8 A.M.—8 P.M.

TEMPERATURE AT BRIXTON AT 8 A.M. 28°

3851 12 02

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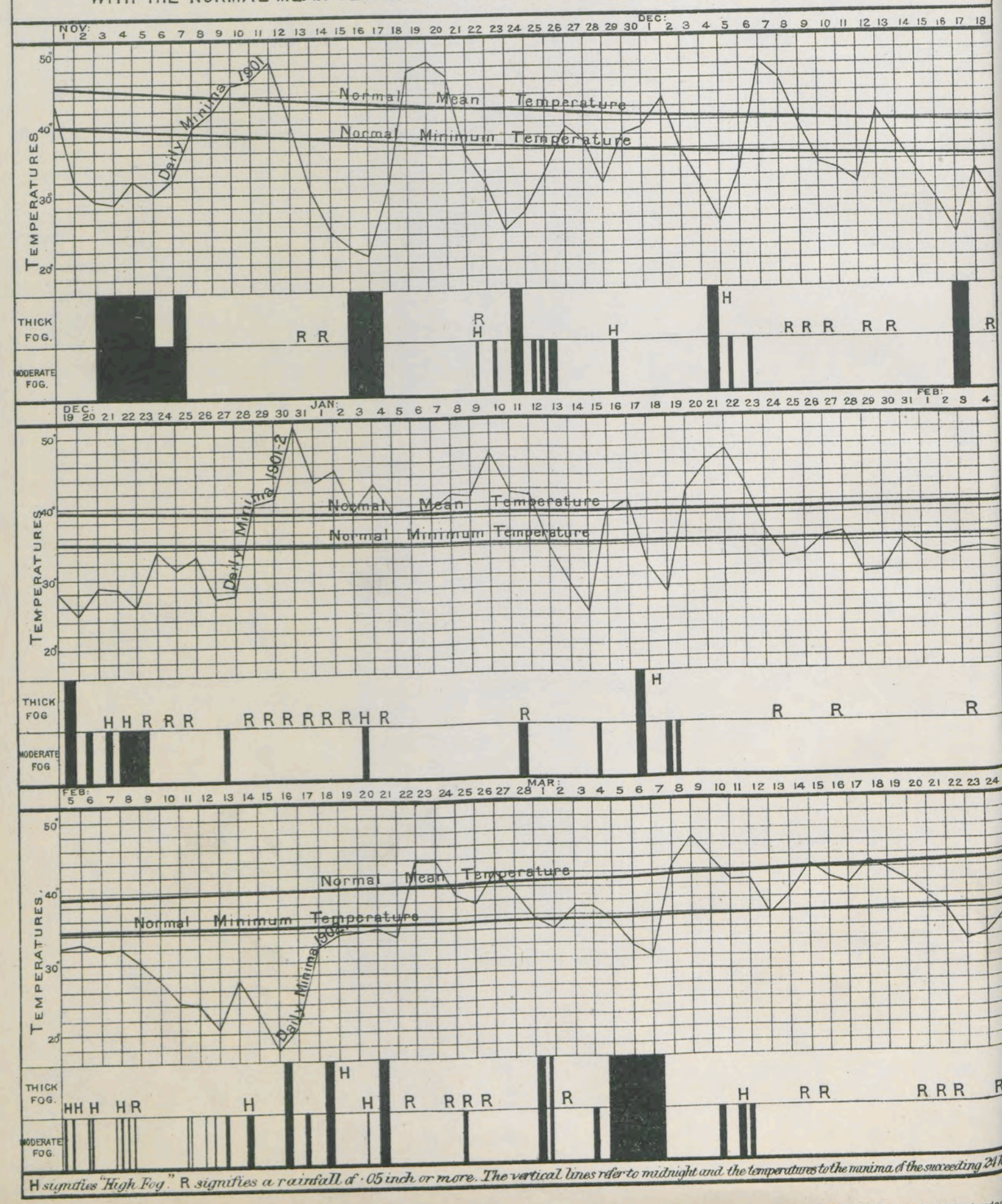
To face page 21.

Plate VI., DIAGRAM SHOWING THE OCCURRENCE AND DURATION OF MODERATE AND THICK FOGS IN LONDON, AND THE DAILY MINIMUM OF TEMPERATURE AT KEW IN THE WINTER OF 1901-2, TOGETHER WITH THE NORMAL MEAN TEMPERATURE AND THE NORMAL MINIMUM TEMPERATURE AT KEW.



E. Weller & Grahams, Ltd Litho. London

It is probable that the warm air over central London rises, as was, I believe, suggested by Dr. H. R. Mill, thereby causing a reduction of pressure, towards which the surrounding air flows. Such a movement of light airs would certainly collect the smoke over a central area, though whether the smoke particles being heavy would fall, or rise with the heated air, is open to doubt. Further observations in this direction should be made, if possible, throughout a whole year on occasions of calm weather.

Temperature.

The relation between the minimum daily temperature at Kew and the occurrence of fog in London is shown on Plates VI., the minimum shade temperature being compared with the normal mean temperature and the normal minimum temperature* at Kew for the 30 years 1871–1900, and the fog shown below by shading over the dates and hours of occurrence.

No severe fogs occurred with a temperature above 40° Fahrenheit.

Fog occurred after a fall of 4°, or more, of minimum temperature for the day, as compared with the previous day, on 23 occasions.

On the other hand fog occurred after a rise of minimum temperature, of more than 4°, on six occasions.

Temperature at Kew remained fairly steady on 13 occasions of fog in London. This does not preclude the possibility that a local fall of temperature may have occurred where fog was recorded.

The minimum temperature, prior to fog coming on, averaged 9° below normal mean temperature for the day. The normal mean temperature is that for the 30 years 1871–1900.

Fog occurred when the minimum temperature was above the normal mean temperature on only four occasions. During foggy weather the temperature varied over different parts of London and at different heights. The following table gives the readings taken on the 29th January, a day of no fog, and the 6th March, a day on which fog was thick over the greater part of London, but became thinner in some places between noon and 6 p.m. They may be regarded as typical of the distribution of temperature on clear and foggy days respectively. The heights of the stations above mean river level are given at the top of each column.

Date and Hour.	St. Paul's Cathedral. 340 ft.	Sanderstead, South Croydon. 320 ft.	Victoria Tower, Westminster. 297 ft.	Greenwich Observatory. 155 ft.	Camden Square. 130 ft.	Regent's Park. 111 ft.	Roof of Meteorological Office. 82 ft.	Kew. 34 ft.	Churchyard, Westminster. 23 ft.	Battersea Park. 18 ft.
29th January, 1902. 9 a.m.	30·5	28·5	29·3	29·9	29·5	30·0	30·2	30·5	31·0	31·0
29th January, 1902. 3 p.m.	35·5	36·0	36·0	—	37·2	37·0	37·5	38·0	38·2	38·0
29th January, 1902. 9 p.m.	35·0	—	35·0	—	33·9	34·2	36·2	35·0	—	35·0
6th March, 1902. 9 a.m.	37·5	37·5	36·0	32·7	36·2	34·0	35·0	32·5	36·5	35·0
6th March, 1902. 3 p.m.	47·0	—	50·0	—	41·0	45·0	51·5	54·0	44·0	44·0
6th March, 1902. 9 p.m.	48·5	—	49·5	—	36·5	40·0	48·0	39·0	—	37·0

The reading at St. Paul's at 9 a.m. on 29th is about 1½° more than would be expected. The daily comparisons of temperature over London showed that the central parts were about 1° warmer than the suburbs—allowing for height.

* The normal minimum temperature has been computed from the Kew records, 1871–1900, in a similar manner to the normal mean temperature, *c.f.* p. 7.

Two points of interest attach to these observations :—

(1.) The differences between the simultaneous readings on January 29th is small (maximum difference 2°·7 at 3 p.m.), whereas on March 6th, readings vary greatly. In discussing this fog in detail on p. 14 attention was drawn to the fact that the colder stations lay mainly in the North-East, which was also the region of thickest fog. It would be premature to state that such a connection between thickest fog and lowest temperature is general, but the point calls for further investigation which may lead to important results.

A further instance may be quoted. On February 13th, both Battersea Park and Sanderstead were 6° below all other stations except Kew, which was only 4° lower. There were wisps of fog lingering from the previous day's fog and the places of low temperature indicated the occurrence of fog.

(2.) The vertical distribution of temperature claims attention.

Temperature at high altitudes.

The temperature at the top of Victoria Tower, Westminster, has been compared with temperature at other stations of varying height above the sea. In the following table the period of observation is from end of December to middle of February. The sign + signifies that the temperature at the stations was higher than on the tower.

Meteorological Office Roof. 82 ft.			Christ Churchyard. 23 ft.		Camden Square. 130 ft.	Regent's Park. 111 ft.	Remarks.
Midnight.	3 a.m.	6 a.m.	9 a.m.	3 p.m.	9 p.m.		
°	°	°	°	°	°	°	
+ 1·1	+ 1·03	+ 0·88	+ 1·9	+ 2·0	− 0·01	+ 0·03	Victoria Tower thermograph is 297 feet above the sea.

Simultaneous observations were made at 3 p.m. on 15 occasions with dry bulbs on top of the tower and in the churchyard. These give an average excess of temperature in churchyard 1·43° above the tower, which is equal to 0·52° F. in 100 feet.

Similar comparison between the top of St. Paul's, 340 feet, and the churchyard gives an excess in the latter of 1·66°, also equal to 0·52° F. in 100 feet.

On January 29th, though the differences were small, the temperatures were generally higher at the low stations than at the high ones, but in the afternoon and evening of March 6th the temperature in the streets was many degrees below that at the more elevated stations. The most remarkable difference is that between the screen in the churchyard in Victoria Street and the roof of the office, nearly vertically above it, which amounted to 7°·5 F. The dynamical conditions arising when a layer of warmer air overlies colder air are very unusual. They are conditions of great stability under which there is no tendency for the smoke in the lower air to become dispersed by rising. A further remarkable instance of the inversion of the normal vertical distribution of temperature occurred on January 18th. At 9 p.m. both Westminster and St. Pauls showed temperatures six degrees higher than Camden Square, Regent's Park, or Kew. A fog came on at 7 p.m. and lasted till 2 a.m. on the 19th.

River temperature.

It will be noted on the frequency lists that the river stations, Bermondsey Wall (Cherry Garden), Deptford, Blackfriars, and Battersea, come out high in fog frequency. This may be partly due to greater range of vision, but it is also in part due to the

frequent formation of fog over the river only. Such fogs are generally low, and they do not seem to spread far over the neighbourhood. They frequently appear to be drifting before currents of air up or down the river, but are not influenced in drift by friction with the river surface.

Observations of water surface temperature were begun at Blackfriars river station on the 19th December, the readings being taken at the time of half flood stream. On the 12th January further observations were commenced and recorded at 9 a.m., 3 p.m., and 9 p.m., at Deptford pier station. No rapid changes occurred, the amount of water that flows in from the sea at a temperature different from the mean river temperature being too small to produce an appreciable effect. Whatever may affect the lower reaches of the Thames in this way does not influence the temperature of the river near London. It was found that the temperature of the river gradually changed to the temperature of the air of the previous three or four days. Thus a sudden fall of air temperature found the water temperature the highest. A sudden rise put the water temperature below that of the air. The period of lowest temperature of water surface was between the 10th and 19th February, when it was steady at 35°F.

Sir George Airy,* the late Astronomer Royal, investigated the effect of river temperature on climate from observations taken from 1844 to 1879. He found that, allowing for difference of height, the mean temperature of the river worked out only a fraction of a degree higher than the mean temperature at Greenwich Observatory. Considering the means for the various months separately, he found that the greatest excess of river temperature over air occurred in October, about 2°·2, and the least in February, about 0°·4.

The mean temperature of the air does not bear greatly on the occurrence of fog. It is the minimum temperature that has to be considered. In October the daily range of air temperature is sometimes 21°, and as the average excess of river temperature over air is then about 2°·2, we may easily find the air temperature in the early morning 13° below that of the river, and at 2 p.m. 8° above it. This difference of 13° would certainly bring about a steaming water fog.

Comparing the river temperatures with the minima on grass observed at Camden Square daily at 9 a.m., and also with the readings on grass taken daily at 7 a.m. in the Royal Botanic Society's Gardens, Regent's Park, we find that on 20 days of fogs, between 3rd January and 11th March, the river temperature was in excess of the 7 a.m. reading on the grass by amounts ranging broadly from 6° to 20°.—I am much indebted to Mr. Bryant Sowerby, F.L.S., Secretary Royal Botanic Society, for these special 7 a.m. readings taken all through the winter months.

See Table C.—Comparison Thames river temperature.

Captain Wilson Barker, of H.M.S. *Worcester*, at Greenhithe, writes to me as follows :—

> "I think you will find that the temperature of the river varies very little during the 24 hours. The controlling influence here with regard to fogs is a cold, moist, stagnant air over the much warmer river. In many cases it extends only a short distance inland, and directly there is any wind it all goes. We are subject to fogs here at all times of the year from the Cement factory chimneys, and a little lower down, off Northfleet, it is often very bad indeed."

Kew Observatory may also be considered a river station. It stands somewhat low on the list of frequency, partly owing to its comparative freedom from general smoky surroundings, and partly also to no observation being taken by night. Notwithstanding its comparative immunity from smoke the damage done to the shrubs during a smoky fog is enormous.

* *See* Proc. Royal Soc. Vol. XXXIV., p. 276.

Table C.

Comparison Thames River Temperature with Temperature on Grass.

Date.	Fog began.	Camden Square Minimum on Grass.	Regent's Park Reading on Grass, 7 A.M.	River Temperature.	Difference River Temperature above or below Regent's Park.
1902.					
3rd January... ...	7.0 A.M.	32·4	31	44	+ 13°
11th „	8.0 „	44·2	45	44	− 1°
15th „	7.0 „	25·2	18	42	+ 24°
17th „	7.0 „	33·5	35	42	+ 7°
19th „	8.0 „	27·3	21	40	+ 19°
5th February ...	6.0 „	31·1	30	36	+ 6°
6th „	8.0 „	31·1	30	37	+ 7°
8th „	8.0 „	29·6	29	36	+ 7°
11th „	8.0 „	22·4	20	35	+ 15°
12th „	6.0 „	21·1	17	34	+ 17°
13th „	6.0 „	18·7	13	34	+ 21°
14th „	9.0 „	24·1	20	35	+ 15°
16th „	6.0 „	14·3	10	35	+ 25°
17th „	7.0 „	17·4	14	34	+ 20°
18th „	7.30 „	24·4	29	35	+ 6°
20th „	10.0 „	31·4	31	34	+ 3°
25th „	6.0 „	41·1	40	39	− 1°
1st March	1.0 „	31·1	35	41	+ 6
10th „	8.0 „	42·6	41	44	+ 3
11th „	7.0 „	35·9	37	44	+ 7°

Note.—At Camden Square the grass minimum at 9 a.m. for the previous 24 hours is given.
At the Royal Botanic Society's Gardens, Regent's Park, the grass bulb was read off at 7 a.m., at what it shewed at that time.
* 2nd March to 7th was a continued fog. The grass minimum ranged between 35·3 and 28·1, and the river averaged 42°.

Conclusions.

The system of recording fogs by the symbols L. M. T. is open to some objection, as those symbols depend on the faculty of the observer to judge distances correctly.

Mr. Shaw, has suggested that hindrance to traffic might form a basis for a scale of notation which would be probably productive of more unanimity among observers as to the density of a fog. I think that it would be so, and accordingly suggest the following scale.

Fog Classification.

—	Notation.	Land.	Sea.	River.
—	0	Clear	Clear	Clear.
Light fogs	1	Street traffic unhindered	Distant objects obscured, but traffic unimpeded.	Traffic unimpeded.
	2	Do. do.		Traffic practicable with moderate caution.
Moderate fogs ..	3	Street traffic difficult ..	Traffic difficult	Traffic practicable with extreme caution.
Thick smoky fog	4	Do. do. ..	Traffic very dangerous ..	Traffic impossible.
	5	Street traffic impossible..	Does not occur	Do. do.

I do not purpose here to follow up any scientific analysis of fogs, but merely to point out on what fog occurrence appears chiefly to depend, and in what direction we may look for an improvement in prediction and a possible amelioration of the conditions which give rise to these scourges.

First, then it is primarily necessary that the atmosphere should be comparatively still so that fog may collect, and this condition is only obtained when the baric gradients are very slight as occurs under either anticyclonic conditions, very open parallel isobars, or a low shallow trough or col between two "highs."

Ordinary fog occurs under all these conditions, but it is accompanied by, and sometimes preceded by, high fog when the high isobaric ridge or col is shallow with low areas adjacent.

Possibly the rising moist air from the "low areas" is overflowing the "high area" and, pressing down, collects the smoke and causes that peculiar darkness called high fog, which sometimes ends in rain but more often causes a dark smoky fog to settle here and there over our city.

A greater period of observation is required before we can say for certain whether or not fog will always follow on such conditions; but we can already safely say that during a period of falling temperature in the winter months fog under these conditions is certain in some parts of London. For, having got a condition of a still atmosphere it is practically certain that a fall of temperature associated with the smoke of many fires will bring about fog if the minimum temperature is below 42°. Such a temperature may easily occur any time between September and April, but of course there are many less fires before November and after March.

Causes of fog.

There appear to be only three causes of fog, viz. :—

A warm atmosphere cooled by contact with a cold earth or water surface, which forms a cold surface fog.

A cold atmosphere warmed by contact with a warm earth or water surface, which forms a steaming water fog.

Two atmospheres of different temperatures in contact with one another, which form a cloud fog.

Any of these fogs may become permeated by smoke, and the fog particles becoming coated with oily hydro-carbons are then impervious to the evaporating power of the sun's heat and may drift long distances, but they slowly settle on ground, houses, and clothes, and are inhaled by all living creatures and plants.

That there is a downward movement of smoky, moisture-laden air, seems to be most probable, but what extent of general downward movement of air takes place under anticyclonic conditions has, I think, not yet been discovered. On the 20th December at 3 p.m. when a fog had just cleared off before a rising wind, it was noticed from the top of Westminster Tower that the smoke lay flat over the houses like a dirty counterpane.

Detailed temperature observations required.

It is possible that a regular system of temperature observation over London may show that fog becomes densest in the coldest areas, and I would recommend that further investigation should be specially made in this direction during next winter, commencing, if possible, at the end of August.

Waves of temperature appear to sweep over London in an irregular manner, which may possibly be reduced to definite order by further observations. If the thermograph curves of Kew, Banstead, Meteorological Office, Victoria Tower, and St. Pauls, are compared, it will be seen that sudden rises or falls at unexpected times occur sometimes synchronously, and at other times at irregular intervals.

Probably a study of all available thermograph records over London may elicit some valuable information towards the prediction of fog, but what is especially wanted is a daily record, when light airs are blowing, of thermometers suspended over London by captive balloon.

On the monthly curve of fog frequency at Greenwich for the 35 years 1844–1879 (Plate I.), we see that the occurrence of fog increases rapidly from the middle of August to the middle or end of November, then decreases till middle of February. It then remains stationary till the middle of March, whence it falls rapidly till May, fogs being rare from then till the middle of August. I have chosen these observations by Sir G. Airy as they all refer to one locality. On comparing tables of frequency by other collectors the curves agree very well, except that the date of maximum frequency varies, and appears, in later years, to come in December.

I consider that forecast may be assisted by more frequent reports of barometrical readings from Dungeness, Yarmouth, Loughborough, and Portland. As fog most frequently arises in the early morning it would be necessary to issue forecasts at a very early hour, and for this a special staff and office would be required.

Information of ground fog should be communicated to such an office by telephone in the early hours from the parks and from open suburban spaces. High fog and smoke fog sometimes thickens only over a small area, and early information of such thickening should be telephoned by the nearest Fire Brigade Station.

Such a forecast department would have to make arrangements for early information of any remarkable fall of temperature over any district.

I do not expect that it will be possible to forecast any movement of a dense fog, but it is probable that notice of its lifting may be given an honr or two beforehand. Information should be received from the suburbs whether the sky is cloudless or overcast. A clear sky may be the harbinger of a fog, or it may by day point to the lifting of fog by sun's heat.

Smoke the cause of all dense fogs.

From the experience gained in the study of the fogs during the past winter I am convinced that but for the mixture of smoke particles, no fogs in London would attain the density T. (thick), and probably only two or three in the winter would reach a density M. Moderate fog certainly hinders river traffic, but it hinders railway traffic less and street

traffic hardly at all. But a thick fog, black or yellow, with unburnt products of combustion, means an arrest of all traffic, danger to health and life, and a destructive agent to all property, whether buildings, goods, or vegetation. Our river from Deptford to a few miles below Gravesend teems with the great shipping trade of London, and it is this very portion which is practically under a continuous fog brought about by hundreds of great chimneys belching forth smoke. It is not perhaps for me to argue here why the great factories are allowed to vitiate the atmosphere to this degree when smokeless coal and smoke-consuming furnaces are readily available; but one silently wonders that the pockets of the factory owners should be considered to the detriment of a shipping interest which is world wide.

Tilbury coast guard, which commenced recording on the 5th January, reported 37 fogs by the 14th March, *i.e.*, in 68 days, while Cliffe Creek coast guard, three miles further down the river, reported 34 in the same period. Certain stations in London continually reported high fog when the direction of wind was such as to favour them with smoke clouds from neighbouring railway depôts.

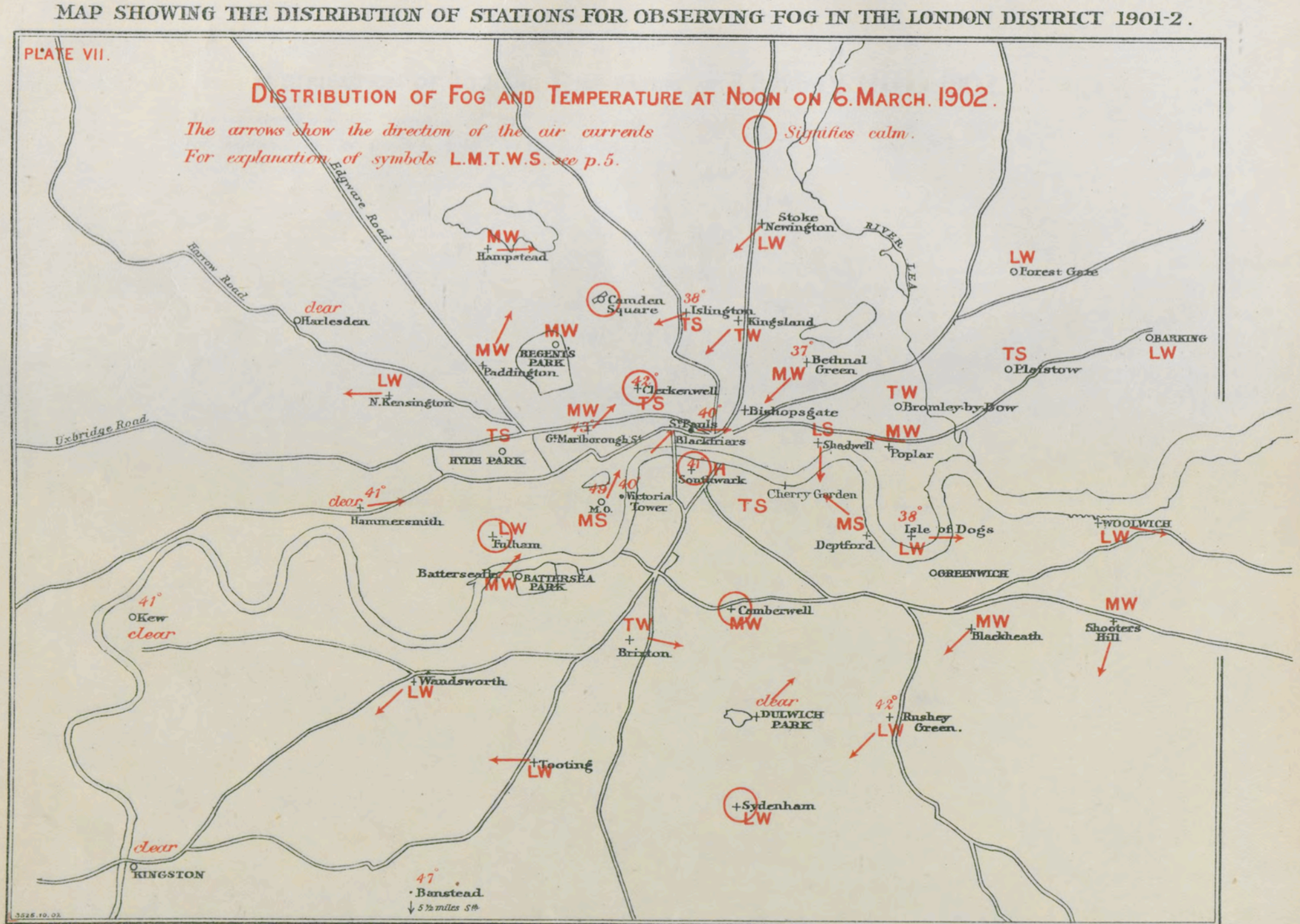
Such observations as were obtained during part of last winter put us in a good position for a more thorough investigation in the future.

I must conclude by expressing my sincere thanks to all the observers for the interest taken in the inquiry, and to the several authorities mentioned in the introduction, for their kindly assistance.

ALFRED CARPENTER,
Captain, R.N., Retired.

To follow page 27 at end.

MAP SHOWING THE DISTRIBUTION OF STATIONS FOR OBSERVING FOG IN THE LONDON DISTRICT 1901-2.



Fire Brigade Stations are shown thus + *Other Stations thus* o

E. Weller & Grahams. Ltd Litho. London.

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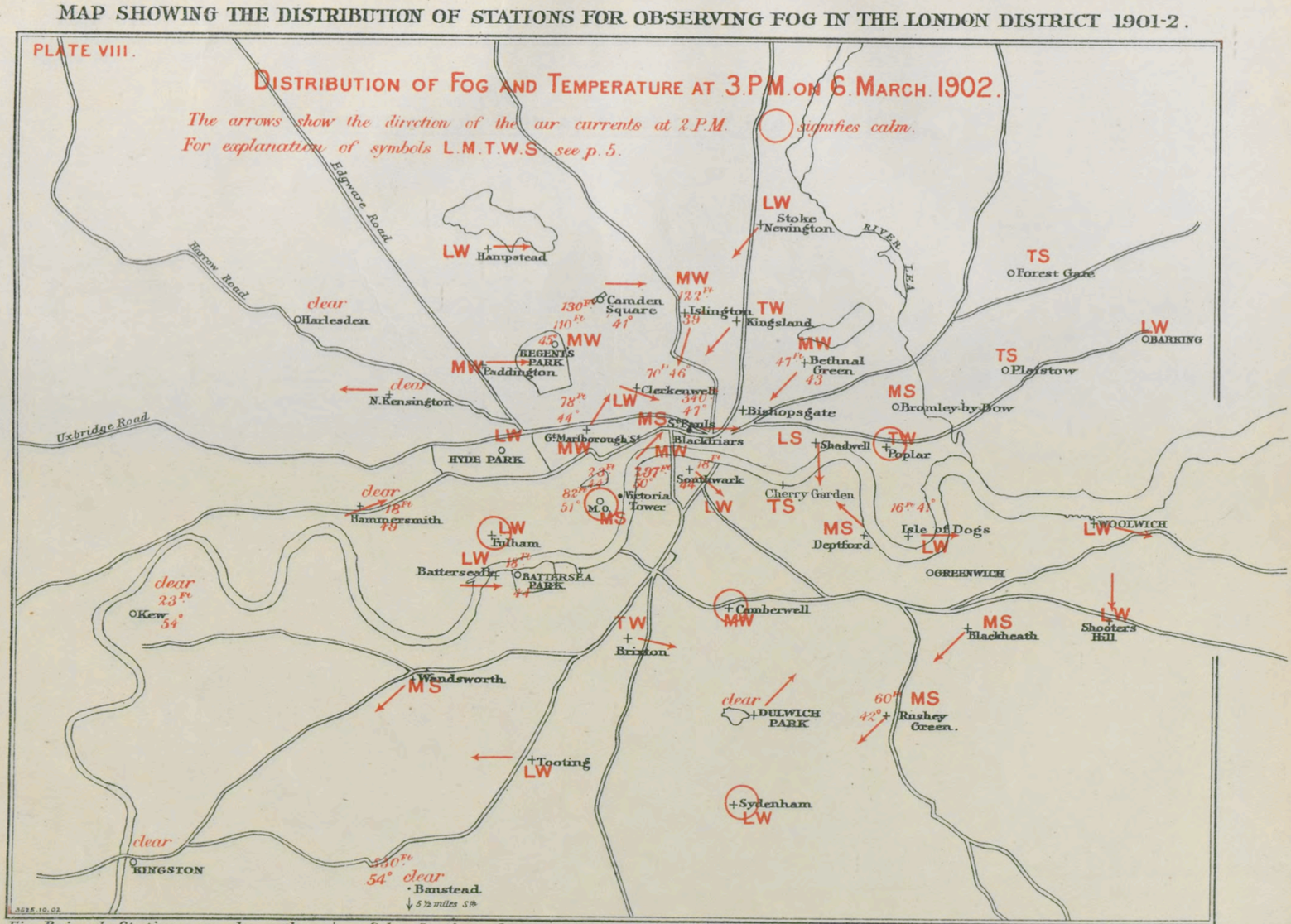
MAP SHOWING THE DISTRIBUTION OF STATIONS FOR OBSERVING FOG IN THE LONDON DISTRICT 1901-2.



E. Weller & Grahams. Ltd Litho. London.

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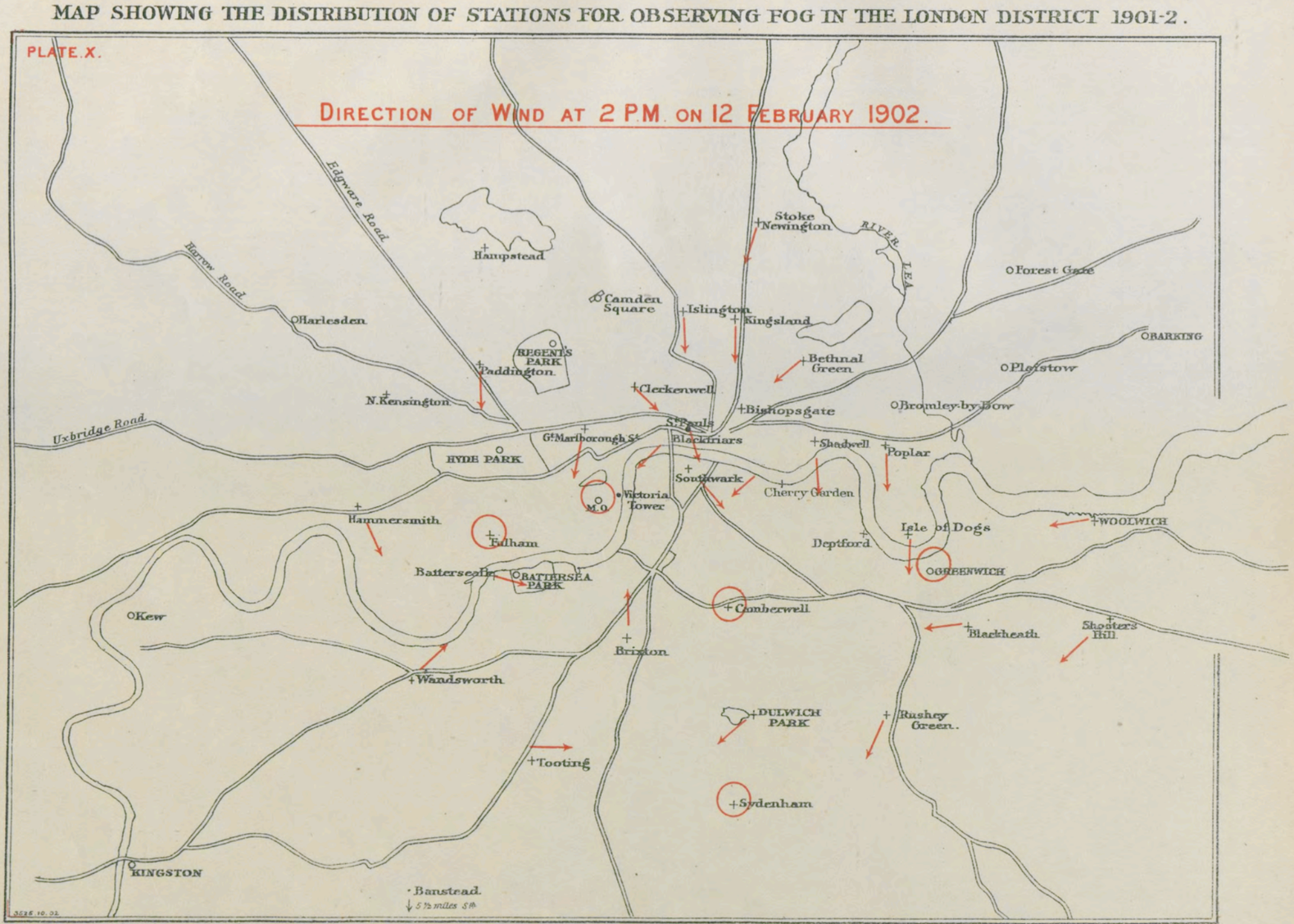

Fire Brigade Stations are shown thus + *Other Stations thus* ○

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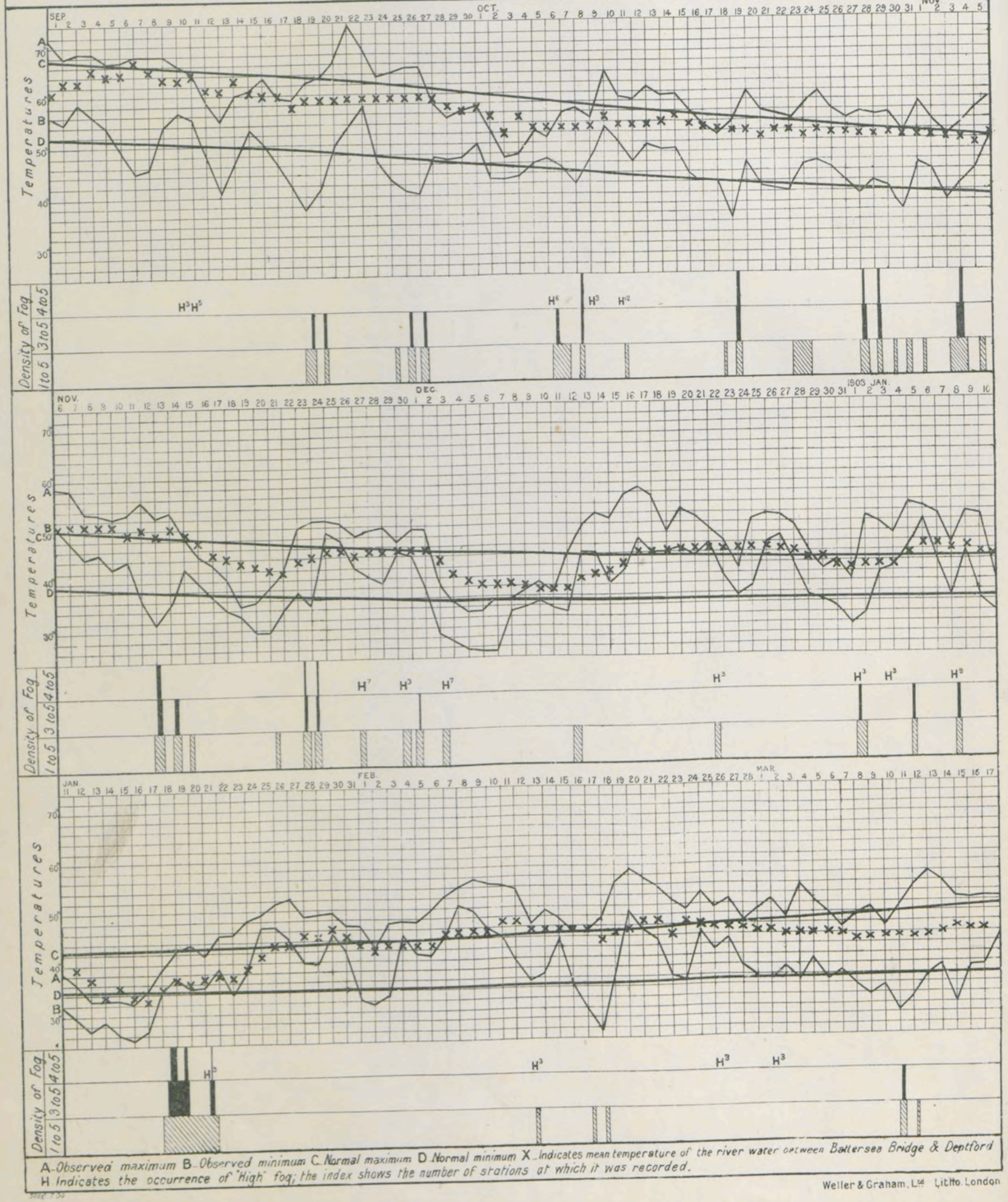
Plate I. DIAGRAM SHOWING THE OCCURRENCE AND DURATION OF FOGS IN LONDON AND THE MAXIMUM AND MINIMUM TEMPERATURES AT KEW IN THE WINTER OF 1902-3 TOGETHER WITH THE NORMAL MAXIMUM AND MINIMUM TEMPERATURES AT KEW.



A. Observed maximum B. Observed minimum C. Normal maximum D. Normal minimum X. Indicates mean temperature of the river water between Battersea Bridge & Deptford
H Indicates the occurrence of "High" fog; the index shows the number of stations at which it was recorded.

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OFFICIAL No. 160.

LONDON FOGS.

REPORT

OF THE

METEOROLOGICAL COUNCIL

UPON AN

INQUIRY INTO THE OCCURRENCE AND DISTRIBUTION OF FOGS IN THE LONDON AREA, DURING THE WINTERS OF 1901-2 AND 1902-3, WITH REFERENCE TO FORECASTS OF THE INCIDENCE AND DURATION OF FOGS IN SPECIAL LOCALITIES,

TO WHICH IS APPENDED

THE REPORT, BY R. G. K. LEMPFERT, M.A., ON THE OBSERVATIONS OF THE WINTER, 1902-3.

LONDON:
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1904.

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STATISTICS OF THE DURATION OF BRIGHT SUNSHINE AT THREE STATIONS IN THE LONDON DISTRICT AND AT FIVE STATIONS IN THE SURROUNDING COUNTRY DERIVED FROM OBSERVATIONS EXTENDING OVER 20 YEARS.

AVERAGE NUMBER OF HOURS OF BRIGHT SUNSHINE FOR EACH MONTH AND FOR THE YEAR.

—	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Westminster	18·4	32·8	68·0	109·8	164·8	164·9	174·7	165·9	116·0	70·6	27·7	13·1	1126·7
Bunhill Row... ...	14·1	30·6	71·2	118·0	175·9	177·8	180·7	162·2	112·7	66·2	22·8	7·5	1139·7
Kew Observatory ...	40·3	54·6	108·8	148·6	201·3	196·3	202·8	187·7	140·4	96·3	50·8	38·1	1466·0
Oxford	46·4	68·1	116·8	149·9	196·3	194·9	200·7	185·7	144·2	102·7	56·4	41·6	1503·7
Cambridge	48·9	73·8	125·3	157·6	203·1	197·4	203·2	187·1	147·7	107·2	61·0	40·6	1552·9
Geldeston	52·1	74·9	129·9	161·2	221·8	210·4	210·6	191·1	155·5	113·1	62·2	48·9	1631·7
Southampton ...	50·2	76·4	129·9	167·7	217·9	214·9	219·5	208·0	159·2	115·0	60·2	48·8	1667·7
Rothamsted	45·5	68·6	119·9	148·1	196·2	191·2	211·5	189·5	144·7	110·2	59·1	42·9	1527·4
Mean of values at Oxford, Cambridge, Geldeston, Southampton and Rothamsted.	48·6	72·3	124·4	156·9	201·1	201·8	209·1	192·5	150·3	109·6	59·8	44·6	1571·0

SUNSHINE AT LONDON STATIONS EXPRESSED AS PERCENTAGE OF MEAN VALUES FOR THE COUNTRY STATIONS.

Westminster	38	45	55	70	82	81	83	86	78	65	46	29	64
Bunhill Row ...	29	42	57	75	88	88	86	84	75	60	38	17	62
Kew Observatory ...	82	75	88	94	100	97	97	97	93	88	85	85	90

PERCENTAGE LOSS OF SUNSHINE AT LONDON STATIONS.

Westminster	**62**	55	45	30	18	19	17	14	22	35	54	61	36
Bunhill Row ...	71	58	43	25	12	12	14	16	25	40	62	**83**	38
Kew Observatory ...	18	**25**	12	6	0	3	3	3	7	12	15	15	10

LONDON FOGS.

An inquiry into the occurrence and distribution of fog in the London district was initiated by the Meteorological Council in 1901 in response to an application from the representatives of various electric lighting authorities for special forecasts of fog.

The forecasts issued from the Office mention the general probability of fog if the meteorological conditions in the South of England are recognised as favourable for its occurrence, but more specific forecasts were desired with reference to London, and if possible, for parts of London.

London fogs have been the subject of much observation, but no authoritative statistics were known to exist as to the distribution of fog in the various parts of the London area. It is recognised by everyone that the effects of London fog are closely associated with the smoke that is thrown into the London air, but whether the smoke simply aggravates the effects of fog, or creates effects of its own, is a question to which no definite answer could be given.

An inquiry into the actual facts respecting the air of London may be acknowledged to be of great importance to the country, as it concerns directly the welfare of one-tenth of the inhabitants of the Kingdom, and indirectly, the effects of London fog are of importance to the whole community.

In London, unfortunately, no provision exists for the systematic investigation of the chemical and physical condition of the air of the metropolis, such as is provided in Paris by the Observatory of Montsouris, and such an investigation is of too specialized a character to be undertaken by the Meteorological Council without special provision, as the establishment under their control is not even sufficient for the adequate treatment of the problems of general meteorology that arise in connexion with the British Isles, the Crown Colonies which have no separate meteorological establishments, and the Ocean. The Council accordingly decided to appeal to the County Council of London for the means for making a special inquiry into the fogs of London, and the following letter was addressed to that body.

Meteorological Office,
63, Victoria Street, S.W.
November 21st, 1900.

SIR,

I am directed by the Meteorological Council to ask you to bring before the County Council of London the following suggestion regarding an inquiry into the occurrence and distribution of fogs in the London district and their relation to other atmospheric and local conditions.

1. The suggestion arises from applications which have been received at the Meteorological Office from the Electric Supply Department of one of the Local Boards of Works and from some of the Electric Supply Companies of London for special forecasts or warnings of the approach of fogs.

2. The occurrence and distribution of fog are subject to variations of so local, and apparently so capricious, a character that the general forecasts drawn up by this Office for the South of England do not meet the requirements of the case; and the information that can at present be procured from day to day by the Office is not sufficient to justify an attempt to issue such special forecasts of fog for the individual districts of London as would meet these requirements.

3. The Council are fully conscious of the importance of a more precise knowledge of the conditions which govern the distribution of fog, not only for the lighting industry, but for many other interests of the population of London, but the funds at their disposal are not sufficient for the investigation of the local details of the atmospheric conditions on which the formation of fog depends in individual districts. These funds are not more than sufficient to enable the Office to deal generally with the meteorology of the British Isles and neighbouring seas and of the oceans traversed by British ships, for which objects the Parliamentary grant was from the outset specifically appropriated; and the Council has no staff at its disposal by whom local investigations can be undertaken.

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4. The Council are of opinion that the appropriate mode of procedure in this present case would be to initiate a special inquiry during the winter months into the conditions associated with the development and distribution of fog in London and its vicinity, and for that purpose (1) to obtain records from properly selected positions in various parts of London; (2) to collate these records with the general atmospheric conditions at the time of the observations as shown by the information regularly furnished to this Office; and (3) as far as possible to ascertain the character of the information requisite for anticipating the occurrence of fogs in particular localities.

5. To carry out this suggestion it appears to the Council that it would be necessary to retain, for a limited period, the special services of a gentleman of suitable scientific qualifications. The course to be adopted at the conclusion of the initial investigation thus carried out would be a matter for further consideration.

6. The Meteorological Council have thought that it would not be beyond the province of the London County Council to provide the means of undertaking such an inquiry, which could not be satisfactorily carried out without the co-operation of many local authorities or bodies, and which in itself is one that may be reasonably expected to lead to ameliorations of the conditions of life in the Metropolitan area of some importance.

7. If, therefore, the County Council could provide for the special expenses incidental to the inquiry, and for the keeping of suitable records in the several districts, the Meteorological Council would, for their part, undertake the superintendence of the inquiry, and would afford any facilities which the organisation of the Office enables them to supply.

I am further directed to say that if the County Council is disposed to give its favourable consideration to the proposal, the Meteorological Council will be glad to furnish any further particulars that may be desired of the form which, in their opinion, the inquiry should take, and an estimate of the special expenses which would be incurred in its prosecution.

I am, &c.,

W. N. SHAW,

Secretary.

The Clerk to the
County Council of London.

In compliance with the request thus conveyed, the County Council, in October 1901, agreed to set aside £250 for the purpose, on condition that the Meteorological Council took the responsibility of directing the inquiry, and commenced it forthwith. They also gave facilities for the co-operation of the Metropolitan Fire Brigade in the undertaking. The season was already far advanced, and the Council forthwith appointed Captain Alfred Carpenter, R.N., D.S.O., to conduct the inquiry, and made the necessary arrangements for the accommodation of the work in the Office, and for the clerical assistance required. The lines of the inquiry contemplated by the Council are indicated in the following extracts from a communication to "Nature" by the Secretary.

"The abundant knowledge based on the prolonged experience of many observers lacks co-ordination. If conditions are favourable for the occurrence of fog, which part of London will be the first to experience it? and at what rate will it spread or move to other parts? and where will it be most dense? Will it begin on the river and gradually extend to the heights, as a sea fog pours over the land? or will the heights first cover themselves with mist rolling down to the valleys? or if some locality is specially favoured as compared with others, by what numerical or percentage estimate should the preponderance be expressed? Statistical answers to the questions stated are clearly within reach. One year's experience will give no final statistical results, but it may at least give an indication of the possibility and prospect of obtaining such results. Some preliminary understanding must be arrived at as to the method of describing the experience of the different observers. There are fogs of many colours, and of diverse character and density; some are on the surface, others, which do not come so low as even the tops of buildings, produce at noonday the darkness of night. It may be assumed that these differences of type, as well as differences of distribution, are not entirely capricious, but are related to some specific difference in the meteorological conditions, general or local, the local topography, or the local geology. All these things can also be ascertained, but whether the differences are sufficiently marked to be

recognisable in individual cases and to form a basis for forecasting is a question for investigation. Nor is it an easy question when one considers the difficulty of securing uniformity of convention among observers, and uniformity of exposure for thermometers, and other instruments.

"There are some physical aspects of the condensation of vapour in the atmosphere which may be of service as a guide to the classification of the conditions of distribution of fog. In the forefront I would place the question as to what is the source of supply of the water which is the main constituent of those fogs which are not simply wreaths of smoke. Does the water come from the ground on which the fog lies? or the air in contact with it? or from some higher region or more distant region? It is a matter of common observation that a surface of relatively hot water covers itself with drifting clouds of so-called steam. There are doubtless surface fogs which correspond to this condition, though when the evaporation is very rapid there may be, as Mr. C. T. R. Wilson has shown, a clear layer immediately above the water surface. Fogs which have their origin in this mixture of the rising vapour with cooler air may be called 'steaming water fogs.' On the other hand, if any surface is sufficiently cold the absorption of heat from the air in contact with it may cause condensation in the air close to the surface, and fogs arising in this way may be called, for the sake of brevity, 'iceberg or cold-surface fogs.' Vigorous radiation may cause a fog of this character, and in regard to the persistence of a fog under these circumstances the transparency, or rather translucence, of fog for radiation is an important but not well-known factor. In these cases the source of the water supply is easily identified as being the water surface in the one case and the air in contact with the surface in the other. Clouds formed in either of these two ways may drift, like the steam from a locomotive, or a sea fog, over land, and a fog may thus visit a locality which has had no share in supplying the water. There is, moreover, another possibility which may be connected with the question as to why fogs are more prevalent in winter than in summer, in spite of the fact that the store of moisture in the air is larger and changes of temperature are more pronounced in the warmer months. Rain has been defined as a falling cloud which reaches the surface before the evaporation of the globules is complete. The rate of fall depends on the size of the particles, but in still atmosphere even the smallest particles make their way downward. In summer the falling cloud may consist of anything between a thunder shower and drizzling rain. In the winter, when the supply of moisture is less, and over towns the supply of nuclei for condensation is greater, the counterpart of the summer drizzle may be so light as to be classed as fog, and fall with extreme slowness. In this case the water supply comes from strata above the surface. There are certainly some fogs in which there seems to be a gradual deposit of moisture on horizontal surfaces, and not merely on specially cold surfaces. Whether electrical conditions, which are exceptional in foggy weather, may account for the formation or accelerate the falling of the cloud in such circumstances is not known.

"If we call this third form of fog, due either to the surface drifting or the downward descent of a cloud formed above the surface, a 'cloud fog,' we have altogether three forms—'steaming water fogs,' 'cold-surface fogs' and 'cloud fogs.' It is evident that of these three, two depend upon local conditions which may possibly be identified, while the third is much more independent of local conditions and its incidence may be as capricious as a summer cloud.

"The consideration of the observations from this point of view requires more than mere organisation. It involves a special knowledge of the physics of the atmosphere applied to observations of a somewhat special kind."

Captain Carpenter's report on the work of the winter was received in May, 1902, and contained the recommendation that the work should be continued for another winter.

Before the report could be printed and communicated to the County Council, the winter had already commenced, and, although only a few pounds of the grant remained, the Council decided to continue the inquiry while an application was made to the London

County Council for further funds. The following letter was sent to the County Council :—

Meteorological Office,
63, Victoria Street, London, S.W.,
December 30th, 1902.

LONDON FOG INQUIRY.

SIR,

IN pursuance of an understanding arrived at in October of last year, I have the honour, on behalf of the Meteorological Council, to report to you upon the work done in connexion with the initiation of an inquiry into the occurrence and distribution of fogs, as follows :—

On November 10th the Council appointed Captain Carpenter, R.N., D.S.O., a member of the Council of the Royal Meteorological Society, to conduct the inquiry, and made the necessary arrangements for office accommodation and clerical assistance. Captain Carpenter at once put himself into communication with Captain Wells, R.N., the Chief Officer of the Metropolitan Fire Brigade, and made arrangements for the systematic observation of fogs at some of the river stations and at other stations of the Metropolitan Fire Brigade. He also arranged for supplementary observations to be taken at certain of the Metropolitan Police stations, at Battersea Park and Regent's Park, and at a number of Coast-guard stations in the Thames estuary, and by one or two private persons. Observations of temperature and other meteorological conditions were obtained from a number of the stations and from the parks; self-recording thermometers were installed on the Victoria Tower at Westminster, the Golden Gallery at St. Paul's, on the roof of the Meteorological Office, and at a private house at Banstead. Regular records of fog in accordance with a conventional scale distinguishing the kind and intensity of the fog, were thus obtained from a series of points in or round London. The points were carefully selected to represent the local circumstances of geological formation, height above sea level, nearness to or remoteness from the river, open or crowded neighbourhoods. The instrumental readings, combined with the information obtained in the ordinary course of the work of the Office, supplied local and general information as to the meteorological conditions.

By arrangement with Captain Wells, special observations were made during fog or when fog was anticipated by the forecast branch of the Office, the intimation of the time for commencing the special observations being sent, on receipt of requests from Captain Carpenter, from the head office of the Fire Brigade to the stations by telephone.

The records thus obtained are exceedingly voluminous and contain particulars of all fogs occurring between the time of the initiation of the inquiry and the end of March, when observations were suspended. The records have all been examined and tabulated by Captain Carpenter, and the detailed history of the occurrence and progress of each fog carefully traced and compared with the meteorological and other conditions. The report upon the observations is appended hereto.* A tabular statement giving a summary of the particulars of each fog is given on pp. 8–11† of the report. It is to be regretted that the earlier fogs of the winter, which occurred before the inquiry was commenced, could not be included.

For the details of the different questions which are discussed, Captain Carpenter's report must be referred to, but I am directed to call attention to a few points.

(1.) In the first place, as was expected, considerable difficulty arose in regard to the specification of the nature and intensity of fogs. The only means of estimating them are by noting their effect on the visibility of objects, and visibility depends upon a number of incidental circumstances in addition to the actual density of the fog; upon the time of day or night, the position of the observer, as well as, to some extent, upon his temperament. The records required careful consideration from this point of view, and instructions to observers had to be revised and modified, and inquiry made from time to time as to outstanding inequalities. The first result of the inquiry is accordingly the suggestion of a scale of fog intensity, arranged according to the interference with traffic upon road, rail, river or sea, and represented by the serial numbers 0 to 5. Particulars of this proposed scale are given on page 25.†

(2.) Passing on to the results derived from the records, it should be noted that when there is no fog, properly so-called, the direct effects of household smoke are much greater than might be supposed. From the observations on St. Paul's and the Victoria Tower, by Captain Carpenter himself, and his assistant, Mr. W. D. Matthews, it appears that on account of the smoke the extreme limit of visibility in winter from an elevated position in London, under most favourable circumstances, is set at 1½ miles. That limit is diminished as the tendency to form fog is developed until the well-known effects of dense fog are reached.

(3.) The stations at which fogs were observed, and the comparative frequency of fogs at the stations, as derived from the observations hitherto obtained, are set out in a table on page 16.†

The results may be enumerated as follows :—

(*a.*) There is no evidence of any special connexion between the frequency or intensity of fogs and geological conditions, nor does the locality of the commencement of fog depend upon geological formation.

* London Fog Inquiry, 1901–02. Report to Meteorological Council by Captain Alfred Carpenter, R.N., D.S.O.
† The references marked thus, †, are to the pages of Captain Carpenter's report.

(*b.*) The well-known circumstance that elevated stations are freer from fog than other stations is confirmed.

(*c.*) The commencement of a fog is not identified with any particular locality; it seems to be a general process depending upon general atmospheric conditions. The actual locality of fog at any particular time seems to depend upon local atmospheric conditions which require further investigation. There is no evidence tending to show that fogs are formed outside, and invade or drift into London. The London fogs are produced in London, possibly at the same time as country fogs, but they do not come from the country.*

(*d.*) The meteorological conditions for the formation of fog are very carefully set forth and illustrated on pages 19 to 24.† The conditions considered include (i.) barometric pressure, (ii.) atmospheric temperature, (iii.) river temperature.

(i.) The barometrical conditions are illustrated by a series of charts of the distribution of barometric pressure in North-west Europe, taken from the Daily Weather Charts of the Meteorological Office.

Observations and diagrams are given tending to show a slight indraught of air from all sides to the central parts of London during dense fogs.

(ii.) No severe fog occurred with an air temperature above 40° F. The minimum air temperature prior to fog coming on, averaged 9° below the normal mean temperature for the day (which ranges between 39° F. and 45° F. during the winter months). On 23 out of 46 occasions when fog commenced, it was associated with a fall of the daily minimum of temperature, but on the other 23 occasions the fog was associated with a steady or rising minimum of temperature.

(iii.) During the period of observations (3rd January to 11th March) the river temperature was reported as ranging from 32° F. to 48° F. In 22 cases out of 25 during the nights preceding days of fog, the temperature of radiation, as indicated by a thermometer on the grass at Regent's Park, fell much below the river temperature, the amounts of difference on these occasions varying from 6° to 25°.

(*e*) There is a very marked tendency for fogs to commence in the early morning when the temperature is lowest, after a clear night, as in the open country, and the differences of fogs on different occasions in London, as compared with the country, depend largely upon whether the conditions are favourable for the dispersal of the early morning fog.

The main purpose of the inquiry is to determine (1) whether or not it is possible to anticipate the formation or dispersal of fog in London more definitely and certainly than at present, and (2) whether it is possible to warn one part of London from observations of actual occurrence of fog made in other parts, or (3) from special readings of thermometers or other instruments.

As regards (1), Captain Carpenter's conclusions render somewhat more definite the conditions of occurrence, and hence add to the efficiency of forecasting.

As regards (2), it seems improbable that any result can be obtained.

The third question is undecided, and Captain Carpenter advises that further investigation should be made. His opinion is expressed thus: "A regular system of observations of temperature might indicate the possibility of local forecasting, especially if these were made in the early hours of the morning." To test this suggestion the inquiry has been reopened in the present winter, and special arrangements for the observation of temperature at various stations have been made, even at the early hour of 5 a.m.

Attention should be called to one point of special importance in connexion with temperature observations, which requires to be followed up. On 7th March, during a dense fog, the temperature in the streets of London was nearly 10 deg. below that on the roof of the Meteorological Office, the elevated stations, and the surrounding country on the Southern and Western sides. This indicates the importance of making further investigation of the vertical distribution of temperature, but at present no adequate means of making such an investigation exist.

If Captain Carpenter's suggestion of a more complete investigation of the effect of possible irregularities in the distribution of temperature be carried out, the outstanding part of the inquiry would be—

(1.) To ascertain whether the proposed scale of classification of fogs puts the observations of locality upon a satisfactory footing, and whether additional observations throw any further light on local distribution;

(2.) To compare the effect of local temperature differences with local distribution of present or subsequent fog;

(3.) To ascertain whether it is possible to make arrangements for the investigation of the vertical distribution of temperature.

* For circumstances under which fog drifts along the surface, *see* p. 31, also p. 29, foot note.

The cost of the inquiry defrayed by the Meteorological Council up to the 30th September (exclusive of the cost of instruments supplied from the Office stock) has been as follows :—

	£	s.	d.
Payments to Capt. Carpenter	100	0	0
Clerical assistance	64	15	9
Instruments and miscellaneous expenses	70	2	3
Total	234	18	0

I am to request that a remittance of this amount may be made to this Office.

To carry on the inquiry to the end of the present winter will probably cost £200. I am to ask whether the London County Council are prepared to find the funds for this additional work. In that case the Council will issue a further report upon the inquiry in the summer or autumn of 1903.

The Council regret that Captain Carpenter is himself unable to continue the investigation on account of his health. The conduct of the inquiry is provisionally placed in charge of Mr. R. G. K. Lempfert, M.A., who has recently been appointed Scientific Assistant to the Secretary of the Meteorological Council.

With these observations I am directed to ask if you will lay this matter before the County Council, and to request that I may be favoured with an intimation of their wishes at an early date, to admit of such arrangements being carried out as may appear to be requisite for the further prosecution of this inquiry, if it be decided to continue it, which the Meteorological Council hope may be found possible.

I am, &c.,
W. N. SHAW,
Secretary.

The Clerk to the
County Council of London.

To this letter a reply was received to the effect that the Council were unable to make any further contribution, and accordingly Mr. Lempfert's report, which is appended hereto, concludes the inquiry. Mr. Lempfert takes up some of the points raised by Captain Carpenter's discussion of the observations of the first winter and finds that some are confirmed, while others were apparently the result of coincidence.

Mr. Lempfert sums up the result of the inquiry from the point of view of more detailed forecasting on pp. 32–34 of his report.

The points of definite importance which come out of the inquiry, in addition to the primary results as regards forecasting, may be referred to as follows :—

1. The establishment of a workable scale for estimating fog.

2. The persistence of fog in London throughout the winter noticed by Captain Carpenter. This may be further illustrated by the table of the average duration of sunshine at various stations in London and in the surrounding country which is printed on the back of the title page. The remarkably small average duration of sunshine at Bunhill Row in winter on the average of 20 years is quite sufficient confirmation of the general appropriateness of Captain Carpenter's observations.

3. The numerical estimates of the geographical distribution of fog and (with the possible exceptions noted by Mr. Lempfert on p. 18) their apparent independence of geological conditions.

4. The relation of the occurrence of fog to the days of wide range of temperature and the reference of a good deal of fog to radiation, which produces particularly conspicuous effects in the parks. In this connexion Mr. Lempfert's suggestion of the relation of the minimum temperature of the nights when fog is formed to the dew point of the previous evening is of special interest.

5. The contradiction of a popular suggestion that fog forms on the river and spreads thence to the adjacent regions.

6. The illustration of the various meteorological conditions under which fog of different kinds occurs as set out in both reports.

7. Both reports cite instances in which an in-draught of air to some central district of London during the incidence of fog was demonstrated by the observations. Such an in-draught must have associated with it a rising column of air over the district towards which the surface air is drawn ; and if it is continued for any considerable time its effects in thickening the layer of fog or in darkening the air by cloud or smoke must be considerable. Indeed, unless there is sufficient motion of the air aloft to carry away the accumulation local darkness must ultimately be the result and the shifting of such an accumulation may account for the rapid local transition from total darkness to comparative daylight experienced in some instances on foggy days. In connexion with this and other matters pertaining to the investigation, observations of the changes in the upper air are still required. In December, 1902, Mr. P. Y. Alexander, of Bath, was good enough to offer to lend for a limited time a signal balloon and instruments for such observations, and through the courtesy of Mr. R. T. Glazebrook, F.R.S., the Director of the National Physical Laboratory, it was arranged that a trial of the apparatus should be made at Bushy. At the trial the balloon unfortunately broke away carrying the instruments with it, and though they were recovered by Mr. Pigeon, master of the schooner "Silver Eagle," and duly brought back from the north coast of France with an interesting record of the voyage, the period for which the apparatus was lent had expired and no opportunity for continuing the experiments has been found.

Returning to the original purpose of the inquiry, the greater precision of forecasts of fog and their application to specific localities, Mr. Lempfert in an appendix (pp. 35–48) gives particulars of the incidence of fog on the 39 occasions in the winter of 1902–3 with which he deals in his report, and quotes the forecasts issued for each occasion in the course of the ordinary work of the office. Accepting provisionally his classification of the several fogs, the results show that of 24 radiation fogs 16 were anticipated in the forecasts ; of eight smoke fogs four were anticipated, but no mention was made of fog or mist on the occasions of three cold surface fogs and four cloud fogs. He has also examined the suggestions made by Captain Carpenter, but with somewhat inadequate material as the winter was singularly free from fog. He gives some useful statements with regard to the relation of the distribution of fog to the drift of wind and distribution of temperature. It should not be forgotten that for the most common kind of fog, viz., that due to the radiation of heat from the surface, the occurrence of the fog itself prevents radiation, and thus tends to stop the cause, as in so many natural processes ; the persistence and thickening of the fog are probably due to secondary causes, particularly the slow drainage of cold air to lower levels, which produce a drift of fog-laden air. It may also be remarked that the physical processes are not so completely separated as might be desired for experimental illustration. Thus while radiation from the blades of grass cools the air in contact with them, evaporation is proceeding from any part of the moist ground which is protected against radiation. A heterogeneous process is thus followed whereby the surface air regarded as a whole becomes cooler and more moist.

To trace these causes, which are comparatively trivial when expressed in the readings of meteorological instruments, very close watching of the changes of atmospheric conditions over various parts of London would be required, and a first step in the attempt to supply more detailed forecasts would certainly be some provision for observations and readings at times intermediate between the epochs 6 p.m. and 8 a.m., which mark the limits of the observations at present at the disposal of the Office.

A special organisation for keeping a department of the Meterological Office open all night, and a corps of observers at a number of stations, would be an undertaking of considerable magnitude, but so much business on railways, at Fire Brigade stations and elsewhere, is from its very nature carried on throughout the night, and the facilities for telephonic communication are becoming so much extended, that it would only require the

co-operation of the municipal organisations of a few towns to provide the material for a very interesting meterological experiment, and might justify the employment of the services of an experienced forecaster on night duty during the winter months.

The Council regret that the investigation is discontinued. They trust that means may be found at some future time to take up the question again as part of an organised system for the investigation of the conditions of the air of London.

In presenting the report of the investigation the Council desire to record their thanks for the co-operation of the observers and others who have given their assistance ; to—

Captain Wells, R.N., Lieutenant Sladen, R.N., and other Officers and men of the Metropolitan Fire Brigade.

Sir E. Bradford and the Officers of the Metropolitan Police.

The Officers and men of the Coast Guard at the River Stations.

The Superintendents of the Parks of the London County Council.

The Royal Botanic Society.

The Mount Vernon Hospital for Consumption, Hampstead.

The Staff of the Poplar Borough Electricity Works.

The names of the several observers are given in the reports by Captain Carpenter and Mr. Lempfert, who have also referred to the facilities given for the exposure of instruments in the Churchyard of Christ Church, Victoria Street, and on the Towers of the Palace of Westminster and St. Paul's Cathedral.

By Order of the Meteorological Council,

W. N. SHAW,

Secretary

REPORT

TO THE

METEOROLOGICAL COUNCIL

ON

THE OBSERVATIONS IN CONNEXION

WITH THE

LONDON FOG INQUIRY IN THE WINTER OF 1902-3.

By

R. G. K. LEMPFERT, M.A.

18555

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TABLE OF CONTENTS.

LIST OF PLATES.

LONDON FOGS.

In accordance with the recommendations made by Captain Carpenter in his report on the observations carried out during the winter 1901–2, the inquiry during the past winter was started on September 1st, so as not to miss any of the early autumnal fogs, which frequently attain considerable intensity.

ARRANGEMENTS FOR OBSERVING.

Observing stations.

The observing stations were practically the same as those used last year. The only changes made in the list of Fire Brigade stations were that Bishopsgate was substituted for Watling Street, and Shepherd's Bush for North Kensington. Watling Street fire station is situated in a narrow street and is surrounded by tall buildings, so that it is not suitable for the observation of fog. The reason for making the other change will be specified in the text (p. 18). The Police and Coast Guard stations which had taken part in the inquiry during the previous winter, again co-operated, as also did the Royal Botanic Society (Regent's Park), the Poplar Borough Electricity Works, and the National Physical Laboratory (Kew Observatory). By the courtesy of the Parks Department of the London County Council, Battersea, Victoria, and Kennington Parks were added to the list of fog observing stations.

At all these stations, a complete list of which will be found in Table A. on page 15, a continuous record of fog was kept on a form similar to that reproduced in Plate II. of the Report issued last year. Fog intensity was estimated by means of the numerical scale 0–5, recommended on page 25 of Captain Carpenter's Report.

Observation of temperature.

The inquiry of the previous winter had shown that considerable local differences of temperature may occur during the prevalence of thick fog, and it was therefore decided, on Captain Carpenter's recommendation, to attempt a more detailed study of the distribution of temperature over London. With this object, arrangements were made with the Chief Officer of the Metropolitan Fire Brigade to issue thermometer screens and dry bulb thermometers to the 30 Fire Brigade stations, and to have observations of the temperature of the air made at 5 a.m., 9 a.m., noon, 3 p.m., and 9 p.m. The early hour of 5 a.m. was selected as it had been very clearly brought out by the observations of the previous winter that the majority of London fogs commence or thicken between 6 a.m. and 9 a.m., and it was thought that a knowledge of the distribution of temperature previous to this time might be useful in forecasting fog. Observations of temperature at these hours* as well as daily readings of the minimum temperature on the grass were also made at the Park stations of the London County Council. Temperature observations similar in character to those made during the previous winter were again available from Regent's Park (Royal Botanic Society), 62, Camden Square (Dr. H. R. Mill), and from Christ's Church Graveyard, Victoria Street, Westminster, opposite the Meteorological Office.

Thermograms were obtained from the self-recording instruments on the Victoria Tower, Westminster, and on the Golden Gallery on St. Paul's Cathedral, from the records of the electric resistance thermometer on the roof of the Meteorological Office, and from the Council's photographic recorder at Kew Observatory. The temperature of the river water was observed at 9 a.m., 3 p.m., and 9 p.m. at the Fire Brigade stations at Deptford Pier (Royal Victualling Yard), and Battersea Bridge.

Humidity

The humidity of the atmosphere was studied by means of readings of dry and wet bulb thermometers taken at 9 a.m., 3 p.m. and 9 p.m., at Regent's Park, Camden Square, Christ's Church Graveyard and Kew Observatory. On November 22nd, a self-recording

* It was not possible in all cases to secure observations at 5 a.m.

hair hygrometer was set up on the roof of the Meteorological Office. Wet bulb thermometers were not issued to any of the Fire Brigade stations, in spite of the importance of a knowledge of local variations in the humidity of the atmosphere. It was feared that as the majority of fogs occur on days when the temperature is not far removed from the freezing point, the temperature of the wet bulb would frequently be below this limit; under such circumstances, if its readings are to be trustworthy, a wet bulb thermometer requires more care and time to be devoted to its manipulation than can reasonably be expected of the officers and men of the Fire Brigade, who have other duties to attend to.

Atmospheric pressure.

No special observations of atmospheric pressure were made; the information received by the Office in the ordinary course sufficed for the needs of the inquiry.

Wind.

For studying the velocity and direction of the wind, the anemograms from Kew Observatory and the daily reports from Greenwich Observatory were again used. In addition to these, arrangements were made for observing the direction of the drift of smoke at all Fire Brigade stations at 9 a.m., noon and 3 p.m. Such 'special' observations were only made on days when fog was anticipated by the forecast branch of the Office; on such occasions a telegraphic request for observations to be made was sent to the Chief Officer, and transmitted by him to the various stations by telephone. These 'special' observations also included observations of the amount of cloud covering the sky at those stations at which the fog was sufficiently light to admit of this being determined.

From the point of view of the inquiry the extraordinary freedom from fog enjoyed by London during the past winter is greatly to be regretted. Instead of the average number of 50 days of fog, only 38 were experienced this year, and on most of these the fog was only light. Really serious fogs, lasting for several days and doing much damage did not occur. The most intense fog was that of the night from November 3rd to 4th, and the most prolonged one lasted from January 18th to 21st.

The result of this absence of fog is that many of the questions raised in last year's report have had but little additional light thrown on them.

Statistical Results of Inquiry.

Table A. gives a list of the stations with the total number of hours of fog of each intensity recorded at each, during the periods of observation in the last two winters. Before proceeding to examine this table, it will be advisable to consider the method by which the figures given therein have been arrived at.

TABLE A.—Number of Hours of Fog experienced at each Station.

Name of Station.	Name of Observer.	Height above Mean Tide Level (in feet).	Geological Formation.	15th December, 1901, to 15th March, 1902. Number of Hours of Fog. Light.	Moderate.	Thick.	Totals. Moderate and Thick.	All Fogs.	Place on Fog Frequency List. Moderate and Thick.	All Fogs.	1st September, 1902, to 31st March, 1903. Number of Hours of Fog of Intensity. 1	2	3	4	5	Totals. All Fogs.	3-5	Place on Fog-frequency List. All Fogs.	3-5
Sheerness	H.M. Coast Guard ..	On river		474	288	39	307	781	1	1	1,009	234	151	36	7	1,437	194	1	1
Southend	" "	"		273	153	10	163	436	2	3	511	76	66	—	3	656	69	6	—
Haven Hole	" "	"		155	106	39	145	291	3	2	410	153	75	12	—	650	87	2	—
Cliffe Creek	" "	"		263	33	43	76	339	4	8	573	153	48	9	—	783	60	7	—
Tilbury	" "	"		207	49	46	95	302	5	6	212	76	38	2	—	328	40	4	—
Deptford, Royal Victualling Yard Pier	W. Gill, M.F.B.	"		101	90	16	106	207	6	15	229	65	38	5	—	342	83	3	—
Cherry Garden, Bermondsey Wall	W. J. Fozzard, M.F.B.	"		388	60	11	61	329	4	5	227	56	34	4	—	321	68	3	—
Blackfriars Bridge	F. G. F. Allshorn, M.F.B.	"		177	11	8	19	147	10	20	245	73	23	12	—	353	98	8	—
Battersea Bridge	S. J. Jeanes, M.F.B.	"		115	22	8	40	177	15	26	101	37	23	4	—	165	35	2	—
Sydenham, Crystal Palace ..	W. J. Bichley, M.F.B.	325		9	—	—	0	9	16	30	93	42	24	12	—	171	75	14	—
Dulwich, East Side of Dulwich Park	C. R. Cook, M.F.B.	185		63	3	—	3	68	25	35	82	7	16	35	—	140	24	1	—
Brixton, Ferndale Road	F. Coates, M.F.B.	50		95	23	—	59	154	10	11	158	8	13	11	—	190	16	2	—
Clerkenwell, Rosebery Avenue ..	E. Williams, M.F.B.	70		283	21	36	57	340	26	27	185	21	2	2	—	210	4	2	—
Hyde Park, Edgware Road	S. Sharp, M.F.B.	107		214	18	11	29	243	27	24	345	55	25	5	2	432	32	3	—
Harleston Police Station	Metropolitan Police	160		157	24	47	71	228	9	9	228	85	31	2	—	346	29	2	—
North Kensington, Faraday Road ..	C. A. J. Cook, M.F.B.	77		—	—	—	—	—	8	12	246	44	46	12	—	304	61	5	—
Shepherd's Bush	G. Bartlett, M.F.B.	18		—	—	—	—	—	—	—	110	—	8	5	—	123	10	2	—
Stoke Newington, Leswin Road ..	W. E. Tanner, M.F.B.	60		146	18	18	36	110	19	21	22	78	22	2	—	102	28	2	—
Woolwich	L. George, M.F.B.	50		110	6	6	12	122	21	22	131	7	24	4	—	166	10	2	—
Blackheath, Tranquil Vale	G. Hearne, M.F.B.	125		117	—	—	—	117	4	10	119	11	8	2	—	140	10	2	—
Dartmouth Row, Greenwich	Metropolitan Police	25		158	6	5	11	169	10	25	183	15	13	5	—	216	18	2	—
Parkhill Road, Peckham		20		105	37	18	55	160	16	30	189	46	18	3	—	256	21	2	—
Plaistow Police Station		21		229	35	8	43	272	15	35	283	22	8	—	—	313	8	1	—
Rushey Green		21		38	2	—	2	40	13	13	106	24	5	—	—	135	5	1	—
Poplar, West India Dock Road ..	E. J. Blampied, M.F.B.	60		51	—	—	—	51	13	39	40	24	1	—	—	65	1	1	—
Bethnal Green, 51, Green Street ..	T. D. Rothwell, M.F.B.	20		80	14	4	18	98	27	34	112	25	4	1	—	142	5	1	—
Shadwell, Glamis Road	S. S. Norris, M.F.B.	47		63	8	8	16	79	23	31	167	42	10	1	—	220	11	1	—
Bishopsgate	W. J. May, M.F.B.	28		10	2	—	2	12	10	19	65	4	1	—	—	70	1	1	—
Kingsland Road	S. Norris, M.F.B.	38		—	—	—	—	—	3	7	151	30	10	1	—	192	11	1	—
Islington, Upper Street	T. V. Simmons, M.F.B.	84		146	6	18	24	170	14	26	129	12	15	6	—	168	21	2	—
Great Marlborough Street	T. Horne, M.F.B.	122		110	18	—	18	128	6	11	159	33	6	2	—	200	8	2	—
Fulham Road (No. 89)	T. J. Grieves, M.F.B.	78		117	—	6	6	134	26	18	240	21	5	—	—	266	5	1	—
Hammersmith	P. C. Shead, M.F.B.	26		134	37	5	42	176	18	34	122	38	12	2	—	174	14	2	—
Wandsworth, West Hill	H. C. D. Holtum, M.F.B.	18		117	35	0	35	152	15	19	60	11	6	—	—	77	6	1	—
Tooting, Balham Hill Road	W. Pearson, M.F.B.	60		158	21	4	25	183	13	12	151	46	16	5	—	218	21	2	—
Southwark, Southwark Bridge Road	Metropolitan Police	18		142	10	—	10	152	19	29	125	62	24	11	—	222	35	2	—
Kingston Police Station	Officer of the Watch	95		69	8	8	16	85	12	31	117	6	5	—	—	128	5	1	—
Shooter's Hill, South End of Common	L. Davis, M.F.B. ..	23		109	21	15	36	145	17	33	117	31	4	—	—	152	4	1	—
Isle of Dogs, Ferry Road	H. T. Dawson, M.F.B.	250		98	—	4	4	102	17	33	408	109	10	—	—	569	32	1	—
Hampstead, Heath Street	G. Staines, M.F.B.	16		87	24	—	24	111	21	21	71	7	34	—	—	112	34	1	—
Kew Observatory†	The Staff	23	Alluvium	21	63	14	77	98	14	21	21	43	12	1	—	77	14	1	—
Regent's Park‡	J. Wilson	104	Gravel	477	—	—	—	587	—	—	304	66	18	3	—	391	21	1	—
Victoria Park‡	The Superintendent	38	London Clay ..	—	—	—	—	—	—	—	374	30	12	1	—	417	13	1	—
Kennington Park‡	"	12	Gravel	—	—	—	—	—	—	—	171	30	18	3	—	222	51	1	—
Battersea Park‡	"	10	"	186	51	33	84	270	1	1	54	38	28	2	—	122	21	1	—
Poplar Borough Electricity Works, Bromley-by-Bow‡	Switchboard Attendants..	25	Brick earth	—	—	—	—	—	—	—	60	60	22	—	—	142	21	1	—
			Gravel	—	—	—	—	—	—	—	566	—	—	—	—	566	—	—	—

* Observations ceased at North Kensington on the day when they commenced at Shepherd's Bush.
† Observations did not commence at Bishopsgate till 21st October.
‡ The figures for this station are not comparable with those for stations above the thick line. *See* p. 17.

Scale of fog intensity.

During the winter 1901–2, fogs were recorded as light, moderate, or thick, and the classification was based on the distance at which it was possible to distinguish objects. This scale was open to the objection that it depended on the faculty of an observer to estimate distance correctly, as well as upon the site of the station, and accordingly it was replaced during the past winter by the following scale,* based on the extent to which traffic is impeded :—

——	Notation.	Land.	Sea.	River.
—	0	Clear	Clear	Clear.
Light Fog ...	1	Street traffic unhindered.	Distant objects obscured but traffic unimpeded.	Traffic unimpeded.
	2	Do. do.		Traffic practicable with moderate caution.
Moderate Fog	3	Street traffic difficult	Traffic difficult ...	Traffic practicable with extreme caution.
Thick Fog ...	4	Do. do.	Traffic very dangerous	Traffic impossible.
	5	Street traffic impossible.	Does not occur ...	Do. do.

In the hands of the officers of the Police and Fire Brigade—observers whose duty brings them continually into contact with questions of traffic—the scale appears to have given results which are as concordant as can be hoped for. The following points must, however, be borne in mind. It is probable that some differences of opinion existed as to when to draw the line between fogs of intensity "1" and "0." The observers at stations which are surrounded by high houses, such as Shadwell or Hammersmith, having only a limited range of vision, would be inclined to overlook a fog which "obscures distant objects," whereas such a fog would attract the attention of observers in the parks and on the river, and consequently we must expect a rather large amount of light fog to be reported by the latter. Again a moderate fog interrupts traffic on the river to a greater extent than traffic by road, and although this fact has been taken into account in drawing up the scale of fog intensity, it still seems probable that observers on the river have also overestimated the more intense fogs. As an example we may take the case of the neighbouring stations, Deptford Victualling Yard and Isle of Dogs. At the former the observer was stationed on the pier running out into the river ; the low lying fogs which hang about the river surface would therefore force themselves on his notice, and he would record them all (quite correctly) as light fogs ; in addition to this the feeling of insecurity engendered by the absence of lamps, buildings and other landmarks, would lead him also to form a high estimate of moderate fogs. At the Isle of Dogs the state of affairs is very different. The station is situated in an open position with a wide range of vision all round it, hence the observer would record all light fogs, but there is comparatively little traffic past this station, so that he would probably be liable to underestimate the intensity of a moderate fog and to class it under the heading "2." It is improbable that the figures as given represent the actual distribution of fog between the two stations.

Another point to be considered is that this year was remarkably free from fog, so that the effect of one or two foggy days at a particular station has been to place this station unduly high in the list of fog frequency : thus 12 out of the 16 hours of moderate fog at Dulwich occurred on the 26th and 27th of September, and 31 of the 34 hours recorded at Hampstead occurred during the fog from January 18th–21st.

The extent to which the "personal equation" of an observer may enter into his estimation of fog intensity is illustrated by a comparison of the figures obtained from Kingsland during the two seasons under consideration. The officer in charge of this

* The designations W and S to distinguish between white and smoky fog were retained.

station during the winter 1901–2, recorded a very large amount of light fog, so much so that we find Kingsland third on the list of fog-frequency (taking all fogs). During the past winter a different officer has been in charge, and the station is now 26th on the list.

Numbers not comparable for all stations.

The numbers given for the stations placed below the thick line in Table A are not strictly comparable with those from the Fire Brigade and Police Stations. The parks of the London County Council did not commence to observe till the 6th of October. Between 10 per cent. and 15 per cent. of the fogs recorded at other stations occurred before this date, so that the numbers from these stations must be increased by this amount before a comparison can be made. At the Electricity Works, Bromley-by-Bow, the observers were not in a favourable position for noticing the effect on traffic, and have decidedly over-estimated the amount of light fog. At Kew Observatory and Regent's Park no observations were taken between 11 p.m. and 7 a.m., so that the totals from these stations are too small.

Bearing these influences in mind, the following conclusions may be drawn from the contents of Table A.

Frequency of fog at river stations.

(1.) Stations immediately on the river, such as the Coast Guard Stations, Deptford, Cherry Garden, Blackfriars, and Battersea Bridge, recorded a large amount of fog. The differences between the records from these stations, and those from stations further inland, are too great to be accounted for by errors of judgment in observing. This high frequency seems to be limited to stations in the immediate vicinity of the river, and is not shared by stations such as Woolwich, Shadwell, or Hammersmith, which are near the river but not actually on it. This may be interpreted as evidence to show that fog formed on the river does not creep far inland. In most cases fog formed as early inland as on the river ; in a number of cases the inland stations actually anticipated the river stations. This was the case with many of the fogs which occurred in September, a time of the year when the conditions might be supposed to be particularly favourable to the spread of fog from the river (cf. Appendix).

Fog frequency in the parks.

Next to the river stations, the parks stand highest in the list of fog-frequency. In the case of light fogs this is no doubt partly due to the greater range of vision enjoyed by observers in the parks, but the large amounts of moderate and thick fog recorded cannot be assigned entirely to this cause. The cooling of the air by radiation is specially noticeable over grass surfaces, and the formation of mist or fog in such cases is to be accounted for by the combination of reduced air temperature with high humidity, due to the grass and the porous soil. Outside the parks, the surface of London consists mainly of paved streets, and the roofs of houses, from which the rainwater is artificially drained away, so that there is both less reduction of surface temperature and also probably less moisture in the atmosphere. A surface fog a few feet in height may frequently be noticed in the low lying parts of Hyde Park ; this is caused by the air, cooled by radiation from the grass to a clear sky, sinking to the bottom of the small valleys and causing condensation to take place as it mixes with the warm moist air it finds there.

As in the case with river fogs, there seems to be no marked tendency for fog formed in the parks to spread far into the neighbouring districts. It is true that Paddington Fire Station, which is near Regent's Park, reported much fog, but Bethnal Green, which is about the same distance from Victoria Park, stands about half way down the fog-frequency list. It is probable that the effect of the parks is limited to the streets in their immediate neighbourhood : thus about midnight on January 18th, fog was thick in the part of Piccadilly contiguous to the Green Park, but it was only light in that part which has buildings on both sides of the road.

Elevation.

Considered with regard to elevation no very decided results are indicated by Table A. Stations over 150 feet above mean river level appear near the bottom of the fog-frequency list ; on the other hand, Islington, Paddington, and Regent's Park, all over 100 feet above mean river level, experienced much fog. Several low-lying stations, such as Rushey Green and Hammersmith, show a marked freedom from fog.

Geological Formation.

The effect of the geological formation on the liability to fog is extremely difficult to determine, if it exists at all. The surface of London, consisting for the most part of made ground, is everywhere much the same, and it seems doubtful whether the layers below the immediate surface have any influence on the formation of fog under such circumstances.

The main formations met with are London clay, brick-earth, lower London tertiaries, gravel and alluvium. The formation on which each of the fog stations is situated has been given in Table A. The large amount of fog experienced at Stoke Newington, which is on brick-earth, raised the suspicion that this soil is particularly favourable to the formation of fog; private reports attributed a similar high fog-frequency to the neighbourhood of Holland Park, where a similar formation is to be met with. To test whether this is so, the Fire Station at Shepherd's Bush was substituted for North Kensington on the 27th of November. Since the change was made there has been too little fog to throw further light on the question.

A further complication is introduced by the fact that the various formations are interwoven to a very large extent, so that many stations are almost on the line of separation between two different kinds of soil. Thus, among the stations on gravel, Tooting and Wandsworth are very close to patches of clay, which appear in the gravel formation, and Islington is not far from the "brick-earth" district on which Stoke Newington is situated. Among the stations on other formations, Brixton, Clerkenwell, and Camberwell, all lie very close to gravel. Hyde Park has been classified as being on clay. The main part of the Park is on gravel, but a narrow seam of clay runs diagonally across it, and the station itself is on clay.

If we confine our attention to stations other than those on the river or in the parks, we can say that the stations on clay and brick-earth, with the exception of the more elevated ones, experienced rather more fog than others during the past two winters. This is more marked, if we allow some influence to the clay in the case of those stations mentioned above which lie close to clay but which are actually on gravel. The period during which observations have been in progress is, however, too short to eliminate the effects of the preponderance of a particular wind direction, or of individual fogs which were markedly local in distribution, for reasons other than geological.

The position of Rushey Green is somewhat peculiar. This station is situated on comparatively low-lying ground between the more elevated districts of Sydenham and Dulwich on the west, and Shooter's Hill and Blackheath on the east. The well-known tendency for cold air to collect in valleys in the early morning causes the temperature to be distinctly low very frequently (*see* Plates IV., V., and VII.), and yet the number of hours of fog experienced was small during both winters. It is impossible to say whether this freedom from fog is due to the fact that this station lies on a narrow strip of gravel running up the valley of the Ravensbourne, or to the comparative freedom from smoke which it enjoys, thanks to its suburban position.

Number of hours of fog on each day of the week.

The total number of hours of fog recorded at all stations on each day of the week during the past winter is as follows:—

Sunday	1,697
Monday	2,278
Tuesday	1,840
Wednesday	1,860
Thursday	2,015
Friday	1,906
Saturday	1,394

The marked freedom from fog shown by Monday in the records given in the report for 1901–2 (page 17) is thus shown to have been a mere coincidence.

Method of dealing with the observations.

All fogs which affected at least 10 stations simultaneously have been discussed in detail. A summary similar to that reproduced in Plate VIII., p. 46, condensing all available information into a single page, was prepared of each of these fogs and was found very useful to work with. In addition to this, the observations made at at least one of the hours at which temperature observations were taken, were plotted on an outline map of London, thus rendering the geographical distribution of the various elements observed more easy to follow. In Table B. a short summary of those particulars which lend themselves to tabular statement has been drawn up. For fuller information the Appendix must be consulted.

TABLE B.—Summary of Observations of Fogs which occurred between September 1st, 1902, and March 31st, 1903.

NOTES.

All fogs which affected at least 10 stations have been included.

Column 6 gives the hours during which at least four stations reported fog.

Column 7 gives the hours during which at least two stations reported fog of intensity 3 or above. When this rule has been departed from, the hours have been enclosed in brackets.

Column 10.—Wherever possible the perpendicular distance between two consecutive isobars, drawn for each 0·1 of an inch, has been measured; the results are given in miles in Column 10. In cases where the gradient was zero, *i.e.*, when London lay on a line of maximum or minimum pressure, the symbol ∞ has been used.

Column 11 gives the direction of the wind on the assumption that it is tangential to the isobars.

Column 14 gives a short summary of the records of the pressure tube anemograph at Kew.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
		Number of Stations reporting Fog of intensity								Wind	
No. of Fog.	Date.	1-5.	3-5.	4 & 5.	Duration of Fog.	Duration of most intense Fog.	Distribution of Fog.	Distribution of Atmospheric Pressure.	Distance between Isobars.	By Isobars.	At Brixton.
1	Sept. 18 & 19.	25	5	—	7 p.m. on 18th to 1 p.m. on 19th.	9.10 a.m. to 12.30 p.m.	In West and North-West; clear in South-East.	Anticyclone over Great Britain.	6 p.m. 250 8 a.m. ∞	6 p.m., NE.; 8 a.m., calm; SE. later.	6 p.m., NE. 2; 8 a.m., calm.
2	Sept. 20	22	4	1	3 a.m. to 10 a.m.	4 a.m. to 7 a.m.	Clear in North: thickest in South (Brixton, and Camberwell).	Anticyclone over Germany; parallel isobars.	200	SSE.	ESE. 1
3	Sept. 25	11	—	—	2 a.m. to 9 a.m.	—	River, Parks, Camberwell, Blackheath, and Southwark.	Anticyclone, centre over Midlands.	120	N.	8 a.m., calm.
4	Sept. 26	30	10	1	Midnight to noon	4 a.m. to 10 a.m.	River and in South; *see* Plate III.	Anticyclone over Midlands.	190	NE.	Calm
5	Sept. 27	29	5	1	Midnight to 11 a.m.	4 a.m. to 10 a.m.	River and in South; clear in North.	Anticyclone over Great Britain.	170	NNE.	Calm
6	Oct. 6	23	7	—	6 a.m. to midnight	Noon to 4 p.m.	At low-lying Stations in East; clear North and North-West.	Very wide and shallow "trough" of "low." (Plate II., Fig. 1.)	150	NW.	8 a.m., calm; 6 p.m., W. 1.
6	Oct. 7	21	2	—	Midnight to noon	(6 a.m. to noon)	River, Isle of Dogs, and Rushey Green; clear North and North-West.	"Col" between two shallow "lows."	190	W.	8 a.m., W. 1.
7	Oct. 8	15	5	4	6 a.m. to 11 a.m.	8 a.m. to 10.30 a.m.	Very locally in South-West.	"Col" between two shallow "lows."	∞	Calm; NE. later.	Calm
8	Oct. 11	14	2	—	7 a.m. to 1 p.m.	11 a.m. to 1 p.m.	Mostly in West; clear in East.	North-East of a shallow "low" over Channel; another "low" over Scandinavia. (Plate II., Fig. 2.)	170	SE., backing SW.	Calm
9	Oct. 18	12	—	—	7 a.m. to 11 a.m.	—	In West and South-West; clear East, North, and South.	Centre of a secondary depression moving to South-East.	∞	Calm; E. or NE. later.	Calm
10	Oct. 19	36	12	5	1 a.m. to 1 p.m.	2 a.m. to 11 a.m. (thick, 6 a.m. to 10 a.m.).	Parks and near River, Islington, Tooting, Harlesden, and Greenwich.	On axis of a ridge of "high."	∞	Calm; SW. later.	Calm
11	Oct. 23	19	2	—	5 a.m. to midnight	8 a.m. to 11 a.m.	Irregular; clear South and West.	Anticyclone, centre over Bay of Biscay.	? 6 p.m. 120	SW.; 6 p.m., W.	S. 1; 6 p.m., SW. 1.
11	Oct. 24	20	—	—	Midnight to 11 a.m.	6 a.m. to 10 a.m.	Mainly in West	Anticyclone over Germany.	?	WSW.	WSW. 1

Column 16 gives the minimum temperatures recorded at Kew Observatory between the hours of 9 p.m. on the day preceding the fog and 9 a.m. on the day of fog. The figures given are strictly comparable with those given in Column 19 for Regent's Park. In Plate I. the absolute minima during the 24 hours which make up the civil day have been used; in a few cases small discrepancies will therefore be found between the values of Column 16 and those used in Plate I.

Column 17 gives the difference between the maximum temperature occurring on the day before the formation of fog and the minimum temperature which occurred during the fog.

Column 18 gives the difference between this minimum and the subsequent maximum.

Column 20 gives the dew point at Regent's Park, as determined from the readings of the wet and dry bulb thermometers, taken at 9 p.m. on the evening before the fog occurred.

Column 21 contains a short summary of the changes of temperature recorded by the electrical thermometer on the roof of the Meteorological Office.

Column 22 gives an abstract from the "Remarks" column of the daily report from Greenwich Observatory. The Greenwich record has been quoted as it frequently gives indications of the character of the weather experienced during the night.

13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
Direction.		Temperature.							
			Kew.			Regent's Park.			
No. of Fog.	By Special Fog Observations.	Wind Velocity in Miles per Hour recorded at Kew.	River Water.	Minimum.	Range between Maximum of previous Day and Night Minimum.	Range on Day of Fog.	Minimum.	Dew Point at 9 p.m.	Temperature Changes on Roof of Meteorological Office recorded by the Electrical Thermometer.	Weather Reported at Greenwich.
			°	°	°	°	°	°		
1	No observations	Almost calm from 6 p.m. to 8.30 a.m.; then increased slowly; 6 at noon.	58	37	22	25	40	44	Max. on 18th, 58°; fall commenced at 7 p.m.; 43° at 6 a.m.; 54° at 10 a.m.; steady till 11.30 a.m.; rose subsequently.	Cloudless night; some fog and hoar frost in early morning; very fine day.
2	No observations	Under 3 till 2 a.m.; 4 to 5 from 2 a.m. to 5 a.m., then over 6; sudden squall (10) at 7 a.m.	59	41	20	21	42	45	Steady fall from 60° on 19th to 43° at 6.40 a.m. followed by rapid rise; 63° at 1 p.m.	Cloudless till 3 a.m.; thick fog, 3 a.m. to 8 a.m.; fine later.
3	No observations	Under 3 from 7 p.m. on 24th, till 9.30 a.m.; then sudden increase to 8.	59	43	23	23	43	47	Steady fall from 65° on 24th to 46° at 6 a.m.; rapid rise commenced 8 a.m.; 62° at noon.	Cloudless generally.
4	North Easterly in North-East; South-Westerly in South. (Plate III.)	Under 2 from 5 p.m. on 25th, till 10 a.m., then increased; 6 at noon.	59	41	23	24	42	49	50° at 2 a.m.; rapid fall to 43° at 5 a.m.; rise commenced at 8 a.m.; 49° at 10 a.m.; 64° at 1 p.m.	Cloudless; fog morning and night.
5	Generally Easterly; calms in South.	Under 2 till 11.30 a.m.: increased suddenly to 8.	59	40	25	25	42	48	53° at 11 p.m.; 47° at 4 a.m.; 42° from 6 a.m. to 8 a.m.; 49° at 10 a.m.; 64° at 1 p.m.	Cloudless with some fog in morning; slight cloud in afternoon.
6	Mainly Westerly, in draught to centre.	4 to 5 from 3 a.m. to 6 a.m.; almost calm from 8 a.m. on 6th, to 8 a.m. on 7th; then increased slowly; remained under 10.	53	47	5	4	46	43	No record; range very small.	Overcast all day, slight rain occasionally.
6	Mainly Westerly, in draught to centre.		53	45	7	11	47	45	No record; range very small.	Overcast all day.
7	North-Easterly; South-Easterly in the South-West.	Calm 6 a.m. to 8 a.m.; 4 from 8 a.m. to 10 a.m.; calm, 10 a.m. to noon; then rapid increase.	57	46	14	14	44	46	50° at 9 p.m.; 48° at 7.30 a.m.; rose slowly to 59° at 2 p.m.	Fine day; small amount of cloud; fog 6 a.m. to 9 a.m.
8	Between SW. and NW. ..	Over 5 till 10 a.m.; 4-5 from 10 a.m. to 11 a.m.; then increased; 15 at 3 p.m.	53	54	10	5	54	53	Between 56° and 59° ..	Overcast; frequent light rain.
9	No observations	Fell to 4 at 7.30 a.m.; calm, 8 to 8.30 a.m.; about 4 till 10 a.m.; then increased.	52	44	9	8	44	39	55° at 4 p.m. on 17th; fell slowly to 46° at 2 a.m.; then slow rise; 52° at noon.	Overcast; frequent rain; cloudless at night.
10	No observations	Almost calm from 11 p.m. onwards; increased rapidly at 1 p.m.	52	35	16	19	35	42	50° at 9 p.m.; 45° at 3 a.m.; 40° at 4 a.m.; steady till 9 a.m.; then rose rapidly; 53° at noon.	Dense fog in morning; then cloudless till 3 p.m.; then overcast.
11	No observations ..	Under 4 (calm intervals) between midnight and 11 a.m.; then rose to average of 7; after 1 p.m. it remained variable but below 5 till 10.30 a.m. on 24th; then rose rapidly to average of 8.	53	41	14	12	40	44	56° at 4 p.m. on 22nd; slow fall to 44° at 2 a.m.; steady till 6 a.m.; rose slowly, 56° at 3 p.m.; fall commenced at 3 a.m. on 24th; 48° at 8 a.m., then rose rapidly, 59° at 11.30 a.m.	Very fine till 2 a.m.; overcast afterwards.
11	No observations ..		51	45		1	45	51		Overcast till 3 a.m.; then fine.

TABLE B.—Summary of Observations of Fogs which occurred between September 1st, 1902, and March 31st, 1903—*continued.*

For Reference Notes, *see* pages 20 and 21.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
		Number of Stations reporting Fog of intensity								Wind	
No. of Fog.	Date.	1-5.	3-5.	4 & 5.	Duration of Fog.	Duration of most intense Fog.	Distribution of Fog.	Distribution of Atmospheric Pressure.	Distance between Isobars.	By Isobars.	At Brixton.
12	Oct. 27 & 28.	33	7	4	10 p.m. on 27th to noon on 28th.	1 a.m. to 8 a.m.	River and Parks, also Islington and Brixton; clear elsewhere in South.	Very complex; a secondary wedge of high pressure over London.	6 p.m. 160 8 a.m. ?	6 p.m., NNW.; 8 a.m., calm; SW. or S., later.	6 p.m., WNW.1; 8 a.m., calm.
13	Oct. 29	33	12	5	2 a.m. to 11 a.m.	4 a.m. to 10 a.m. (thick, 6 a.m. to 9 a.m.).	River, Stoke Newington, Islington, Dulwich, and Tooting; clear or light in North-West.	"Excentric anticyclone," centre over Russia.	190	SSE.	Calm
14	Oct. 30	17	1	—	7 a.m. to 11 a.m.	[8.30 a.m. to 10 a.m.]	Moderate at Kingsland; clear in West and South-West.	Parallel isobars, near a ridge of "high."	150	W.	NW. 1
15	Oct. 31	21	2	—	2 a.m. to noon	[6 a.m. to 10 a.m.]	Mainly in East; moderate at North Kensington and Harlesden.	"Excentric anticyclone," centre over Bay of Biscay.	220	WNW.	WSW. 2
16	Nov. 1	16	—	—	7 a.m. to noon	—	Mainly in the East ..	Parallel isobars, near a ridge of "high"	160	W.	W. 2
17	Nov. 3 & 4	38	28	11	5 a.m. on 3rd to 9 a.m. on 4th.	5 p.m. to 6 a.m. (thick 9 p.m. to 3 a.m.).	General	A wedge of high pressure passed Eastward over London.	?	6 p.m., WNW.; 8 a.m., SE.	6 p.m., calm; 8 a.m., SE. 1.
18	Nov. 5	17	—	—	6 a.m. to 4 p.m.	—	Irregular	Parallel isobars; "low" advancing from West.	110	SSE.	SE. 1
19	Nov. 12 & 13.	35	17	1	6 p.m. on 12th to noon on 13th.	9 p.m. to 11.30 a.m. (thick, 7 a.m. to 10 a.m.).	*See* Plates IV. and V. ..	Anticyclone over Poland, from which a wedge of "high" extended over France.	6 p.m. 140 8 a.m. 100	6 p.m., W.; 8 a.m., SW.	6 p.m., W. 1; 8 a.m., SSW. 1.
20	Nov. 14	31	5	—	5 a.m. to 5 p.m.	7 a.m. to 11 a.m.	Mainly in North and on River; clear South and South-East.	Similar to 19th	?	Calm; S. or SW. later.	Calm
21	Nov. 15	12	—	—	7 a.m. to 2 p.m.	—	Mainly in North-West ..	Open parallel isobars; anticyclone over Sweden.	250	SE. Fresh	E. 1 ening.
22	Nov. 21	17	—	—	7 a.m. to 2 p.m.	—	Mainly in South-West ..	High ridge; "low" advancing from West.	?	NE.; SE. later.	Calm
23	Nov. 23	18	4	2	7 a.m. to 7 p.m.	8 a.m. to 11 a.m. (thick, 8 a.m. to 10 a.m.).	Thickest in West, Paddington and Battersea.	Open parallel isobars; "low" travelling along North-West coast; "Westerly type."	150	WSW.	SSW. 2
24	Nov. 24	25	8	2	1 a.m. to 1 p.m.	7 a.m. to 9 a.m. (thick, 8 a.m. to 9 a.m.).	Thickest on River and at Paddington	"Low" advancing from West; steep gradient in West of England.	100	S.	S. 1
25	Nov. 27	26	1	—	7 a.m. to 5 p.m.	[9 a.m. to 2 p.m.]	Clear in South and South-East; mainly in West before 11 a.m.; in East after 1 p.m.; much high fog.	High pressure over the Bay of Biscay and over Sweden; a "low" advancing from West.	?	?	8 a.m., E. 1; 2 p.m., W. 1.
26	Nov. 30	12	—	—	7 a.m. to 10 p.m.	[7 a.m. to 6 p.m.]	Mainly in West and South-West.	Between a "high" over Scandinavia, and a "low" over the Bay of Biscay.	180	E.	E. 2
27	Dec. 1	27	3	—	5 a.m. to 4 p.m.	11 a.m. to noon (8 a.m. to noon).	Mainly in North, but irregular.	"Col" between a depression and its secondary.	∞	Calm; S. later.	8 a.m., calm; 2 p.m., S. 2.
28	Dec. 3	30	—	—	2 a.m. to 2 p.m.	[7 a.m. to 10 a.m.]	Mainly in West	Very complex; North of a "low" over the Bay of Biscay.	?	NE.	8 a.m., calm; 2 p.m. NE. 3

For Reference Notes, *see* pages 20 and 21.

13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
Direction.		Temperature.							
			Kew.			Regent's Park.			
No. of Fog. By Special Fog Observations.	Wind Velocity in Miles per Hour recorded at Kew.	River Water.	Minimum.	Range between Maximum of previous Day and Night Minimum.	Range on Day of Fog.	Minimum.	Dew Point at 9 p.m.	Temperature Changes on Roof of Meteorological Office recorded by the Electrical Thermometer.	Weather Reported at Greenwich.
12 Southerly generally, but North-Easterly in North-East.	Under 5 after 4 p.m.; almost calm. 11 p.m. till 10 a.m.; then over 6.	° 52	° 40	° 15	° 16	° 40	° 46	54° maximum on 26th; 52° at 7 p.m.; fall commenced at 11 p.m.; 43° at 4 a.m.; rise commenced at 5 a.m.; 56° at noon.	Fog till 8 a.m.; then occasional rain.
13 South-Easterly generally: North-Easterly at some stations in North-East.	5-6 till 10 a.m.; then increased.	51	44	12	11	44	48	53° at midnight; 45° at 8 a.m.; 55° at noon.	Very fine day; fog in morning.
14 Westerly generally; South-Westerly in South.	Generally over 6, but fell below that limit from 7 a.m. to 10 a.m.	53	42	14	14	45	44	Slow fall to 48° at 3 a.m.; then slow rise; 56° at noon.	Overcast; frequent slight rain.
15 Westerly; Southerly at North Kensington.	Under 5 till 11 a.m.; then increased.	50	38	19	16	36	40	Slow fall to 41° at 5 a.m.; rise commenced at 8 a.m.; 53° at 2 p.m.	Very fine; slight hoar frost in early morning.
16 W. or SW.	Average 4 till 11 a.m.; then increased.	52	46	7	11	46	41	About 52° till 9 a.m.; then increased; 58° at 1 p.m.	Overcast till 5 p.m.
17 9 a.m. on 4th; SE. or E. ..	Almost calm from 2 a.m. on 3rd to 1 a.m. on 4th; then average of 4; rapid rise commenced at 9 a.m.	50	38	15	15	40	44	53° at 12.30 p.m. on 3rd; 51° at 10 p.m.; 44° at 2 a.m.; rise commenced at 5 a.m.; 52° at noon.	Overcast; light showers till evening, then dense fog; overcast 7 a.m. to 11 a.m. on 4th; then fine.
18 No observations	Over 10 miles an hour ..	49	44	9	12	43	41	About 46° from 10 p.m. till 8 a.m.; then rose slowly to 56°.	Clear till 6 a.m., then overcast.
19 No observations	Fell to 4 at 6 p.m.; calm, midnight to noon; then rose rapidly to 13 by 1 p.m.	49	32	23	21	36	44	Max. 53° at 2 p.m.; slow fall to 44° at 8 a.m.; then rapid rise to 58° at 1 p.m.	Fine; fog and hoar frost in morning.
20 SW. generally; distinct indraught to centre.	Almost calm from 11 p.m. to 11 a.m.; then increased rapidly to 6.	50	36	16	17	40	44	48° at midnight; steady till 7 a.m. (min. 47°); then commenced to rise; 56° at 2 p.m.	Fine till 3 a.m.; then overcast.
21 E.; SE. in South	5 till 2 p.m., then increased rapidly.	48	42	11	6	42	48	52° at midnight; 44° at 6 a.m.; secondary min., 44° at 10 a.m.; then rose, 50° at 1 p.m.	Hoar frost in morning.
22 No observations	Almost calm, 7 a.m. to 9 a.m.; then under 4 till 3 p.m.; then rose rapidly.	42	30	6	8	29	27	Max. on 20th, 36°; 32° at 1 a.m.; steady till 5 a.m.; then slow rise to 41° at 2 p.m.	Some cloud; hoar frost in morning
23 No observations	Under 4 till noon, then increased to 8.	44	38	4	13	36	34	46° at 3 a.m.; constant till 9 a.m.; sudden fall to 42° at 9.45 a.m.; then rapid rise.	Cloudy; occasional slight rain.
24 No observations	Under 3 till 6 a.m.; increased to 8 by 8 a.m.; then increased to 11.	44	35	15	17	37	42	Slow fall to 44° at 4 a.m.; rise commenced at 6 a.m.; max. 50° at 11 a.m.	Generally overcast; frequent rain.
25 9 a.m., Easterly; noon, indraught; 3 p.m., Westerly.	Under 4 till 6 p.m.; calm from 11 a.m. to 1 p.m.	44	46	4	2	45	46	Very small range, 47° to 50°.	Overcast
26 No observations	12 till 2 p.m., then fell to 8.	45	46	4	2	45	44	Very small range, 46° to 48°.	Continuous rain.
27 SE., with well marked indraught.	3 from 5 a.m. till noon; increased later.	45	44	4	6	43	45	Range 46° to 49°	Overcast, gloomy; occasional rain during day.
28 No observations	Almost calm from midnight to 4 a.m.; under 4 till 9 a.m.; then increased rapidly.	45	32	18	7	33	39	Irregular fall from 52° at 3 p.m. on 27th to 33° at 8 p.m. on 28th (rise from 37° to 41° between 8 a.m. and 11 a.m.).	Very fine early, then overcast.

TABLE B.—Summary of Observations of Fogs which occurred

For Reference Notes, *see* pages 20 and 21.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
		Number of Stations reporting Fog of intensity								Wind	
No. of Fog.	Date.	1-5.	3-5.	4 & 5.	Duration of Fog.	Duration of most intense Fog.	Distribution of Fog.	Distribution of Atmospheric Pressure.	Distance between Isobars.	By Isobars.	At Brixton.
29	Dec. 12	22	—	—	7 a.m. to 11 p.m.	—	Mainly in West and North-West; clear in South and South-East.	A secondary wedge of "high."	8 a.m. ∞ 6 p.m. 150	Calm; S. or SE. later.	8 a.m., calm; 6 p.m., S. 1.
30	Dec. 22	14	—	—	7 a.m. to 5 p.m.	—	Mainly in West; clear in North and South.	Anticyclonic	?	N.	NE. 1
31	Jan. 1	24	3	—	7 a.m. to midnight	Noon to 2 p.m. (8 a.m. to 10 p.m.)	Clear in West; mainly near Isle of Dogs.	Anticyclone over France; ridge extending to Scandinavia.	160	WNW.; SW. later.	8 a.m., NW. 1; 6 p.m., SW. 2.
32	Jan. 5	13	2	—	5 a.m. to 11 a.m.	7 a.m. to 8 a.m.	Mainly in North-West ..	At base of a wedge of "high" in front of an advancing "low."	?	SW.	SW. 4
33	Jan. 8	29	7	—	7 a.m. to 5 p.m.	9 a.m. to 1 p.m.	Mainly in East before 11 a.m.; in West after 11 a.m.	Wedge of high pressure travelling Eastward. (Plate II., Fig. 3.)	?	?; SE. later.	Calm; SE. later.
34	Jan. 18	41	19	5	Midnight to midnight.	9 a.m. to midnight (thick after 1 p.m.).	General; but lightest in East.	*See* Plate II., Fig. 4. High pressure over the Baltic; a "low" off the West of Ireland; open parallel isobars over London; the main features of the distribution of pressure remained constant while the fog lasted.	200	S.	Calm
	Jan. 19	10	16	4	Midnight to midnight.	Midnight to 5 a.m., and 7 a.m. to 6 p.m.	General; thickest Parks and River.		200	S.	Calm
	Jan. 20	32	1	—	Midnight to midnight	[6 a.m. to noon]	General		180	SE.	ESE. 1
	Jan. 21	36	17	4	Midnight to 9 p.m.	9 a.m. to 2 p.m.	General		?	ESE.	ESE 1
35	Feb. 13	25	2	—	7 a.m. to 1 p.m.	[9 a.m. to noon]	Clear North and North-West, also South-East.	High pressure West of Ireland.	∞	Calm; N. later.	Calm
36	Feb. 17	17	—	—	7 a.m. to 11 a.m.	—	North of River	Anticyclone, centre over Belgium.	250	S.	S 1
37	Feb. 18	13	—	—	6 a.m. to 11 a.m.	—	Irregular	Anticyclone, centre over Belgium.	170	SSW.	Calm
38	Mar. 11	23	9	2	Midnight to 10.30 a.m.	3 a.m. to 1 p.m. (3 a.m. to 10 a.m.)	*See* Plate VII.	Anticyclone over Eastern Europe extending Westward; "low" off the North-West coast.	100	WSW.	W. 1
39	Mar. 12	16	1	—	6 a.m. to 10 a.m.	—	Clear in South-East, South, and South-West.		140	S.	S. 1

between September 1st, 1902, and March 31st, 1903—*continued*.

For Reference Notes, *see* pages 20 and 21.

13	14.	15.	16.	17.	18.	19.	20.	21.	22.
Direction.		Temperature.							
			Kew.			Regent's Park.			
No. of Fog.	By Special Fog Observations.	Wind Velocity in Miles per Hour recorded at Kew.	River Water.	Minimum.	Range between Maximum of previous Day and Night Minimum.	Range on Day of Fog.	Minimum.	Dew Point at 9 p.m.	Temperature Changes on Roof of Meteorological Office recorded by the Electrical Thermometer.	Weather Reported at Greenwich.
			°	°	°	°	°	°		
29	Easterly and South-Easterly.	Under 5; slight increase after 5 p.m.	37	32	4	11	32	30	About 33° from 3 a.m. to 11 a.m.; 30° at 4 p.m.; more rapid rise after 8 p.m.	Overcast till 11 a.m.; fine but cloudy later.
30	N.E., slight indraught in West.	Under 4 all day; calm, 3 p.m. to 6 p.m.	45	48	3	1	46	46	Range from 50° to 52° ..	Overcast; mild.
31	No observations	Calm from 11 p.m. on 31st. till 10.30 a.m.; then over 3; almost calm from 4 to 5 p.m., and from 7 to 8 p.m.; increased at midnight.	41	33	12	9	31	32	44° at 3 p.m. on 31st; 34° at 5 a.m.; steady till 9 a.m.; slow rise, max. 42° at 2 p.m.	Very fine; hoar frost in morning; slight fog in evening.
32	No observations	Under 4 from 3 a.m. to 7.30 a.m.; then rose rapidly to 15.	43	44	2	8	45	43	No record; very small range.	Overcast; frequent rain.
33	No observations	5 from 5 a.m. to 7.30 a.m.; almost calm till 2 p.m.; then increased to 14.	44	35	16	9	37	37	Fell to 42° at 6 a.m.; steady till 9 a.m.; 46° at 11.30 a.m.	Very fine till 9 a.m.; hoar frost in morning; then overcast and frequent rain.
34	No observations ..	5 to 10 between midnight and 8 a.m.; about 5 till noon; calm till 2 a.m. on 19th; then increased to about 6; fell calm at 11 a.m. on 20th; and remained in this condition till 9 p.m. on 21st, with the exception of a few short intervals.	35	35	0	5	34	28	A slow rise of temperature in progress; 34° at 2 p.m. on 17th; 36° at midnight; 37° at noon on 18th; it then remained between 39° and 43° till the evening of 20th; temporary fall to 37° at 8 a.m. on 21st; then rose steadily.	Overcast; sleet and rain in early morning; fog during day. Sky remained overcast till the fog cleared.
	„ „ ..		37	38	2	5	38	38		
	E. or S.E.		34	40	2	3	40	42		
	9 a.m., E. or S.E.; noon, very variable; 3 p.m., Easterly.		33	35	8	6	38	38		
35	General Northerly drift, well marked indraught.	Under 3 till 10.30 a.m., then about 8.	46	36	18	11	37	36	54° at 4 p.m. on 12th; 43° at 1 a.m.; rise commenced at 11 a.m.; 48° at 3 p.m.	Fine and bright; fog in forenoon.
36	S., slight indraught ..	Under 3 till 10 a.m.; then increased rapidly.	46	30	15	15	33	30	45° max. on 16th; 37° at 3 a.m.; rise commenced at 8 a.m.; 48° at 2 p.m.	Hoar frost; cloudy in morning; fine later.
37	Very variable; generally S.	Under 3 till 10 a.m.; then increased rapidly.	43	25	19	22	28	30	34° from 4 a.m. to 8 a.m.; 50° at 2 p.m.	Fine; hoar frost morning and night.
38	No observations	Calm till 10.30 a.m., then rose rapidly.	—	28	18	22	31	39	Readings on March 10th lay between 43° and 45°; fall commenced 10 p.m.; min., 34° at 6.30 a.m.; secondary min. at 8.15 a.m.; then rapid rise.	Slight fog till 8 a.m., then very fine; hoar frost morning and night.
39	No observations	Calm from 11 p.m. till 9 a.m.; then rose rapidly.	—	31	19	22	33	37	Fell from 52° to 40° between 1 a.m. and 7 a.m.; then rose rapidly.	Very fine; hoar frost in the morning.

Meteorological Conditions and Classification of Fogs.

In dealing with the meteorological conditions under which the fogs included in Table B. occurred, an attempt will be made to identify, as far as possible, the physical causes most active in bringing about the formation of fog. In an article in *Nature* (vol. 64, p. 649) Mr. Shaw has distinguished three types of fog: (1) 'steaming water fogs,' (2) 'cold surface fogs,' (3) 'cloud fogs.' The first type occurs near rivers and lakes, when the temperature of the air falls considerably below that of the water, and other conditions are favourable. The second type tends to form when the surface of the ground is cooler than the superincumbent air. Vigorous radiation can cause such a fog; the air in contact with the ground may then be cooled to such an extent that condensation takes place when it mixes with warmer and, therefore, probably moister air; it can also occur when warm air currents pass over a previously cooled surface. From the point of view of forecasting it is convenient to distinguish as 'radiation fogs' those cases in which the cooling of the surface occurred during the period under consideration by the forecaster, and to reserve the name 'cold surface' fog for those cases in which fog was caused by the passing of warm air over a previously cooled surface. The third type may be regarded as a very fine drizzling rain, in which the water particles are so minute that they fall with extreme slowness, thus reproducing all the effects of a fog.

In dealing with fog in London we may perhaps include a fourth type. On calm days the accumulation of the products of combustion in the atmosphere of large towns may be sufficiently great to produce the appearance of a fog, even though no appreciable cooling of the air, with its attendant condensation of moisture on the smoke particles, occurs. Such 'smoke fogs' are generally only light, but they are frequently accompanied by much high fog. In cases in which they attain moderate intensity they are very black in marked contrast to the damp, white country fogs. We should expect a rather low relative humidity on occasions when such 'smoke' fogs occur, but this expectation has not been confirmed by the observations. It is true that on occasions of light smoke fog the relative humidity was frequently below 90 per cent., but on the occasions when the phenomenon was most marked (Nos. 6, 25 and 27) the values lie between 95 per cent. and 98 per cent. Further observations of humidity, and especially of changes in humidity associated with the development of smoke fogs, would probably yield interesting results. Many 'radiation' fogs which commenced as white fogs developed subsequently into thick smoky fogs. and it would be of great interest to know whether these changes were associated with changes in the relative humidity of the atmosphere.

Barometric conditions.

Typical cases of pressure distributions favourable to fog formation were illustrated in Plates III. to V. of the report for 1901–2. Some further examples are given in Plate II. of the present report. Fog forms under such very varying isobaric conditions that generalisation becomes difficult. An indispensable condition for its formation at inland stations is that the wind velocity should be very small. As the wind velocity is generally looked upon as a function of the barometric gradient, this quantity has been measured in all cases when it was possible to do so: the results are given in column 10 of Table B. The numbers there quoted are the distances between two successive isobars (drawn for each 0·1 in.) measured perpendicularly to the isobars. It will be seen that the steepest gradient occurring in the Table is 0·1 in. per 100 miles (Nos. 19, 24, 38).

Cases in which fog remained light, in spite of isobaric conditions favourable for fog.

If the isobaric charts for the past winter published in the Daily Weather Report be looked through, several occasions will be noticed on which the distribution of pressure was distinctly favourable to the formation of fog, and on which very little or no fog was observed. The maps for September 7th and 8th may be quoted as examples: both show typical anticyclonic conditions, and the wind at Kew, as recorded by the Dines pressure tube anemometer, sank to calm during the night and early morning, nevertheless only very small amounts of light fog were recorded in London; the minimum temperatures recorded at Kew on these two days were 45° and 46° respectively, the relative humidities recorded at 9 a.m. were all below 84 per cent. Another remarkable instance is furnished

Barometric Distribution

6 October, 1902.
8 A.M.

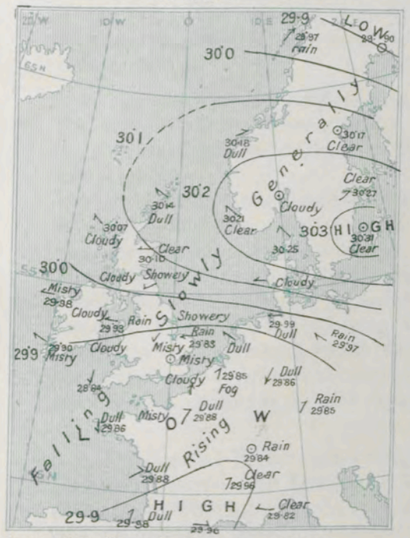


Fig. 1. High Fog during morning.
Temperature at Brixton at 8 A.M. 48°.

Fig. 1.

11 October, 1902.
8 A.M.

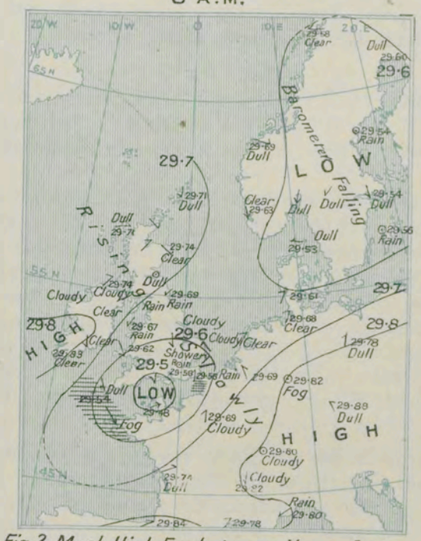


Fig. 2. Much High Fog between 11 A.M. & Noon.
Temperature at Brixton at 8 A.M. 55°.

Fig. 2.

8 January, 1903.
8 A.M.

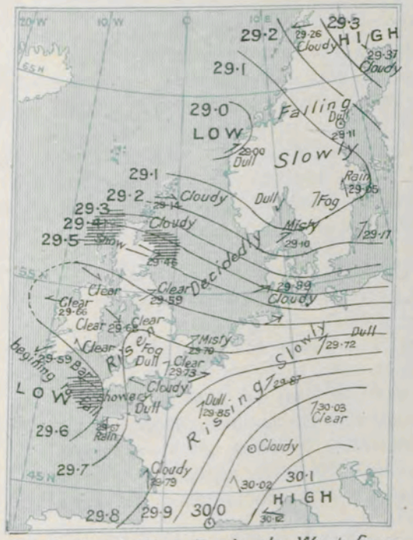


Fig. 3. Much High Fog in the West from 11 A.M. to 12.30 P.M.
Surface fog in the East at 9 A.M.
Temperature at Brixton at 8 A.M. 35°.

Fig. 3.

19 January, 1903.
8 A.M.

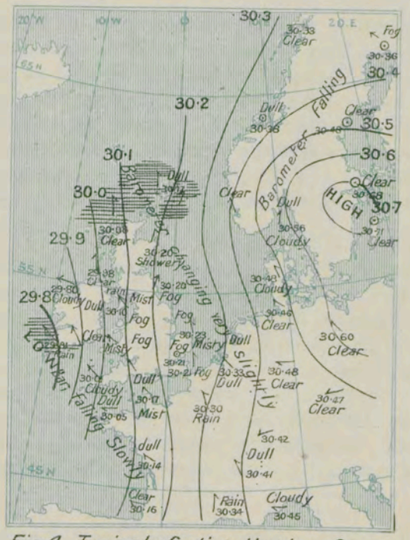


Fig. 4. Typical of distribution of pressure from Jan. 18 to 21 a period of prolonged fog.
Temperature at Brixton at 8 A.M. 39°.

Fig. 4.

by the map for December 22nd: the conditions were again anticyclonic and the wind velocity was very low, but the sky remained overcast in London, so that the temperature did not change appreciably during the whole of the 21st and 22nd (*see* columns 17 and 18, Table B.). The relative humidities reported from the various stations were between 93 per cent. and 99 per cent. at 9 a.m., and did not change much during the days mentioned.

Absolute wind velocity.

The absolute velocity of the wind during the occurrence of fog was obtained from the records of the anemographs at Kew. The majority of the fogs which attained the density "3" at two stations at least occurred with wind velocities not exceeding three miles an hour.

This value cannot, however, be taken as a limiting one; when other conditions are favourable fogs form with a higher wind velocity. On October 29th (No. 13) the wind velocity remained between five and six miles an hour, and yet thick fog was reported at five stations. On this occasion the minimum temperature at Kew also remained high (44°), but the relative humidity was very great. (*See* Appendix.) Similarly on January 19th (No. 34), during the prevalence of a fog caused by warm air currents passing over the ground which was still very cold after a severe frost, a velocity of about six miles an hour was maintained. 'Cloud' fogs (Nos. 8, 18, 24, 26, 32) were usually associated with much higher wind velocities—the values were frequently over 10 miles an hour.

Indraught to centre of London.

During the occurrence of fog when the wind velocity is very small, the direction of the air currents over London is largely affected by local influences; the heating of the atmosphere which takes place in the interior of the City causes the air there to rise, and this produces an indraught from the outlying districts towards the centre. Examples of this were given in Captain Carpenter's report, but in no case was the phenomenon shown as clearly as it was on November 27th, 1902 (No. 25). Plate VI. gives the direction of the air currents, as observed at the Fire Brigade Stations by watching the direction of drift of the smoke from elevated chimneys, at Noon on this date. The pressure tube anemograph at Kew shows that a light North-easterly breeze which had been blowing till 11 a.m. died away completely at this hour. From 11 a.m. till 1 p.m. the atmosphere remained completely calm; at the latter hour a light South-westerly breeze sprang up.

Fog thickest on leeward side

It is not usual for the air currents to be directed so uniformly towards the centre as they were in this case; as a general rule a preponderance of wind direction is very clearly shown. This direction plays a very important part in determining the districts in London which experience the thickest fog. A comparison of column 8 of Table B. with columns 11, 12, and 13, will show that in the majority of cases the thickest fog occurred on the leeward side. On such occasions the 'special' observations generally showed a distinct indraught at the stations under fog. In some cases (Nos. 2, 11, 13, 23, and 38) the most intense fog occurred on the windward side; some of these cases will be referred to again in dealing with local variations of temperature.

Visibility from the towers.

The observations of visibility from the tops of the Victoria Tower and of St. Paul's Cathedral, were continued during the past winter on the occasions of the weekly visits necessary to change the papers on the thermographs. Though the effects of smoke are always obvious, the limit of $1\frac{1}{2}$ miles assigned to the maximum range of vision in the last report, was decidedly too small under the more favourable conditions which prevailed during the past winter. It was possible to see from one tower to the other on a considerable number of occasions. Attempts to trace some connexion between the direction of the greatest visibility and that of the wind did not meet with success. On days of moderate wind the smoke rolls up in great drifts or banks, so that the view is subject to constant and very rapid changes.

High fog.

The phenomenon known as 'high' fog can occur under a large variety of circumstances, but certain conditions are more favourable to it than others. During the last two winters, there were fourteen occasions on which the phenomenon was particularly strongly developed, five during the past winter, and nine during the previous one. A short summary of these occasions is given in the accompanying Table C.

The isobaric conditions under which these fogs occurred were of the following types :—

(1.)	The N.E. side of a shallow depression	2 occasions.
(2.)	A ridge or wedge of high pressure with a "low" advancing from the West	6 ,,
(3.)	A "col" between two "lows"	3 ,,
(4.)	Centre of a very elongated anticyclone (almost a "ridge")	2 ,,
(5.)	Trough of low pressure between two "highs" ...	1 ,,
	Total ...	14 occasions.

TABLE C.—Summary of Conditions on 14 Occasions When High Fog was Particularly Marked.

Date.	Isobaric Conditions.	Barogram.	Notes on Changes of Wind.	Notes on Distribution of High Fog.	—
		1901–2.			
Nov. 22 ...	A "col" between a large depression in East and a secondary over South Wales.	Steady rise ...	Changed from N.W. to N.E.	In East 10 a.m. to Noon, in South at Noon, in S.W., during p.m.	
Dec 4 ...	On ridge of a very elongated anticyclone.	Max. 10 a.m. ...	Changed from S. to S.E.	Dark 11 a.m. to 3 p.m.	
Dec. 19 ...	"Col" between two "lows."	Max. 11 a.m. ...	W. then very variable.	Irregular	Plate III., b. (2), 1901–2.
Dec. 21 ...	Ridge of "high" between a "high" over Spain and another over Norway; "low" advancing from West.	Max. 10–11 a.m.	Changed from N.W. to S.E.	In East and North ...	Similar to Feb. 18, 1902 (Plate IV. (a) 1901–2).
Jan. 11 ...	Wedge of "high" extending Northward from a "high" in South. "Low" advancing from West.	Max. 8 a.m. ...	Changed from W. to S.W.	High fog commenced at 8 a.m. in N.W. and S.E.	Similar to Jan. 8, 1903 (Plate II., Fig. 3).
Feb. 5 ...	Wedge of "high." "Low" advancing from S.W.	Rapid fall after 10 a.m.	Changed from S. to E.	Commenced in N.W.	
Feb. 8 ...	"Col" between a "low" over Irish Sea and another over Germany.	Min. at 2 p.m.	Changed from S.W. to W.N.W.	High fog at Noon.	
Feb. 18 ...	Ridge of "high" from Spain to Norway. "Low" advancing.	Max. at Noon	Changed from N.E. to S.W.	Mainly in West about Noon (M.O. 1.15 p.m.).	Plate IV., a. (2), 1901–2.
Mar. 11 ...	Centre of narrow anticyclone.	Max. at Noon	Changed from W. to S. S.W. at 2 p.m.	Irregular.	
		1902–3.			
Oct. 6 ...	Trough between two "highs."	Min. at 3 p.m.	Calm; smoke drift changed from N.W. to S.W.	In South and S.W. ...	Plate II., Fig. 1.
Oct. 11 ...	N.E. of a "low" over Channel.	Rapid rise at 7 a.m.	Changed from S.E. to N.W.	Wave of darkness travelled from Regent's Park to Tooting, Wandsworth, and Sydenham, at 11 a.m.	Plate II., Fig. 2.
Nov. 27 ...	Ridge of "high" between anticyclone in S.W. and another in N.E. "Low" advancing from West.	Max. 11 a.m. ...	N.E. at 8 a.m. S.W. at 2 p.m. S.E. at 6 p.m.	High fog at 8 a.m. ...	Similar to Feb. 18, 1902 (Plate IV., a. (2), 1901–2).
Dec. 3 ...	North of a shallow depression; very complex.	Steady rise ...	N.E.	High fog in West.	
Jan. 8 ...	Wedge of "high." "Low" advancing from West.	Max. 11 a.m. ...	W. changed to S.E., as high fog developed.	High fog in West at 11 a.m.	Plate II., Fig. 3.

On eight (first two groups) out of these 14 occasions, London was in front of, or on the boundary of the warm circulation (generally S.W. to S.E.) in front of an advancing depression. Plates IV., *a.* (2) and V., *b.* (2) of the previous report illustrate some of these conditions. Plate II., Figs. 1, 2 and 3 of the present report offer further examples. It will be seen that in all these types except the first, a region of maximum or minimum pressure is shown on the maps in the neighbourhood of the fog area. A line of maximum or minimum pressure plays an analogous part in the circulation of the atmosphere to that of a mountain ridge in a flow of water on the earth's surface; its passage over a station is associated with a more or less decided change in the wind direction. As the winds in the neighbourhood of the ridge are necessarily very light, it is not possible as a rule to fix any particular instant as the moment of the change in the wind; it has already been pointed out that the direction of the air currents over London varies in different places when the wind is very light. A distinct change in the direction of the local air currents usually takes place at the time when high fog commences. (cf. October 6th, January 8th, Nos. 6 and 33.)

Temperature.

The observations of temperature made during the past winter may be dealt with under two headings, (1) general changes of temperature, (2) local variations of temperature.

General changes of temperature.

(1.) The maximum and minimum temperatures at Kew for each day during the period over which the observations extended are shown on Plate I., p. 13. The readings plotted are the absolute extremes recorded by the photographic thermograph during the 24 hours which make up the civil day. The mean temperature of the river water is shown by means of crosses on the same plate: as the temperature of the water is not subject to sudden changes, it is justifiable to regard the mean of the observations made at 9 a.m., 3 p.m., and 9 p.m., at Deptford and Battersea Bridge, as giving a satisfactory value for the general temperature of the water. The intensity and duration of the fogs included in Table B. have been shown graphically in the diagram.

Fogs due to nocturnal radiation.

It will be seen that of these fogs Nos. 1–5, 7, 10–15, 17, 19–21, 28, 31, 33, 35–39 occurred in connexion with more or less pronounced downward surges in the minimum temperature curve, and also, with large ranges (generally over 14°) between the maximum temperature recorded on the day preceding the fog and the minimum on the day of fog (*see* Table B, Column 17). On most of these occasions London was situated in the region of an anti-cyclone (either near its centre, or on its boundary), or on a ridge (or wedge) of high pressure. These conditions favour a clear sky and are consequently accompanied by nocturnal radiation; from the abstracts of the daily meteorological report from Greenwich Observatory given in Column 22 of Table B., it will be seen that most of these fogs occurred after a clear night. Hoar frost, another result of radiation was frequently noted.* On such occasions it was not unusual for the minimum temperature recorded on the grass at Camden Square or Regent's Park to be 8° or 9° below that recorded in the screen at a height from 3 to 4 feet above the level of the ground. There can therefore be little doubt that these fogs were 'cold surface fogs,' due to radiation.

In the neighbourhood of the river some of them partook largely of the character of 'steaming water fogs.' The mean temperature of the water and the minimum temperature of the air at Kew are given in Columns 15 and 16 of Table B. The differences between these two temperatures were often of considerable magnitude (over

* A remarkable instance of the formation of fog by nocturnal radiation occurred in London on the night of May 24th, 1904. A light, moist, warm air had set in and in the evening the sky was clear. Fog began to form towards 10 o'clock. At 11.10 there was moderately thick fog in the Park area, North of the water in St. James's Park, *none over the water*, little over the South side, and none in the neighbouring streets; later the fog had covered the water, but the bridge was clear. At midnight fog was passing out of Hyde Park by the Albert Gate, down the streets leading Southward, but not extending to the streets running East and West. All these phenomena are consistent with the formation of fog by the cooling of the surface through radiation, and the drainage of the cooled air carrying fog with it to lower levels. *See* a paper by J. B. Cohen, Q. J. Royal Met. Soc., Vol. xxx., p. 211.

15° on 10 occasions). As might be expected the largest differences occurred early in the season, at a time of the year when the river water still retains much of its summer heat. On the 19th of September the temperature of the air at Kew fell 21° below that of the river water; this fog was, however, not particularly thick on the river (*see* p. 17 and Appendix p. 35).

Inversion of the normal temperature gradient.

These 'radiation' fogs were not accompanied by any very striking cases of inversion of the normal temperature gradient; the minimum temperature recorded on the roof of the Meteorological Office was usually as low, and often a degree lower, than that recorded in the Churchyard. Only on six occasions do the records show a higher minimum on the roof, and in these cases the differences did not exceed 3°. A comparison of the readings made at the hours fixed for observations show no larger differences. Conspicuous differences such as that observed on March 6th, 1902 (7°.5) did not occur during the winter of 1902–3.

Many decided surges of minimum temperature, shown on Plate I., p. 13, were not accompanied by much fog. November 20th and 21st, December 5th–7th, January 12th–17th, February 1st, 3rd, 17th, 18th, furnish examples of this.

Reference to the Daily Weather Reports for these days will show that on all these occasions the wind velocity either remained high (over 10 miles an hour) or the atmosphere was very dry; in several cases both these causes combined to prevent the formation of fog.

'Cold surface' fogs due to warm air passing over a cooled surface.

Some fogs can be identified as 'cold surface fogs' caused by the warm moist air of an advancing depression coming in contact with cold ground. A conspicuous example of this type of fog is furnished by No. 34 (January 18th to 21st) which formed the close of a period of sharp frost. Full details of this fog will be found in the Appendix. No. 23 must probably also be referred to this type; an irregular rise of temperature caused by a warm South-Westerly wind was taking place while the fog lasted.

'Cloud' fogs.

Fogs Nos. 8, 18, 26, and 32 have already been referred to as 'cloud' or 'drizzling rain' fogs. They all occurred under the influence of cyclonic conditions, in the neighbourhood of shallow depressions, or on the outskirts of deep ones. They have the following features in common, a relatively high wind velocity (10 to 15 miles per hour), a high minimum temperature, and complete absence of all sign of inversion of the normal negative temperature gradient. As a general rule, the range between the minimum temperature and the previous day's maximum was small. No. 24 commenced under other conditions (cold surface fog), but it developed into a typical cloud fog during the morning.

'Smoke' fogs.

There remain eight fogs (Nos. 6, 9, 16, 22, 25, 27, 29, 30) which have been included in Table B., which must be regarded as representatives of the smoke fogs peculiar to large towns. On all these occasions the temperature changes were small.

Highest minimum temperatures reported during fog.

From the experience gained last year, the statement was made that no serious fog occurred with a temperature of more than 40°. If we take as the definition of the term "serious fog," a fog which attained the intensity "3" at two stations at least, we find that 46° (No. 7) is the highest minimum temperature at Kew to be found among the radiation fogs coming within the definition, and on the 6th of October (No. 6, a smoke fog), we find that seven stations reported moderate fog in spite of the fact that the temperature did not fall below 47°. The formation of fog depends on the combination of so many different elements that no definite limit can be assigned. On May 30th, 1903, after a heavy thunderstorm, a fog which certainly attained the intensity "2," over a wide area, came on at about 7 p.m., the temperature was 68°.

Local variations of temperature.

The results obtained from the frequent observations of temperature made at the Fire Brigade Stations are disappointing. The hope that it would be possible to obtain useful information from these observations on occasions similar to March 6th, 1902, when some very conspicuous differences of temperature prevailed over the London area during the

occurrence of a thick fog, was not realized, as no similarly thick fogs occurred. The most prolonged fog of the winter (No. 34) was marked by surprising uniformity of temperature over the whole area considered.

The yard of a Fire Brigade Station does not afford an ideal exposure for a thermometer screen, as the close proximity of brick walls, etc., cannot be avoided; wherever practicable, the screen was placed on the North wall of an out-house, frequently the coal cellar, in which there was no artificial heating. As was to be expected, the stations near the centre of London generally reported rather higher readings than those on the outskirts. On most occasions the majority of the observations made simultaneously within the London area, lay within a range of 5°, and it was not possible to trace any connexion between the distributions of temperature and fog.

Conspicuous local differences of temperature occurred with some 'radiation' fogs. On these occasions the fog generally remained light or did not occur in those districts in which the temperature was highest. Plates III., IV., V., and VII., are examples of typical cases. Plate III. gives the isotherms for 5 a.m. and 9 a.m. on September 26th (Fog No. 4); temperature, it will be seen, was distinctly higher in the North (and at Sydenham) than in the South; and the thick or moderate fog was confined to the cold southern districts. At 5 a.m., the differences were not so marked as at 9 a.m., but the general features of the distribution of temperature were similar.

Plates IV. and V. (Fog. 23, Nov. 13), show a relatively warm area in the centre and in the South of London. Fog occurred mainly in two patches, (1) on the North-Eastern or leeward side, (2) on the Western or windward side. The warmer central and Southern districts remained almost free from thick fog (*see* Appendix, p. 42). Low temperatures were also reported from Rushey Green, but no fog was experienced at this station; this point has already been touched on in dealing with the local variations in fog frequency, p. 18.

In some of the cases in which the thickest fog occurred on the windward side, we find decidedly higher temperatures prevailing on the leeward side. Plate VII. which gives the distribution of temperature at 5 a.m. on March 11th (Fog No. 38), is a case in point. Very little fog was experienced in the warm North-Eastern district. Several other cases in which the thickest fog occurred on the windward side show similar characteristics; for details the Appendix must be consulted (Nos. 2, 11, 13). In these cases there appears as a rule to be a drift of cold air into London from the surrounding districts, and probably this cold air causes the formation of fog within the town, but there is no evidence to show that the fog itself drifts to great distances. On comparing the records from different stations, it is not possible to detect any definite spread of fog from one locality to another; in some cases fog is reported as commencing at a number of stations almost simultaneously, in others the process seems to go on quite irregularly. Only on one occasion was it possible to trace the spread of fog from one station to another (*see* Appendix, No. 34, p. 47). The exact time at which fog commenced was probably not recorded with great accuracy during the night.

Relative Humidity.

Throughout the winter a comparison was made between the dew point in Regent's Park at 9 p.m., and the minimum temperature recorded there during the ensuing 12 hours. Out of 188 days, the latter fell to the level of, or below the former, on 71 occasions, of which 29 were days of sufficiently thick fog to be included in Table B. On the remaining 42 days the wind velocity remained above 6 miles an hour on 34 occasions, on 23 of which it was for the most part over 10 miles an hour, values which are in excess of those which usually prevail during fog. (*See* p. 27.)

There remain eight occasions on which the fog did not become sufficiently conspicuous to be included in Table B.; three of these occurred in September on brilliantly fine days on which the sun's influence became powerful before 8 a.m.; on four more occasions the wind began to increase very early and passed the limit of 6 miles an hour before 8 a.m. On the remaining occasion, December 24th, light fog was recorded at only seven stations; the conditions which prevailed would lead us to expect more fog.

Of the fogs included in Table B., all those classed as 'radiation' fogs except four (Nos. 14, 35, 36, and 37), show minima of temperature below the value of the dew point at 9 p.m. on the previous evening. In these exceptional cases the fog was very light. In the cases of fogs due to other causes, the temperature of the air generally remained higher than the dew point observed at 9 p.m.

Fog Forecasts.

The question of the possibility of issuing special fog forecasts for London is a very complex one. The first point on which a forecaster would be called upon to make up his mind would be that of the probable velocity of the wind. This part of the problem is the counterpart of the issue of storm warnings as at present practised, and it is probable that a similar percentage of successes could be attained in it. In forecasting, the wind velocity is usually looked upon as a function of the barometric gradient, and on page 26 an attempt has been made to determine the value to which this quantity must sink before fog can form.

It would occasionally be useful to have 'special reports' on the height of the barometer and other meteorological elements similar to those at present asked for during unsettled conditions, telegraphed to the Meteorological Office at hours other than the regular observing hours, but as the majority of fogs commence or become thick between the hours of 6 a.m. and 9 a.m.,* they would not be required, as a rule, unless arrangements were made for dealing with them during the night. They might, however, be useful for forecasting the continuation or dissolution of an already existing fog.

Here the analogy between storm warnings and fog warnings ceases. In the case of fog phenomena questions of temperature and humidity play an important part. It has been pointed out that all serious 'radiation' fogs occurred with a minimum temperature at Kew not higher than 46°, but perhaps the dew point at, say, 9 p.m, may be looked upon as a more satisfactory limit to which the temperature must fall before fog can form. The maximum temperature of the previous day might prove useful in this connexion, a high maximum having the effect of increasing evaporation, and so, on the reduction of temperature, subsequently increasing the humidity of the atmosphere. On 21st and 22nd of December the temperature remained very uniform and was not far removed from the dew point throughout, but little fog formed.

The success of a forecast must depend largely on the accuracy with which a forecaster is able to estimate the amount of the fall of temperature in the immediate neighbourhood of London due to radiation ; a fall of temperature due to cold air being brought from any considerable distance by wind will not occur, as we have postulated that the motion of the atmosphere should be small. In a large number of cases it is possible to forecast "mist or fog locally" with tolerable certainty. Whether the fall of temperature in a particular locality will be sufficiently large to cause a fog depends largely on the accident whether the sky is clear or overcast. Under such circumstances the large number of nuclei present in London air may act as an incentive to condensation and cause our city to be one of the localities visited by fog, but in some cases the dust cloud seems to act as a check to radiation, with the result that the temperature remains high and little fog is formed.

Seeing that the majority of fogs assume their greatest intensity between the hours of 6 a.m. and 9 a.m., it is obvious that a forecaster who commenced work at the early hour of, say 5 a.m., would be in a much more favourable position for judging of the probability of serious fog forming during the ensuing morning than his colleague who has to draw up his forecast at 6 p.m. on the previous evening. He would be able to tell from personal observation whether the night had been favourable to radiation, and would also be able to inform himself of how great the fall of temperature had been up to the hour at which he issues his forecast. A few 'special' telegrams, giving the height of the barometer at selected stations over England, would then be of great use to him.

* *See* p. 17 of Captain Carpenter's Report.

In the case of 'cold surface' fogs caused by a warm air current passing over previously cooled ground such information would be of still greater use. Such fogs presuppose a certain amount of wind velocity, and the forecaster must then decide whether this velocity is likely to increase or not. None of the 'cold surface' fogs which occurred during the winter 1902–3 were forecasted ; in each case the forecaster anticipated that the wind would be too strong for fog to form. All the 'cloud' fogs were also missed, and for the same reason.

'Smoke' fogs are certain to occur in London during the winter months whenever the wind velocity becomes sufficiently light for a sufficiently long period, and there is no fall of temperature to give rise to the more serious type of radiation fog ; their successful forecasting, therefore, depends on the correct anticipation of the wind velocity.

The conditions which appear to be specially favourable to 'high fog' have been discussed on pp. 26–29 ; successful forecasts could probably be issued of them in a considerable number of cases, but reference to column 9 of Table B will show that barometric conditions apparently particularly favourable to high fog occurred on several occasions which passed off without high fog being reported. It must, however, be remembered that the phenomenon would escape notice at night.

Local forecasts.

The question of local forecasts is still more difficult to deal with. The most conspicuous factor in determining which part of London will experience the thickest fog appears to be the direction of the wind. Out of a total of 44 days of fog recorded in Table B, 27 showed the thickest fog on the leeward side, 5 showed it on the windward side, and on 12 days the fog showed no particular preference for any one locality. Forecasts based on the direction of the wind would necessarily be very vague ; a phrase such as "in the West" would have to be understood as covering a very large area throughout which the fog might vary greatly in intensity.

In some cases the distribution of temperature over London furnishes information which might be useful in this connexion ; examples have been given (p. 31) of cases in which certain districts were distinctly warmer than others, and these warm regions generally experienced the lightest fog. This was particularly the case with some of the fogs which were thickest to windward ; in four of the five cases mentioned above the temperatures remained distinctly highest on the side shielded from the wind. In the remaining case, No. 23, temperature was very uniform over London.

Given an organization for putting information of the distribution of temperature over London in the hands of a forecaster at say 5 a.m., a possibility is indicated that it might be made useful in determining the districts least likely to experience fog, in a forecast which could be issued at, say 6 a.m. Whether the number of successful forecasts would ultimately be large enough to justify the considerable expenditure which would be involved is a question which cannot be settled at present ; more evidence must be accumulated and discussed before the attempt could be made with much hope of success.

Suggestions for continuation of the inquiry.

It is greatly to be desired that further observations be made, even if it is found impracticable to continue the inquiry on the extensive scale on which it has been carried out during the past two winters.

The daily meteorological report of Greenwich Observatory, the Daily Weather Report of the Meteorological Office, and probably also the registers of a number of the second order stations in and around London, contain records of the occurrence of fog which extend over a considerable period, and of late years more detailed observations have been made at Kew Observatory, and at the Poplar Borough Electricity Works, but before the commencement of the present inquiry no attempt had been made to co-ordinate these observations, which for the most part are not sufficiently precise as to intensity and

duration of fog to be of great value for such a purpose. The following suggestions are therefore offered for the continuation of the inquiry.

There is a great advantage in having the observations made by a homogeneous body of observers such as the officers and men of the Metropolitan Fire Brigade. If the present scale of fog intensity, based on the extent to which traffic is interfered with be adhered to, there is the additional advantage that the duties of a fireman bring him continually into contact with questions of traffic, and hence a greater uniformity in the results may be hoped for than could be obtained, without long training, from a body of volunteer observers taken from different walks of life. Only such stations should be selected as have an unimpeded range of vision. The following stations are suggested provisionally :—

Kingsland, N.E.
Paddington, N.W.
Battersea Bridge, W. (River.)
Tooting, S.W.
Rushey Green, S.E.
Deptford, E. (River.)
Bishopsgate, Centre.
(Electricity Works, Bromley-by-Bow.)
(Meteorological Office, Westminster.)

The indifferent exposures obtainable for thermometer screens at fire stations, do not render them particularly suited for taking temperature observations. It, therefore, seems preferable to limit the inquiry to the discussion of observations made with the recognised standard exposure (Stevenson or Glaisher screen) in the parks or gardens where there are no buildings in the immediate neighbourhood to influence the readings. There are at present a considerable number of stations in and around London at which observations of temperature are taken at regular hours :—

Meteorological Office.
Greenwich Observatory.
Kew Observatory.
Camden Square. (Dr. H. R. Mill.)
Regent's Park. (Royal Botanic Society.)
Croydon. (Royal Met. Soc.)
Brixton. (Met. Council for D.W.R.)
Barnet. (Gas Works.)

Observations at hours such as 5 a.m. would be impracticable in most cases ; readings of dry and wet bulb thermometers taken at the hours of observation for a second order station (9 a.m., 3 p.m., and 9 p.m.), together with maximum and minimum temperatures would afford a large amount of valuable information. It would be advantageous to have the minimum temperature read at 9 a.m. and 9 p.m., in order to get the minimum temperature experienced during the night in all cases.

Temperatures on the grass and below the surface of the ground would also be useful.

These stations are not by any means uniformly distributed over the London area ; to remedy this defect public bodies or private observers possessing facilities for providing suitable exposures can perhaps be induced to take part in such a scheme.

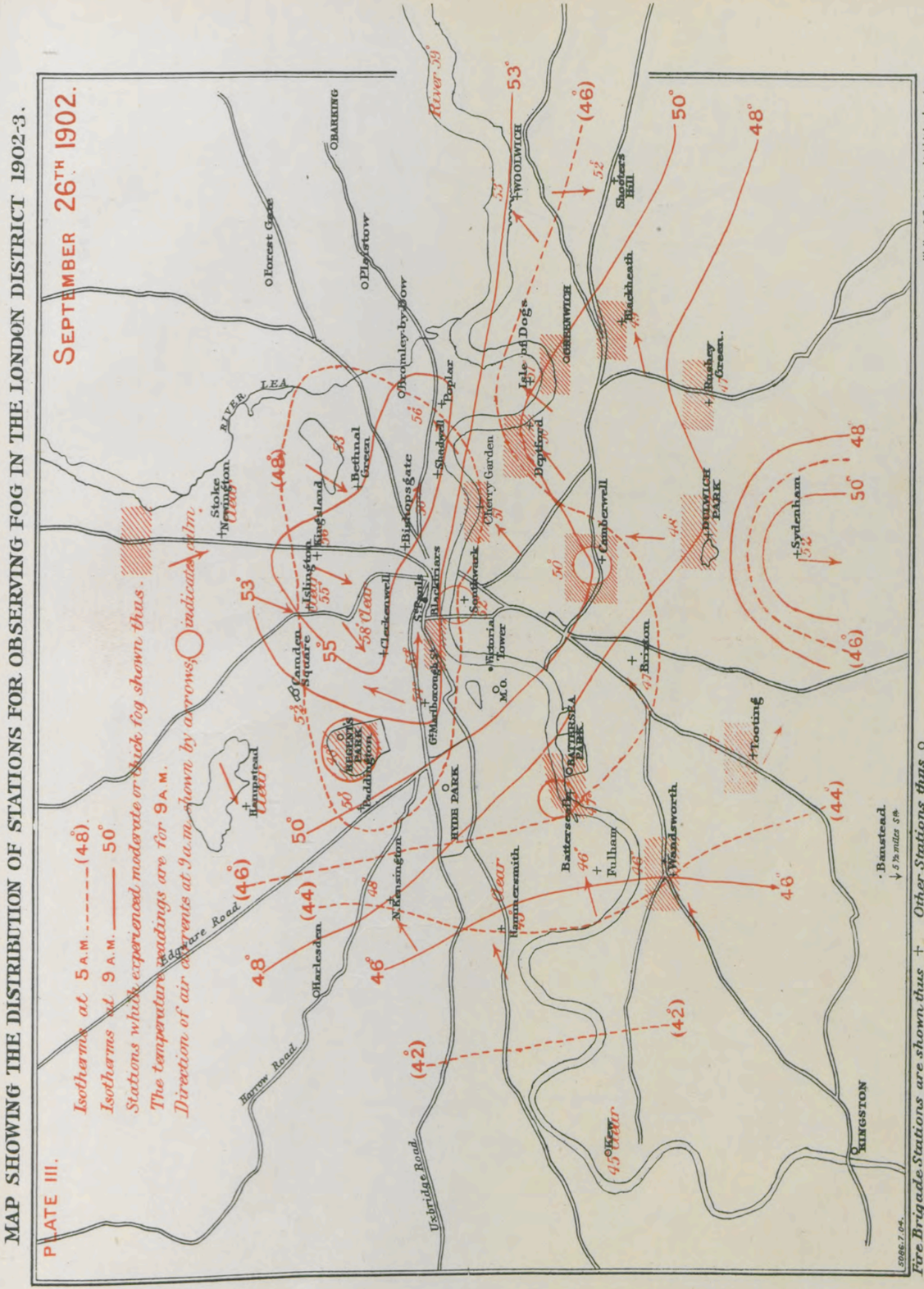
It would be desirable to have the temperature of the river water taken at Battersea Bridge, or Deptford Pier Fire Brigade Station.

R. G. K. LEMPFERT.

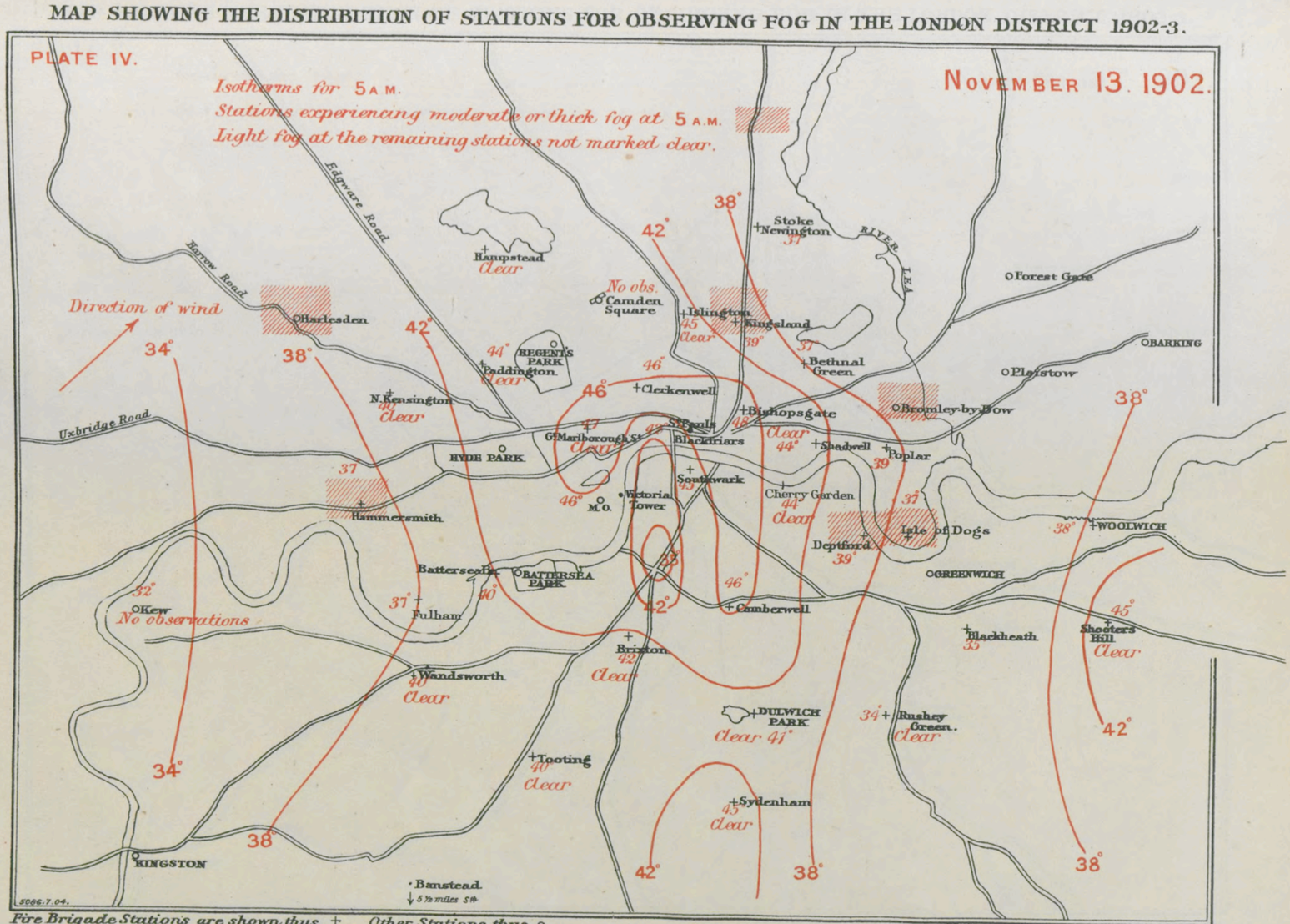
June 1903.

MAP SHOWING THE DISTRIBUTION OF STATIONS FOR OBSERVING FOG IN THE LONDON DISTRICT 1902-3.

PLATE III.



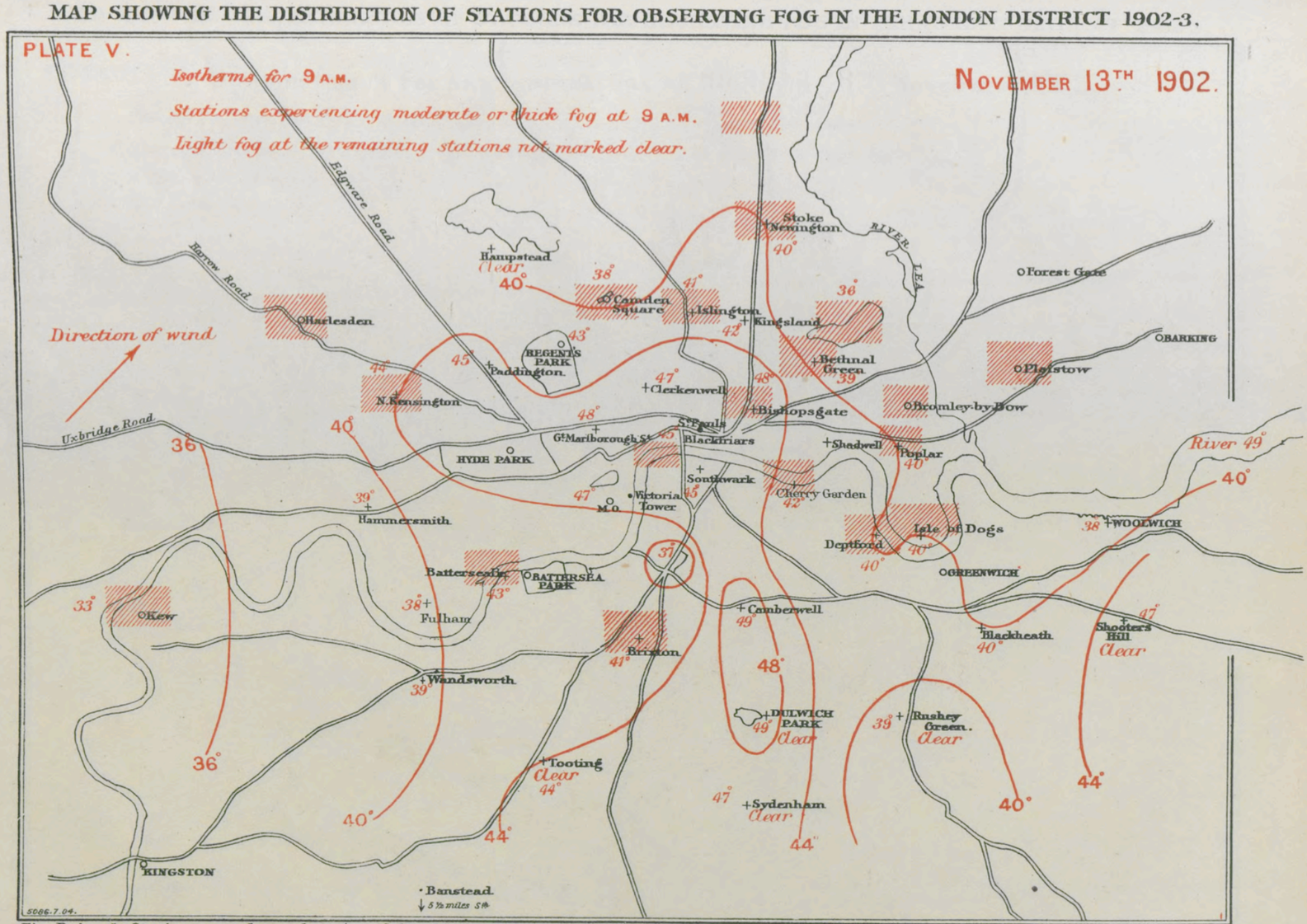
MAP SHOWING THE DISTRIBUTION OF STATIONS FOR OBSERVING FOG IN THE LONDON DISTRICT 1902-3.



Fire Brigade Stations are shown thus + *Other Stations thus* o

Weller & Graham Ltd Litho. London.

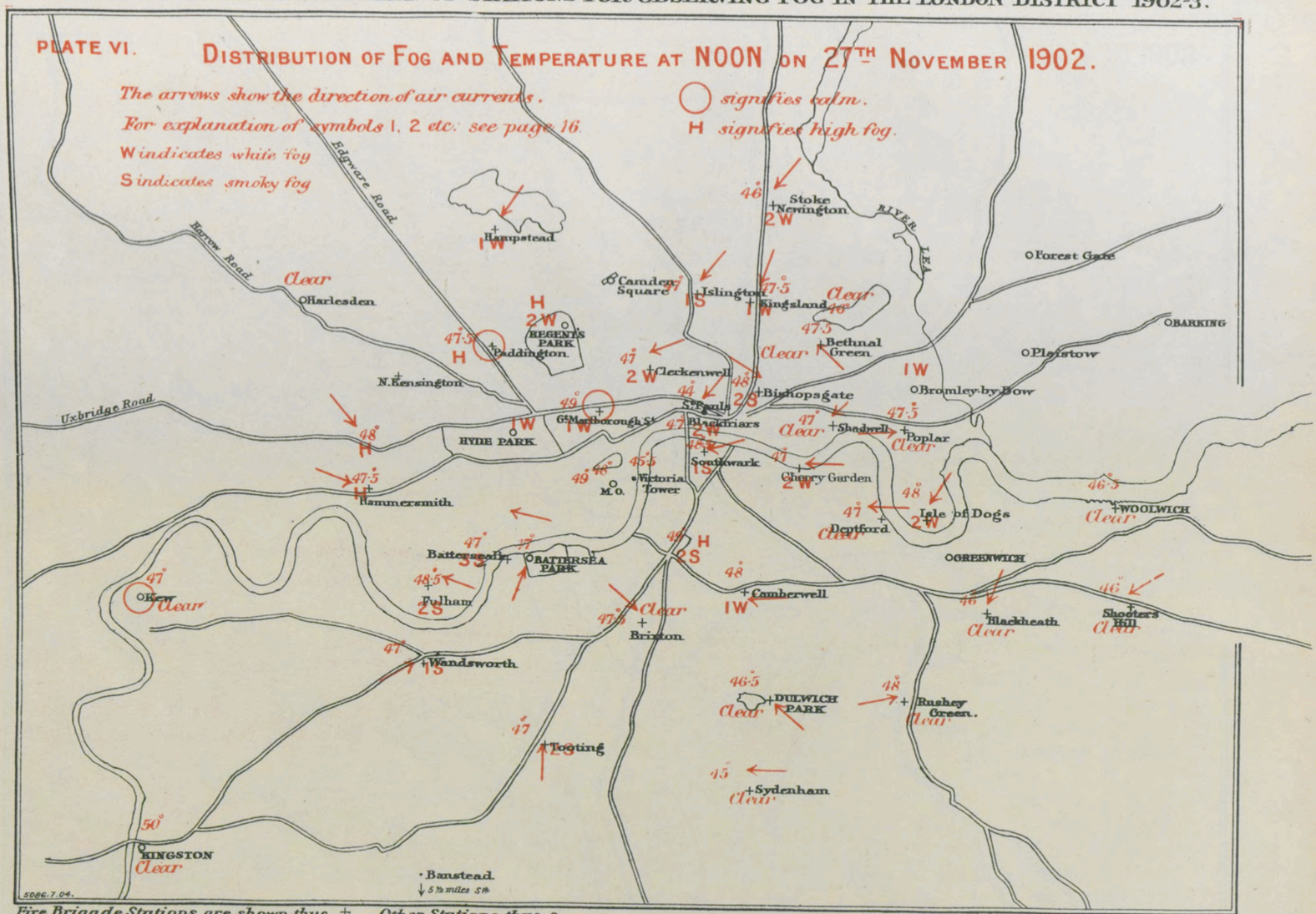
MAP SHOWING THE DISTRIBUTION OF STATIONS FOR OBSERVING FOG IN THE LONDON DISTRICT 1902-3.



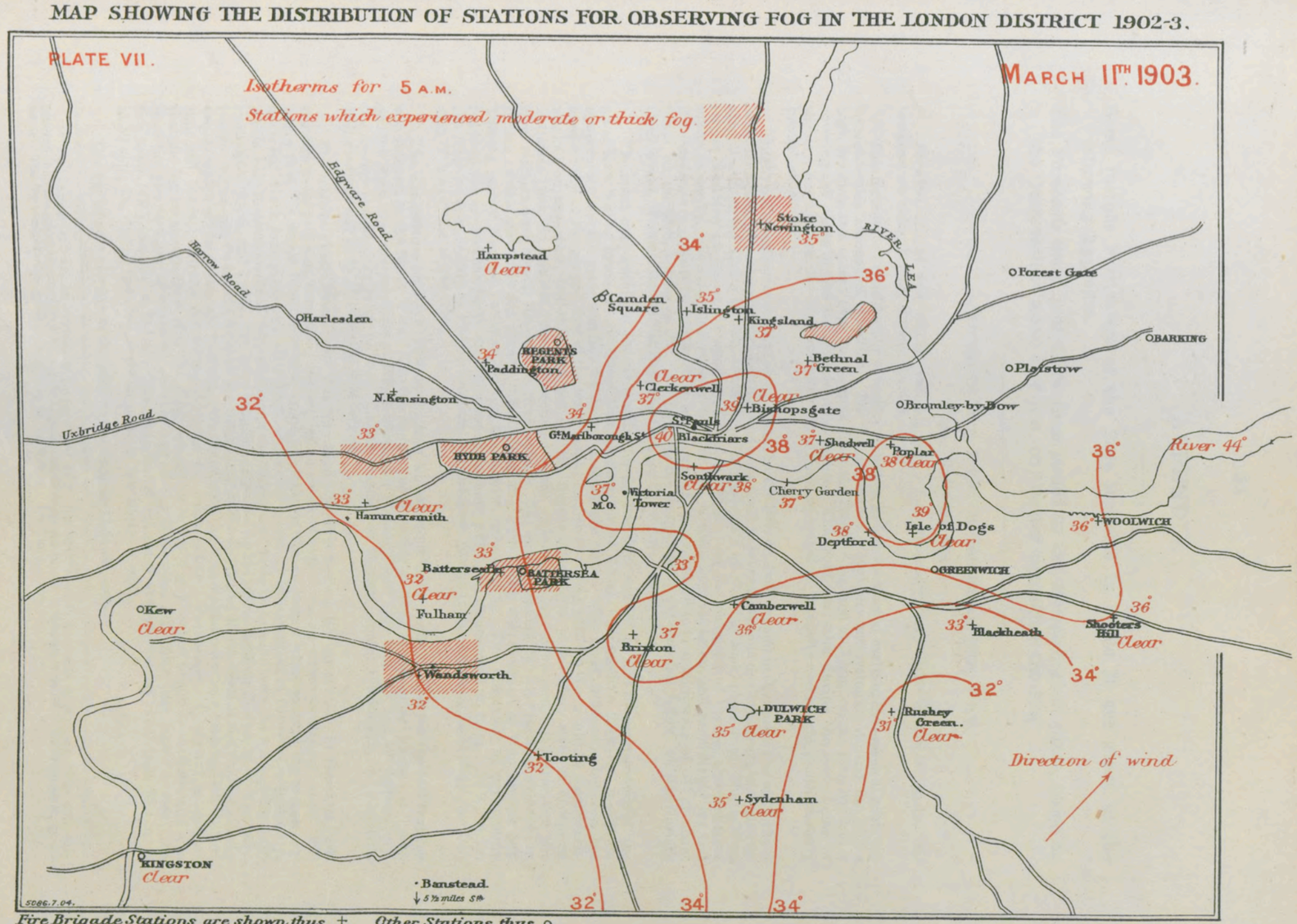
Fire Brigade Stations are shown thus + Other Stations thus ○

Weller & Graham Ltd Litho. London.

MAP SHOWING THE DISTRIBUTION OF STATIONS FOR OBSERVING FOG IN THE LONDON DISTRICT 1902-3.



MAP SHOWING THE DISTRIBUTION OF STATIONS FOR OBSERVING FOG IN THE LONDON DISTRICT 1902-3.



Fire Brigade Stations are shown thus + *Other Stations thus* o

Weller & Graham Ltd Litho. London.

APPENDIX.

Some further Particulars of the Fogs included in Table B. are given in the following Appendix.

The Forecasts there quoted are those issued by the Meteorological Office, based on the Observations made at 6 p.m. on the day preceding the Fog.

No. 1.—September 18th, 7 p.m., to September 19th, 1 p.m.

Type: Radiation Fog.

Forecast.—Light and rather variable airs; fine generally, very cold with mist early, but temperature rising briskly during the day.

This fog attained considerable intensity in places, and as it occurred early in the season it attracted a considerable amount of attention. The conditions were typically anticyclonic; during the 18th a high pressure area spread over our Islands from the South-West, and at 8 a.m. on the 19th we find it covering the whole of the British Isles and France. The wind was calm during the early hours of the day, but later on the high pressure over France increased in intensity and a light South-Easterly breeze set in.

Light white fog commenced at about 7 p.m. on the 18th on the river and in the parks, also at Clerkenwell, Islington, Wandsworth, and Tooting, and continued at several stations during the night. Shortly after 9 a.m. on the 19th a sudden increase in the intensity of the fog took place in the North-West (Great Marlborough Street, Islington, and Regent's Park), and the character of the fog changed from white to smoky. The cloudless state of the sky was favourable to radiation, and accordingly we find the temperature at Kew falling from a maximum of 59° on the 18th to a minimum of 37° at about 6 a.m. on the 19th, a drop of 22°. In London the temperature did not fall below 44° in Christ's Churchyard, Westminster, 40° at Regent's Park, or 38° at Camden Square.

The mean temperature of the river water for the two days was 58°, so that the temperature of the air at Kew was as much as 21° below that of the river at 6 a.m. At Regent's Park the minimum temperature on the grass was 34°, 24° below that of the river. This large difference between the temperature of the air and that of the water might lead us to expect that the fog would be particularly marked on the river, but this was not so; the fog remained light at all river stations excepting Battersea Park, its greatest intensity occurred at the stations already mentioned. It is true that the river stations were among the earliest to experience fog, but this cannot be construed as evidence in favour of the view that fog spread inland from the river. Fog was recorded at Wandsworth and Tooting earlier than at Battersea Bridge, the nearest river station. The difference of temperature between the air and the water was not great at the hour when fog commenced to form. At 9 p.m. on the 18th the temperature at Cherry Gardens and Battersea Bridge (both reporting light fog) was 53°, only 5° below that of the river.

The temperature readings show no features which throw light on the reasons for the fact that fog was thickest in the North-West. The fog showed no tendency to form in the coldest places: at 9 p.m. on the 18th the temperatures at Wandsworth and Tooting (light fog) were 48° and 49° respectively, the average temperature being 51°; on the other hand, at Rushey Green, Blackheath, and Shooter's Hill readings fell to 45°, but no fog was formed.

The relative humidity at 9 a.m. was very high (Camden Square, 100 per cent.). At Regent's Park the dew point at 9 p.m. was 44·5°; the minimum temperatures of the air subsequently fell to 40°, 4·5° below this. It would be of interest to know whether the change from a white country fog to a smoky town fog which took place soon after 9 a.m. was accompanied by a diminution of the relative humidity. As the only measurements of the humidity of the atmosphere made in London were the wet and dry bulb readings at 9 a.m. and 3 p.m., the observations unfortunately throw no light on this point.* The only feature which can be associated with the thickening of the fog in the North-West is the South-Easterly breeze which set in during the morning; unfortunately the inquiry had only been restarted for a short time and the opportunity for taking "special fog observations" was missed. It should be noticed that the fog became thickest after the wind velocity as recorded at Kew had begun to increase, and also after the temperature as recorded on the roof of the Meteorological Office had begun to rise; the minimum (43°) occurred at 6 a.m. The temperature remained almost constant at 54° from 10 a.m. to 11.30 a.m., *i.e.*, during the time of thickest fog in the North-West.

The fog lifted suddenly at the majority of stations at about noon.

* The readings at 9 a.m. at Regent's Park were Dry 44·0°, Wet 39·0°, relative humidity 65 per cent. The difference between the readings of the dry and wet bulbs is so great that it raises the suspicion that an error of 5° has been made in the latter. The fog is reported as having changed from "2 W." to "3 S." at 9.10 a.m.

No. 2.—September 20th, 3 a.m. to 10 a.m..

Type: Radiation Fog.

Forecast.—Easterly to South-Easterly winds freshening somewhat; very cold, with local mists or frosts early; warm and fine during the day.

The barometric conditions remained typically anticyclonic.

This fog was thickest in the South of London (Camberwell and Brixton (cf. No. 4), the North remaining clear; as the wind was South-East it forms an exception to the rule that the thickest fog occurs on the leeward side. The local differences of temperature were somewhat similar to those shown in Plate III., *i.e.*, warmest to the North of the river, and also at Sydenham and Shooter's Hill.

The minimum temperature at Kew fell 18° below that of the river, but, like its predecessor, this fog was not very marked on the river; it commenced at Camberwell and in the extreme West at midnight. At 3 a.m. fog began to form in the East as well. The thick fog, which was reported as white, not smoky, dispersed at 7 a.m., the hour at which the temperature commenced to rise at the Meteorological Office. Between 9 a.m. and 10 a.m. the fog cleared completely.

The relative humidity of the air at 9 a.m. was 97 per cent. at Camden Square and Regent's Park; at the latter station the minimum temperature 42° was 4° below the temperature of the dew point recorded at 9 p.m. on the 19th.

No. 3.—September 25th, 2 a.m. to 9 a.m.

Type: Radiation Fog.

Forecast.—Calm or light variable airs; cold at first, with local fog, then fine and warm.

Barometric conditions anticyclonic.

The gradient was for Northerly winds, and the fog was most pronounced near Camberwell, and Blackheath in the South. The difference between the minimum temperature of the air and that of the river was 16°, but the fog was not particularly marked on the river. The minimum temperature at Regent's Park fell 3·6° below the temperature of the dew point recorded at 9 p.m. on the previous evening, but at 9 a.m. the values of the relative humidity all lay between 74 per cent. and 87 per cent. The fog cleared at 8 a.m., the hour at which a rapid rise of temperature commenced at the Meteorological Office.

No. 4.—September 26th, Midnight to Noon.

Type: Radiation Fog.

Forecast.—Variable and light North-Easterly airs; fine generally, but local fogs in the early part of the day.

Barometric conditions anticyclonic.

The gradient was for North-Easterly winds, and the thickest fog occurred on the South side of the river. The local variations of temperature show some interesting points: Plate III. shows the distribution of temperature and the direction of the air currents at 9 a.m.; the stations which experienced moderate or thick fog on this day have been shaded over; and the isotherms for 55°, 53°, 50°, and 48° have been drawn. It will be seen that the readings were distinctly highest in the Northern and Central districts, and also at Sydenham and Shooter's Hill. All those stations which experienced serious fog lie to the South of the 55° isotherm, and most of them are also South of the 50° line. Blackfriars and Regent's Park are the only stations North of this line at which the fog reached the intensity "3." At both these stations fog commenced late (8 a.m.). Regent's Park is further remarkable as being the only station which reported the fog as smoky, everywhere else it was white. The isotherms for 5 a.m. (shown as dotted lines) bear a distinct resemblance to those for 9 a.m., but the differences of temperature were not so marked. The readings taken at 9 p.m. on the previous evening show that the temperatures were warmer in the North than in the South at this hour also.

The "special" observations taken at 9 a.m. show that Northerly to North-Easterly air currents prevailed at the warm stations in the North and also at Sydenham. The stations under fog reported South-Westerly to Westerly currents.

The Kew minimum temperature fell 18° below the river temperature; although this fog was thick on the river it did not commence there, Blackheath and Dulwich were the earliest stations to experience fog. At 9 a.m. the values of the relative humidity reported lie between 92 per cent. and 94 per cent. In Regent's Park the minimum temperature 42° was 7° below the temperature of the dew point observed at 9 p.m. on the previous evening.

No. 5.—September 27th, Midnight to 11 a.m.

Type: Radiation Fog.

Forecast.—Light variable airs; fine generally, but local fogs in the morning.

Barometric conditions anticyclonic. Relative humidities at 9 a.m., all between 94 per cent. and 97 per cent.

The gradient was for N.N.E. winds, and the fog occurred mainly in the South (Dulwich and Sydenham), the atmosphere remained clear in the North. The isotherms for 5 a.m. and 9 a.m. again show the highest readings in the North and centre of London (cf. Fog No. 4). The "special" observations show a general North-Easterly air current, but at Dulwich, where the fog was thickest, a distinct indraught is shown, very light airs from the South being reported. Sydenham unfortunately did not observe.

The temperature of the air at Kew fell 19° below that of the river water. Fog commenced in the South-East.

The fog cleared suddenly at 10 a.m. before an increasing wind and rising temperature.

No. 6.—October 6th, 6 a.m., to October 7th, Noon.

Type: Smoke Fog.

Forecast for 6th.—North-Easterly wind, light or moderate; cool, cloudy, some rain. (The request for special fog observations was not sent till 11 a.m. on the 6th.)

Forecast for 7th.—Variable to Westerly airs; milder, cloudy; misty or foggy locally, slight rain not improbable.

On the 6th London was situated in a very shallow trough of low pressure between "highs" over Spain and Norway respectively;* on the morning of the 7th minima of pressure had developed in the East and West, so that a typical "col" had formed over the South-East of England. There was no gradient over the London area at 8 a.m. on the 6th, but subsequently it became favourable for Westerly winds. The wind velocity as shown by the Kew anemographs was exceedingly small (almost a calm) on the 6th; on the 7th it increased rapidly after 8 a.m. Most of the fog had accordingly cleared away by 9 a.m., but at some stations in the South-East it lingered till noon. The "special observations" show light Westerly airs on both days, with a slight indraught towards the centre of London; the fog occurred mainly in the Eastern districts.

On the morning of the 6th there was much high fog in the West and South; at the Meteorological office the direction of drift of the smoke changed suddenly from North-West to South-West as darkness came on at 10.15 a.m.

On both days the diurnal range and the local variations of temperature were small, the readings remained very high, the minima recorded at Kew being 47° and 45° respectively.

The relative humidities recorded did not exceed 95 per cent., and for the most part the values were under 90 per cent. The conditions were, therefore, not particularly favourable to the formation of a true fog, *i.e.*, for the condensation of water on dust particles, and we may consequently regard this fog as a typical example of the 'smoke' fog of large towns. This view is confirmed by the fact that the fog was smoky at a large number of stations, though at many stations where its intensity was not great it was put down by the observers as a white fog.

Fog was also experienced in Brussels on the 6th.

No. 7.—October 8th, 6 a.m. to 11 a.m.

Type: Doubtful; classed as a Radiation Fog.

Forecast.—Light and variable to Easterly winds; mist or fog locally; fair as a whole, cool.

The barometric conditions were in this case not anticyclonic; London lay on the "col" between two shallow areas of low pressure. Under such conditions a clear sky is often observed, and the fog has consequently been classed as a radiation fog. The large range of 14° between the maximum temperature at Kew on the 7th and the subsequent minimum, and also the peculiar local fall of temperature associated with the local thickening of the fog described below are probably radiation effects. The thermograph at the Meteorological Office records an almost constant temperature of between 48° and 50° from 9 p.m. on the 7th to 7.30 a.m. on the 8th, so that it appears probable that in many parts of London the fog was a mere 'smoke' fog.

A very marked thickening of the fog took place in the South-West (wind N.E.) at Battersea, Tooting, Fulham, and Kew from 8 a.m. to 10.30 a.m. At 9 a.m. the "special" observations show a general North-Easterly air current, but light South-Easterly or Southerly airs were reported from the above-mentioned stations and also from Wandsworth.

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* *See* Plate II., Fig. (1).

At 9 a.m. the 48° isotherm separated these stations from the rest of London in which the readings were generally over 50°. The 5 a.m. observations show much greater uniformity; at most stations they were slightly lower than the 9 a.m. readings, but at the stations where fog was experienced the reverse was the case; a fall of temperature occurred between 5 a.m. and 9 a.m. in these districts.

At 5 a.m. there were no indications of the great thickening which was to occur subsequently at the South-Western stations, except perhaps the gradient for North-Easterly winds.

The relative humidities at 9 a.m. were :—

Camden Square ...	... 86 per cent. ...	... clear ...	... Dry bulb, 50°.
Regent's Park ...	... 80 per cent. ...	... clear ...	... Dry bulb, 51°.
Kew Observatory	... 93 per cent. ...	... thick fog ...	... Dry bulb, 43°.

No. 8.—October 11th, 7 a.m. to 1 p.m.

Type : Cloud Fog.

Forecast.—Wind variable between South-East and South-West or West; changeable, showery, mild.

On the evening of October 10th, storm warnings were still displayed on the South-East coast of England, and though a gale was no longer expected, it was not considered safe to lower the cones, thereby indicating that all danger had passed away. From this it is clear that the forecaster expected the wind to remain too strong for fog to form.

This fog is an example of the 'cloud' type. On the morning of October 11th London was on the North-East side of a shallow depression over the Channel,* and a second very shallow "low" lay over Scandinavia, the "col" between the two low pressure areas being over the North Sea. The gradient was for winds from the South-East. The Kew anemogram shows a velocity of over 6 miles an hour all day except between the hours of 9 a.m. and 10 a.m., when it fell to between 4 and 5 miles an hour; after noon it freshened to over 10 miles an hour. The wind being South-Easterly in direction, the fog was most pronounced in the North-West. The minimum temperature at Kew was 54°. The temperatures on the roof of the Meteorological Office and on the towers were lower than those recorded in Christ Churchyard; the local differences of temperature were small. Drizzling rain fell at intervals, and the relative humidity was high (values between 95 per cent. and 99 per cent.). Thick high fog was experienced for a short time about noon at most stations.

No. 9.—October 18th, 7 a.m. to 11 a.m.

Type : Smoke Fog.

Forecast.—South-Westerly to Westerly or North-Westerly winds, fresh or strong at times (fog, therefore, regarded as impossible), changeable, some showers, temperature rising rapidly.

An unusual type of pressure distribution; London was near the centre of a shallow secondary cyclonic system which moved away to the South-East during the day. Calm was recorded at Brixton at 8 a.m., but later on the wind became North-East; the fog remained light and occurred mainly in the South-West and West. Wandsworth and Tooting report it as being smoky, elsewhere it was entered as a white fog. Rain set in as the fog cleared.

The range between the previous day's maximum and the minimum temperature experienced during the night was as much as 9°, but the minimum occurred as early as 10 p.m., subsequently to this hour the local variations of temperature were small. The minimum temperature at Kew was 44°. At 9 a.m. the values of the relative humidity lay between 94 per cent. and 99 per cent.

No. 10.—October 19th, 1 a.m. to 1 p.m.

Type : Radiation Fog.

Forecast.—Wind shifting to West or South-West; fair with low mists at first; less settled later; temperature unsteady, low in the morning.

At 8 a.m. London was on the axis of a wedge of high pressure extending Northward from an anticyclone over Spain. There was consequently no gradient and the atmosphere was calm; during the morning a South-Westerly air current which increased rapidly in velocity after 1 p.m. set in.

The barometric conditions were favourable for radiation, and the records from Greenwich report a cloudless night, so that this fog must be looked upon as a radiation fog. The minimum temperature at Kew (35°) fell 16° below the maximum experienced on October18th. At the time of occurrence of this minimum there was a difference of 17° between the air temperature and that of the river water The fog was thick on the river and in the parks, and in some other localities irregularly distributed

* *See* Plate II., Fig. 2.

(Islington, Tooting, Dulwich, Harlesden). The temperature observations show that the air was warmest in the North-West, both at 5 a.m. and at 9 a.m., but no connexion can be traced between the temperature and the distribution of fog. Islington, which reported thick smoky fog (intensity 4) from 8.30 a.m. to 10.45 a.m. was near the centre of the warm area. Regent's Park shows a similar state of affairs. The wind was South-Westerly, and also affords no explanation of the distribution of fog.

The hours of commencement of the fog at different stations varied greatly throughout the night. The thickest fog occurred between 6 a.m. and 10 a.m. At 11 a.m. it had cleared generally, but fog still prevailed at some stations in the extreme South-West. At 1 p.m. the fog had dispersed completely in consequence of a rapidly increasing wind and rising temperature.

No. 11.—October 23rd, 5 a.m., to October 24th, 11 a.m.

Type : Radiation Fog.

Forecast for 23rd.—Westerly or North-Westerly winds moderate or fresh; cloudy, local showers (fog, therefore, regarded as improbable).

Forecast for 24th.—Light breezes, chiefly South-Westerly; fair generally, but local fog in the morning.

This fog which lasted for two days has been classed as a radiation fog; on both days London lay on the boundary of an anticyclone, and the Greenwich records show that the nights were partially clear. The temperature remained high (minima 41° and 45° respectively), but the relative humidity was great; in both cases the minima recorded in Regent's Park were 4° below the dew point measured at 9 p.m. on the previous evening.

The fog was light on both occasions; on the 23rd it occurred mainly in the East, the wind being South-Westerly; the local differences of temperature were small. On the 24th the fog was limited to the Western half of London, in which the temperature readings were 48° or 49° at almost all stations. In the Eastern half of London, which remained clear of fog, the readings varied between 50° and 53°. The readings taken at 5 a.m. (at which hour the fog was limited to four stations) show a preponderance of high temperature in the North-East. As the wind was still from W.S.W. this fog furnishes another case in which the thickest fog and the lowest temperature occurred on the windward side. (cf. Nos. 2, 13).

No. 12.—October 27th, 10 p.m., to October 28th, Noon.

Type : Radiation Fog.

Forecast for 28th.—Light breezes, chiefly Westerly, mild and dull, slight rain in places.

The isobaric conditions were very complex. A ridge of high pressure extended North-Eastward from the Bay of Biscay and from this a secondary wedge of high pressure protruded over London. The conditions have been regarded as in the main anticyclonic, and the fog has been classed as a radiation fog. The weather at 6 p.m. was bright, and there was a difference of 15° between the minimum at Kew and the maximum of the previous day. The minimum temperature was high, 40°, but the relative humidity was also high. (Dew point in Regent's Park at 9 p.m. on 27th, 46°; minimum temperature, 40°.) The local differences of temperature were small and show no special features of interest. The special observations show a general Southerly current at 9 a.m., but at Islington and Brixton, where thick fog was experienced, light airs from the North were reported. The same was the case at Kingsland and Camberwell, where no thick fog was observed. The fog remained white at all stations.

No. 13.—October 29th, 2 a.m. to 11 a.m.

Type : Radiation Fog.

Forecast.—Variable and light Southerly airs; cloudy, with mist or fog in most places.

An anticyclone in which the highest pressures were to be found over Russia extended Westward over Europe. The wind was South-Easterly both by the gradient and by observation. The 'special' observations show a slight indraught towards the centre at the stations on the North-East side.

Moderate fog occurred in many localities, but in the North-West, *i.e.*, on the leeward side, it remained comparatively clear, with the exception of a short spell of moderate fog in Regent's Park from 8 a.m. to 9 a.m.

The temperature observations show that this district of generally light fog remained warmer than the rest of London. At 9 a.m. the 48° isotherm enclosed the stations in the North-West, and separated them from the cooler surrounding districts. A similar distribution of temperature was shown at 5 a.m. The

relation between the fog and the temperature is here somewhat analogous to that shown in Plate VII., (cf. also Nos. 2 and 11). The fog was reported as white in all cases.

The relative humidity was very great; at 9 a.m., all stations reported values of 99 per cent. or 100 per cent. This is probably the reason why the fog attained the density it did in spite of the fact that the temperature sank no lower than 44° at Kew; Regent's Park, minimum, 44°; dew point at 9 p.m. on the 28th, 48°.

No. 14.—October 30th, 7 a.m. to 11 a.m.

Type: Radiation Fog.

Forecast.—Light breezes, chiefly Southerly; some fog in the morning, then fair; cooler.

Light white fog; relatively high wind from South-West or West. No fog was recorded in the South-West or West.

The temperature readings show no points of interest.

No. 15.—October 31st, 2 a.m. to Noon.

Type: Radiation Fog.

Forecast.—North-Westerly winds, light; fine generally, cooler.

The 'special' observations show a general Westerly current (gradient from the North-West) and the fog was most pronounced in the East.

Moderate fog was reported from Willesden and North Kensington in the North-West; at the latter station the wind was Southerly and not Westerly. The temperatures were highest in the East, but show no special points of interest.

No. 16.—November 1st, 7 a.m. to Noon.

Type: Doubtful; classed as a Smoke Fog.

Forecast.—Westerly winds freshening; mild, cloudy, some rain.

A light fog mainly in the East; wind Westerly. Temperatures were very uniform over London, and the difference between the minimum at Kew and the maximum of the previous day was small (7°). Relative humidities at 9 a.m. lay between 94 per cent. and 96 per cent.

The classification of this fog is doubtful. It cannot be included in any of the three main types of fog mentioned on p. 26, and it has therefore been assumed that it was due to the accumulation of smoke and dust in an almost calm atmosphere. As it was very light, it was entered as a "white" fog at all stations. As a general rule smoke fogs were thus recorded when they remained very light; observers did not use the symbol "S" until the smoky character became very pronounced.

No. 17.—November 3rd, 5 a.m., to November 4th., 9 a.m.

Type: Radiation Fog.

Forecast for 3rd.—Based on observations at 6 p.m., November 2nd.—Variable breezes, finally South-Westerly; cold in morning with local fogs, then fair and mild.

Forecast for the 24 hours ending Noon, November 4th.—Based on observations at 8 a.m. on November 3rd.—Light breezes, chiefly South-Westerly; mild, fair generally, but misty in places.

Forecast for 4th.—Based on observations at 6 p.m. on November 3rd.—Calms, or light variable airs; cooler, fair as a whole, but fog or mist locally.

In point of intensity this was the worst fog of the year. Thirty-eight stations reported fog; of these 28 recorded moderate and 11 thick fog. Unfortunately the thickest fog occurred between 9 p.m. on the 3rd and midnight, so that only the 9 p.m. temperature readings were taken during the prevalence of thick fog.

On November 3rd an anticyclone lay over the continent of Europe; its centre was over Hungary, and a wedge of high pressure extended Westward over the Channel. During the night the wedge travelled in a North-Eastward direction, and at 8 a.m. on the 4th it extended over the North Sea.

The wind was almost calm all day on the 3rd; the slight gradient favoured Westerly winds. As the wedge passed over London a change in the wind direction must have occurred, for the map for 8 a.m. on the 4th shows a light South-Easterly breeze.

Light white fog commenced at 5 a.m. on the 3rd at a few stations irregularly distributed, and continued during the day. A few light showers occurred occasionally, and these had the effect of rendering the atmosphere very damp.

At 3 p.m. the 'special' observations show a general Westerly air movement with a slight indraught at the Eastern stations, several of which reported light fog. The temperatures recorded at this hour were for the most part between 50° and 53°. During the afternoon a fall of temperature set in in the outlying districts. At 9 p.m. we find the 48° isotherm enclosing a small area in the centre of London, and the 45° line forming an approximate circle with Hammersmith and the Isle of Dogs at opposite ends of a diameter; at Kew and Blackheath the temperature had fallen to 41°. Small as this fall of temperature was, it was sufficient to cause the formation of much fog of a very smoky character in the damp atmosphere prevailing.

At 9 p.m. the thick fog appears to have been confined mainly to the parks and to the East and North-East.

About 10 p.m. thick fog spread further Westward and developed independently in the South-West. At Hammersmith, Fulham, Blackfriars, Great Marlborough Street, and Southwark, the intensity did not get beyond "2." At Kingston and North Kensington the air remained clear. The reason for the comparative lightness of the fog at these stations is not apparent; perhaps the temperature did not fall sufficiently low; in the churchyard at Westminster the minimum was as high as 43° (Regent's Park 40°, Camden Square 39°). The temperature of the river water was 50°.

The fog began to disperse at 3 a.m., and at 5 a.m. only two stations still reported moderate fog; at 9 a.m. it had dispersed entirely. Unfortunately lack of observations at 3 a.m. makes it impossible to study the conditions which caused the fog to clear: the wind velocity at Kew increased at 1 a.m. to an average of four miles per hour, but it was not till 9 a.m. that any conspicuous increase of velocity took place; and the temperature at the Meterological Office did not commence to rise till 5 a.m.

The relative humidities reported at 9 p.m. were between 93 per cent. and 99 per cent. The dew point at Regent's Park at 3 p.m. on the 3rd was 46° (minimum temperature 40°).

The minimum temperature on the roof of the Meteorological Office was only 1° higher than that recorded in the churchyard. At 9 p.m. the temperature on the Victoria Tower was 4° higher than that in Kennington Park.

The great intensity of this fog appears to have been due to a combination of great humidity and a rather sudden fall of temperature in an almost stagnant atmosphere. It is one of those cases which it is impossible to forecast in the present state of our knowledge of general meteorology. The accident that the sky would clear in the neighbourhood of London just about the hour of sunset and allow of a rather rapid decrease of temperature at a time when conditions were most favourable to the formation of fog, could not be foreseen by a forecaster. The forecast on the observations taken at 8 a.m. (see above) contain no more serious warning than "misty in places"; this much was to be expected, as there were no signs of any increase in the wind velocity.

No. 18.—November 5th, 6 a.m. to 4 p.m.

Type: Cloud Fog.

Forecast.—Strong winds or gales, mainly from South-East; squally, cloudy or dull; becoming rainy. (Fog was regarded as impossible, as a high wind was anticipated.)

A light white fog, irregularly distributed. Minimum temperature at Kew, 44°. Drizzling rain commenced at about 1 p.m. Wind velocity relatively high, 10 miles an hour.

No. 19.—November 12th, 6 p.m., to November 13th, Noon.

Type: Radiation Fog.

Forecast.—Wind backing to South-West or South; fair at first, less settled and probably some rain later in the day, continuing mild.

The wind velocity was left doubtful; the decrease of velocity was not expected. "Continuing mild" seems to indicate that the forecaster expected the sky to remain overcast: fog was therefore not anticipated.

This was a typical radiation fog and shows some conspicuous differences of temperature over the London area. An anticyclone was situated over the Eastern part of the Continent of Europe, and from it a wedge of high pressure extended Westward towards England.

November 12th was a dull day, with slight rain in the morning. At 3 p.m. the temperature was extremely uniform over London, almost all the readings being between 53° and 56°. Towards evening the sky cleared in places (*see* Greenwich record, Table B., column 22), and a fall of temperature commenced; at 5 a.m. on the 13th, we have a difference of 15½° between Kew Observatory, 32°·4, and Bishopsgate Fire Station, 48°. Plate V. gives the lines of equal temperature and the distribution of fog at 9 a.m. on the 13th. The 44° isotherm bounds a warm area which extended southward from the central parts of London so as to include Camberwell, Dulwich, Sydenham, and Tooting. Within this area lie two smaller regions bounded by the 48° isotherm, one in the centre, the other stretching from Dulwich to Camberwell. The temperature was also high at the elevated station Shooter's Hill. At the outlying stations in the West, North-East and South-East it was below 40°. The moderate or thick fog was limited in the main to the cold regions in the West and North-East. The fog in the North-East spread to Bishopsgate at 7.40 a.m. in spite of the high temperature recorded there. (The exposure was not very good, and possibly the reading is somewhat high.) Moderate fog was also recorded at Blackfriars on the river. (Temperature of the river, 49°; Blackfriars, 45°.) No fog was recorded at Rushey Green and Blackheath, in spite of the fact that low temperatures were observed there.

The isotherms and fog distribution for 5 a.m. are given in Plate IV.; the general features of the distribution of temperature at 9 a.m. are distinctly foreshadowed.

The relative humidities at 9 a.m. were :—

—	Relative Humidity.	—
	Per Cent.	
Camden Square	100	Fog.
Kew Observatory	93	Fog.
Regent's Park	82	Clear.
Meteorological Office	86	Clear.

A considerable inversion of the normal temperature gradient occurred on this occasion. The minimum temperature recorded on the roof was 3° above that recorded in the churchyard. At 9 p.m. and also at 5 a.m., the temperature on the Victoria Tower was 10° above that recorded at Kennington Park, when a large and probably very local fall occurred. Compared with Southwark and Blackfriars, the differences were much smaller; at 9 p.m. the Tower was 2° colder than these stations, at 5 a.m. it was 3° warmer than Blackfriars and at the same temperature as Southwark.

The wind direction was South-Westerly; in this case, moderate fog occurred both on the windward and on the leeward side; but, whereas the fog on the former was of the white variety, that met with on the Eastern or leeward side was markedly smoky at all stations except those near the river.

The thick fog began to lift at 10 a.m. as the temperature rose, and at 11 a.m. it had all dispersed. By 11.30 a.m. the light fog had also cleared away.

No. 20.—November 14th, 5 a.m. to 5 p.m.

Type : Radiation Fog.

Forecast.—Light South-West or South winds; colder with local fogs or mist early; milder and mostly fair later.

The isobaric conditions were very similar to those which prevailed on the previous day (No. 19). A low minimum temperature (36°) was again recorded at Kew, but at Westminster the temperature did not fall below 47°. The river temperature was 50°.

The temperature observations at 5 a.m. and 9 a.m. show similar features to those of the 13th (Plates IV. and V.); the readings were again highest in the centre and South, but the differences were not so pronounced. The wind was again between South-West and South. The moderate fog, which was white in character, was on this occasion limited to the river (Blackfriars) and to a group of stations in the North-East, Islington, Kingsland, Stoke Newington, and Bethnal Green. At these stations the 'special' observations taken at noon show a well marked indraught towards the centre. The greatest fog intensity was attained between the hours of 7 a.m. and 11 a.m. The process of clearing was a very gradual one; it was not till 5 p.m. that London was clear of fog.

The relative humidity at 9 a.m. was 92 per cent. at Kew and Regent's Park, where the fog was light. At Camden Square, near the area of thick fog, saturation was reached.

No. 21.—November 15th, 7 a.m. to 2 p.m.

Type : Radiation Fog.

Forecast.—Calm or light airs from some Easterly point; fair, but fog or mist in many places; temperature falling.

Light white fog at 12 stations, mainly in the North-West, lasting from 7 a.m. to 2 p.m., at which hour the wind freshened considerably. The 'special' observations show South-Easterly or Easterly air currents at most stations, but in the North-West the smoke drifted from a North-Easterly, or in some cases a North-Westerly, direction. Temperature remained high (42° at Kew); the river temperature was 48°.

The local variations of temperature were small and showed no regularity.

No. 22.—November 21st, 7 a.m. to 2 p.m.

Type : Smoke Fog.

Forecast.—Easterly winds, freshening; fair generally, temperature remaining low.

Light fog at 17 stations, mainly in the South-West, where the fog was reported as being of a smoky character; wind North-East.

The local variations of temperature were small and showed no regularity.

The relative humidities recorded at 9 a.m. were all under 80 per cent., with the exception of Regent's Park, where 89 per cent. was reached.

No. 23.—November 23rd, 7 a.m. to 7 p.m.

Type : Cold Surface Fog.

Forecast.—South-Westerly winds, moderate to fresh; weather becoming brighter and much milder, but showers probable.

This fog occurred unexpectedly. The weather was of a "Westerly" type; a ridge of high pressure extended from Spain into France, and a depression was passing along our North-West coasts. Under these conditions the wind usually remains too strong for the formation of fog, but on this occasion it fell to under 4 miles an hour during the night and remained at this velocity till noon. A slow and somewhat irregular rise of temperature was in progress, and it is probable that the fog was caused by a warm South-Westerly air current passing over the ground, which was still cold. (Regent's Park minimum on grass 30°.) The fog, which was white in character, occurred mainly in the West and South-West; as the wind was Westerly this is another case of the most marked fog occurring on the windward side. Thick fog was reported from Paddington and Battersea Park between 8 a.m. and 10 a.m. About this time a temporary fall of temperature was recorded on the roof of the Meteorological Office.

The local differences of temperature were small and do not show any specially cold readings on the foggy windward side, as is the case in Nos. 2, 11, and 13.

The relative humidities at 9 a.m. were between 95 per cent. and saturation. The minimum temperature at Regent's Park, 36°, was 2° above the dew point at 9 p.m. on the 22nd (34°). The weather was cloudy, and slight rain fell at intervals.

No. 24.—November 24th, 1 a.m. to 1 p.m.

Type : Radiation Fog, becoming a Cold Surface Fog, and finally a Cloud Fog.

Forecast.—Wind backing to South and increasing in force; fine at first, but becoming squally and rainy later; continuing mild.

Like its predecessor on the 23rd, this fog also occurred quite unexpectedly. The isobaric conditions were somewhat similar to those which prevailed on January 19th (cf. Plate II., Fig. 4). A "low" lay to the West of Ireland, and caused strong winds in the West of England, but further East the gradient remained slight, and the velocity of the wind at Kew was under 3 miles an hour all night. After 6 a.m. a freshening wind from the South set in and attained a velocity of over 11 miles per hour by 9 a.m.

The temperature at Kew had risen to 50° during the afternoon of the 23rd, but a gradual fall set in subsequently. Shortly after 1 a.m. this fall became more rapid, and light fog commenced at a number of stations. It is, therefore, probable that this fog commenced as a radiation fog. The minimum temperature in Regent's Park was 5° below the dew point recorded at 9 p.m.

The rise of temperature and freshening Southerly wind which set in about 6 a.m. were accompanied by a marked increase in the intensity of the fog, which, however, remained white on the North side of the river, where eight stations reported fog of intensity "3" or more between 7 a.m and 9 a.m. In its second stage this fog affords a good example of condensation occurring when warm air comes in contact with a cold surface. At 9 a.m. the thickness of the fog decreased at many stations simultaneously, but it was not till 1 p.m. that the North-West of London was clear of fog. Frequent rain fell during the day, and the fog in its final stages must be classified as a "cloud" fog.

The local variations of temperature show no features of special interest and offer no explanation of the great thickening of the fog reported from Paddington.

No. 25.—November 27th, 7 a.m. to 5 p.m

Type: Smoke Fog.

Forecast.—Light variable breezes; cloudy, some fog or mist; cooler.

This fog affords an example of a typical smoke fog. At many stations it was reported as being of a smoky character. The temperature remained high and the range was small; the local variations of temperature were small and irregular. Though only light, it shows the dependence of the distribution of fog on the direction of drift of the air in a striking manner. At 8 a.m. a light easterly wind is recorded in the Daily Weather Report, and at 9 a.m. the 'special' observations still showed a distinct Easterly air current. Light fog was recorded at most stations in the West at this hour. From 11 a.m. to 1 p.m. the pressure tube anemogram at Kew shows a dead calm; the special observations taken at noon show the most complete case of indraught towards the centre of London that has hitherto been observed. Plate VI. gives the direction of the air currents recorded at the Fire Brigade Stations at this hour. At 3 p.m. the 'special' observations showed a general South-Westerly drift of the air, but some of the stations in the North-East still reported North-Easterly currents. The fog at this hour was all to be found in the East.

The change in the wind direction was accompanied by much high fog in the West between 10 a.m. and 2 p.m.

No. 26.—November 30th, 7 a.m. to 10 p.m.

Type: Cloud Fog.

Forecast.—Easterly winds, strong, a gale on coast, dull, squally, some rain; cooler.

London lay between a "low" over the Bay of Biscay, and a "high" over Scandinavia, but the conditions were distinctly cyclonic.

The wind velocity at Kew remained relatively high (over 12 miles an hour till 2 p.m., at which hour it fell to eight miles an hour), though the strong winds anticipated in the forecast did not occur.

The minimum temperature on the roof was 2° below that recorded in the churchyard. The range between the minimum temperature and the previous day's maximum and the local variations of temperature were small. The temperature remained high (minimum at Kew 46°). Drizzling rain occurred at intervals during the day. The fog was most pronounced in the West and South-West, the wind being Easterly.

No. 27.—December 1st, 5 a.m. to 4 p.m.

Type: Smoke Fog.

Forecast.—Variable and light Easterly airs; cloudy with fog or mist in many places.

The 8 a.m. map shows London on the "col" between a deep depression off the West of Ireland and a secondary off the Dutch coast.

The minimum temperature was high (Kew 44°), and the range between the minimum and the maximum on the previous day was only 4°. The local differences of temperature were also small and irregular.

Fog was reported from 27 stations; at Hampstead and Stoke Newington the intensity "3" was attained between the hours of 11 a.m. and noon. Moderate fog was also experienced at Deptford.

The wind, which was Southerly, remained under three miles an hour till noon, when it increased rapidly.

The relative humidities were between 96 per cent. and 98 per cent. The fog was generally regarded as a white fog by the observers, but at Islington and Hampstead it was smoky.

No. 28.—December 3rd, 2 a.m. to 2 p.m.

Type: Radiation Fog.

Forecast.—Wind backing to South-West or South, and subsequently veering again, fresh or strong, perhaps a gale in places; unsettled, rain in places; temperature changing but little.

As strong winds were anticipated, fog was regarded as out of the question.

Light fog at 30 stations, high fog at six.

The distribution of pressure was very complex. The South-East of England was under the influence of a "low" over the Bay of Biscay, which caused a North-East wind which increased rapidly in velocity after 9 a.m. This wind produced a sharp fall of temperature during the day, with the exception of a temporary rise from 47° to 51° between 8 a.m. and 11 a.m. Much high fog occurred during the morning.

No. 29.—December 12th, 7 a.m. to 11 p.m.

Type: Smoke Fog.

Forecast.—Wind shifting towards South-East, light or moderate; fair as a whole, but fog or mist in some localities inland; becoming milder.

Light fog at 22 stations, mainly in West and North-West. Wind South-East to South.

The local variations of temperature were small, and the difference between the minimum temperature and the maximum of the previous day was only 4°. The relative humidity was also low:—78 per cent. at Regent's Park at 9 a.m.

No. 30.—December 22nd, 7 a.m. to 5 p.m.

Type: Smoke Fog.

Forecast.—Wind backing towards West, but remaining light; fair generally, but much cloud; mist or fog in places; mild.

Light fog at 22 stations.

The conditions were typically anticyclonic, and might consequently be supposed to be specially favourable to the formation of fog. The sky however remained overcast, and the temperature remained high; the range between the minimum and the previous day's maximum was only 3°, and very little fog formed.

The relative humidities observed at 9 a.m. were between 93 per cent. and 99 per cent. The dew point at 9 p.m. on the 21st in Regent's Park was 46°; the minimum temperature was also 46°.

The fog occurred mainly in the West; it remained clear both North and South. As the wind was Northerly, it is not possible to refer the fog either to the leeward or the windward side.

No. 31.—January 1st, 7 a.m. to Midnight.

Type: Radiation Fog.

Forecast.—Wind backing to South-West, light or moderate; fair and cold with local mist or fog; then becoming milder and less settled.

The distribution of pressure was again very complex.

The fog occurred mainly in the East, and was most pronounced between noon and 10 p.m. The gradient was for Westerly winds.

A considerable inversion of the normal temperature gradient occurred towards evening. At 9 p.m. the reading on the roof of the Meteorological Office, 42°, was the highest recorded in London. That recorded on the Victoria Tower was also high, 40°. Observations were not made in the churchyard at 9 p.m., so that we have no readings available from the immediate neighbourhood for making a comparison (Blackfriars 39°, Southwark 38°).

No. 32.—January 5th, 5 a.m. to 11 a.m.

Type : Cloud Fog.

Forecast.—South to South-West or Westerly winds, fresh or strong generally, a gale in places ; squally, rainy, temperature changing fitfully.

A cloud fog, showing the typical features of this class of fog :—

(1.) A relatively high wind velocity (15 miles per hour after 7.30 a.m.).

(2.) A high minimum temperature (44° at Kew).

(3.) Absence of any signs of temperature inversion ;—the readings on the Victoria Tower were 2° below those in Kennington Park.

(4.) A small range between the minimum temperature and the maximum of the preceding day (2°).

(5.) Small local variations of temperature.

(6.) Great relative humidity. At 9 a.m. saturation was attained at Camden Square and Regent's Park.

No. 33.—January 8th, 7 a.m. to 5 p.m.

Type : Radiation Fog.

Forecast.—Wind chiefly Westerly, moderating ; fair as a whole ; colder (no fog anticipated, as the wind was expected to remain too strong).

This fog was mainly interesting on account of the thick high fog which occurred in the West.

The distribution of pressure at 8 a.m. is given in Plate II., Fig. 3. The wedge of high pressure shown over the South-East of England was advancing eastward, with a "low" following it. The night had been clear and the temperature had consequently fallen considerably. The minimum at Kew was 35°, 16° below the previous day's maximum.

At 7.30 a.m. the wind dropped almost to a calm, and light fog formed at a number of stations in the East, the drift of the air being from the West (Meteorological Office observation of smoke drift).

At 11 a.m. the barometer, which had been rising slowly, reached a maximum—indicating that the axis of the wedge had reached London—and a fall set in. At the same time the direction of the smoke drift changed to the South-East ; high fog began to form in the West immediately after, and in a short time the darkness became so intense that traffic was considerably hindered. This was particularly noticeable in thoroughfares such as Whitehall, where there are no shops to provide artificial light ; as the fog came on very suddenly the street lamps had not been lighted, and most vehicles were unprovided with lights. There was very little surface fog ; the light from lamps was only slightly obscured.

Many stations in the South-West reported surface fog of intensity "2" about noon. Rain came on about 1 p.m. as the "low" in the West advanced, and the fog dispersed. Some inversion of the normal temperature gradient occurred during the early hours of the morning. The minimum temperature on the roof of the Meteorological Office was 2° higher than that recorded in the churchyard, and at 9 a.m. a similar difference was shown by the readings. At this hour the thermometer on the Victoria Tower recorded a temperature 5° above that observed in Kennington Park.

No. 34.—January 18th, Midnight to January 21st, 9 p.m.

Type ; Cold Surface Fog.

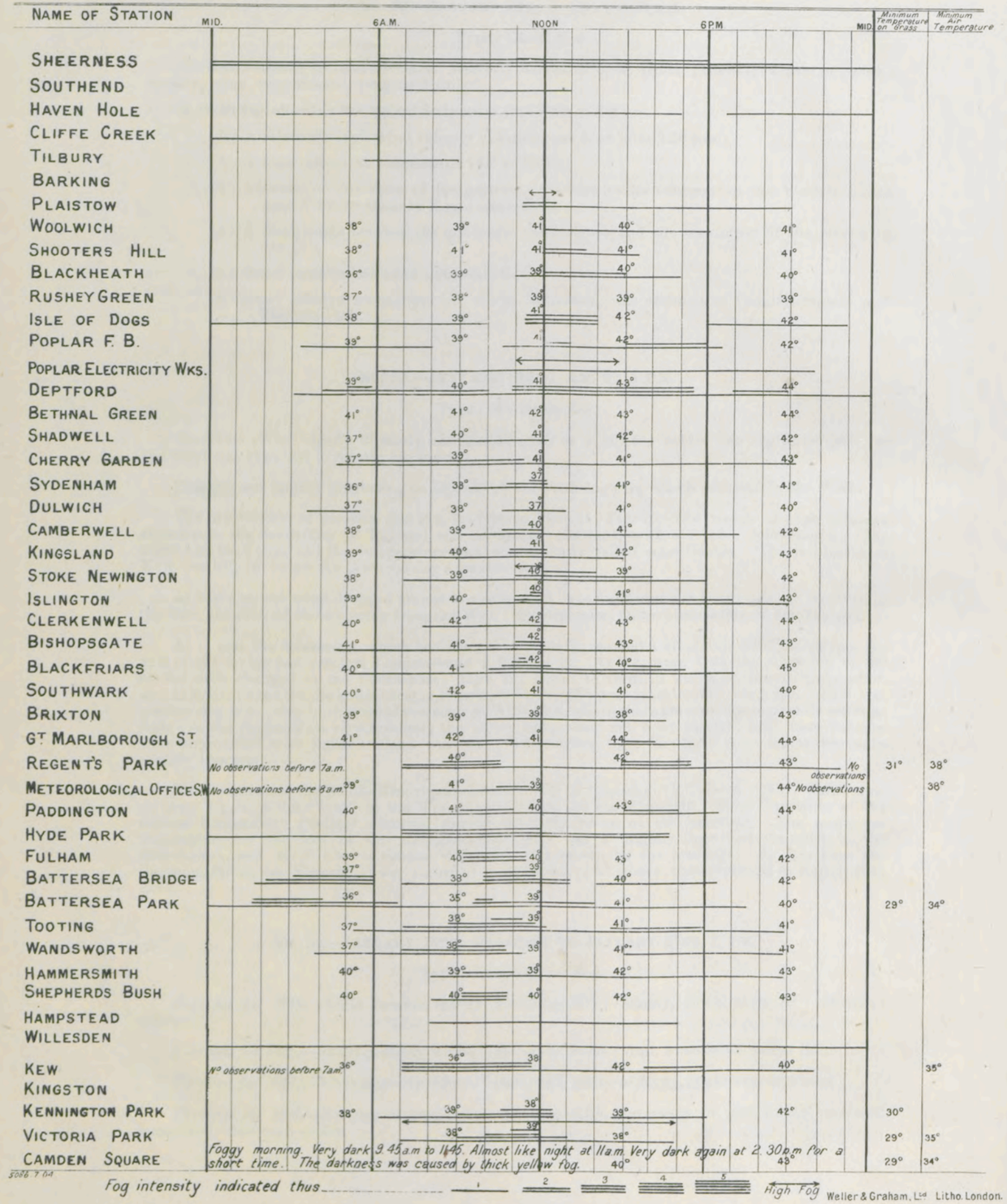
Forecast for 18*th.*—Light breezes, chiefly South-Easterly ; cloudy, some sleet or cold rain ; milder.

Forecast for 19*th.*—South-Easterly winds, light or moderate ; dull, some rain ; rather milder.

Forecast for 20*th.*—South-Easterly winds, light ; dull, misty or foggy, slight rain in places.

Forecast for 21*st.*—Easterly winds, light ; fair generally, but misty in places ; air becoming temporarily drier and cooler.

Plate VIII. SUMMARY OF THE OBSERVATIONS OF TEMPERATURE AND FOG MADE ON JANUARY 21ST 1903.



3086 Y 04 Weller & Graham, Ltd Litho. London.

This fog occurred at the close of a period of sharp frost, during which no fog had formed as the atmosphere was very dry and a moderate wind prevailed throughout. The distribution of pressure, the chief features of which remained constant while the fog lasted, is shown in Plate II., Fig. 4. An anticyclone lay over the Baltic, and a cyclonic system was situated near our Western coasts; the wind over England was consequently Southerly to South-Easterly in direction.

During the night from 17th to 18th, the wind fell somewhat unexpectedly to less than 6 miles an hour by 7 a.m.; and at noon a further fall to below 3 miles an hour occurred. The comparatively warm moist air brought by the Southerly wind caused fog to form universally as it came in contact with the ground, which was still frozen hard. In addition to this, a light drizzle occurred from time to time, so that this fog must be looked upon as a combination of a cold surface fog and a cloud fog. Fog occurred in all parts of London, but during the morning it remained light; during the afternoon, as the breeze died away, it became very smoky, and intensity "3" was reached in the West and at Hampstead, while intensity "4" or "5" was reported from Hyde Park and the river stations. The temperature of the river water, 35°, was at the time lower than that of the air, which ranged from 36° to 40°.

In the case of cold surface fogs we should expect to find a considerable inversion of the normal negative temperature gradient; unfortunately, owing to an accident the thermograph on the Victoria Tower did not record, and no observations were taken in the churchyard, Westminster, with which to compare the record of the electrical thermometer, as the day was a Sunday. The readings of the latter instrument were among the highest obtained at all hours of the day, but in no case were they more than 3° above those taken at the same hour in Kennington Park, the nearest station. The local variations of temperature were strikingly small, and show no special points of interest.

On the 19th the conditions were very similar to those which prevailed on the 18th, but the fog was almost entirely of the white variety. At the hours when temperature observations were made the temperature in the churchyard was only $\frac{1}{2}$° lower than that on the roof of the Office.

On the 20th a slight rise of temperature occurred, and the fog became much lighter. After noon it cleared in many districts, but it lingered on at as many as 18 stations.

On the 21st temperature fell again and remained between 40° and 42° all day on the roof of the Office.

The local differences of temperature still remained small. The "special" wind observations made on this day show that at 9 a.m. the prevailing direction of movement of the air over London was from between East and South-East. At noon this had changed to West, but at 3 p.m. the Easterly current again predominated. This Westerly wind was associated with the formation of moderate or thick smoky fog at Fulham and Wandsworth at about 9 a.m. During the hours between 9 a.m. and 3 p.m. this spread somewhat irregularly eastward, the period of thickest fog lasting from one to three hours at each station. The progress of the fog may be traced on the graphic summary given in Plate VIII. This was the only occasion on which it was possible to trace the spread of fog from station to station.

The fog cleared away towards evening on the 21st before a rising wind.

During the whole period the relative humidities remained between 95 per cent. and 100 per cent. The hair hygrometer on the roof of the Office showed an almost constant value of about 97 per cent. from 10 a.m. on the 18th till 10 a.m. on the 20th, at which hour the fog diminished in intensity. By 4 p.m., when the fog had cleared away, the relative humidity had fallen to 90 per cent. The fall of temperature on the 21st was associated with a slight temporary increase of the humidity between 6 a.m. and 8 a.m. The period of thick smoky fog alluded to above, which commenced at about 11 a.m., was accompanied by an increase of the humidity by about 2 per cent.

No. 35.—February 13th, 7 a.m. to 1 p.m.

Type: Radiation Fog.

Forecast.—Northerly wind, light; colder, fair generally, but with some fog or mist in places.

A light fog, remaining clear in the North and West, also in the South-East. Wind generally Northerly. The intensity "3" was attained at Shadwell and Cherry Garden from 11 a.m. to noon, but neither the temperatures nor the special wind observations afford any clue to the reason for this.

The relative humidity was low (85 per cent. at Camden Square at 9 a.m.). Dew point at Regent's Park at 9 p.m. on the 12th, 36°, minimum temperature 37°.

No. 36.—February 17th, 7 a.m. to 11 a.m.

Type : Radiation Fog.

Forecast.—Variable or light Easterly airs ; fair generally, but mist or fog in places in the early part of the day ; rather colder.

A light fog North of the river ; wind South.

The relative humidity was low (74 per cent. at Camden Square at 9 a.m.).

No. 37.—February 18th, 6 a.m. to 11 a.m.

Type : Radiation Fog.

Forecast.—South to South-East winds, light or moderate ; cold at first with local fog or mist, then fine and mild.

A very light fog. (13 stations.)

No. 38.—March 11th, Midnight to 10.30 a.m.

Type : Radiation Fog.

Forecast.—Light breezes, chiefly South-Westerly ; fair generally ; milder.

At 8 a.m. an anticyclone lay over the Continent of Europe, with a "low" off our North-West coast. The gradient was for South-Westerly winds ; the distribution of moderate or thick fog is shown on Plate VII. It will be seen that the stations on the leeward side experienced no moderate or thick fog (with the exception of Victoria Park). This is, therefore, again a case in which a forecaster would be misled if he allowed himself to be guided by the rule that the thickest fog is to be expected on the leeward side, but on the other hand, the temperature observations for 5 a.m. show that the North-Eastern part of London remained distinctly the warmest (Wandsworth 32°, Bethnal Green and Kingsland 37°). This may possibly be the reason for the absence of fog in this region.

At 9 a.m. the relative humidity was over 90 per cent. at all the observing stations, but all the observations happen to have been made in the foggy area.

No. 39.—March 12th, 6 a.m. to 10 a.m.

Type : Radiation fog.

Forecast.—Southerly wind freshening ; mild and fine in the early part of the day, some rain later.

Light fog at 16 stations, clear in South ; wind Southerly.

I.—ON LONDON RAIN.

II.—ON THE AMOUNT OF CARBONIC ACID IN LONDON AIR.

III. On the Impurities in London Air.

By W. J. RUSSELL, Ph.D, F.R.S.,

LECTURER ON CHEMISTRY AT ST. BARTHOLOMEW'S HOSPITAL MEDICAL SCHOOL.

(*From the Appendix to the Monthly Weather Report for April* 1884).

and Aug. 1885.

E 14137

APPENDIX.

APPENDIX I.

On London Rain.—By W. J. Russell, Ph.D., F.R.S., Lecturer on Chemistry at St. Bartholomew's Hospital Medical School.

It has been well shown by Dr. Angus Smith and others that much may be learnt with regard to the composition of the air of any place by examining the rain which falls there. I was therefore naturally led, while arranging and carrying on experiments on London fogs, to examine London rain.

These experiments have now extended over some length of time, in fact since November 1882, and up to a certain point they are sufficiently complete to allow of an account of them being given.

The composition of London rain has not, so far as I am aware, been much studied. Dr. Angus Smith, in his work on "Air and Rain," gives a few analyses of samples of rain collected for him, chiefly at the different Fire Brigade stations, but the composition of these samples, Dr. Smith states, was affected to a considerable extent by long exposure to the air, and are, therefore, hardly comparable with other samples more rapidly collected. It is undoubtedly difficult, and when the experiments extend over a long space of time almost impossible, to collect in a perfectly satisfactory way samples of rain. If a large open vessel be used to collect the rain, evaporation occurs to a very appreciable extent, and soot from some neighbouring chimney collects in the vessel, and thus causes varying results. By using a large funnel in a narrow-necked bottle the loss by evaporation to any detrimental extent is stopped, and large flakes of soot may be excluded by stretching a piece of rather coarse muslin, after well washing it, tightly over the funnel. The funnel is held by a ring of black india-rubber in the mouth of a Winchester quart bottle firmly supported to prevent its being blown over.

Another plan was tried, namely, putting a filter of Swedish paper inside the funnel and holding it in its place by the muslin over the top, so that all solid matter should as soon as possible be removed from the water; but this plan, as is shown by the following table, increases, not diminishes, the impurity of the samples:—

TABLE I.

Comparison of Filtered and Unfiltered Rain Waters.

	1884.							
	Jan. 26–8.	Jan. 31.	Feb. 1, 2.	Feb. 2–19.	Feb. 19–26.	Mar. 3, 4.	Mar. 4-9.	Mar. 9.
Sulphuric acid:—								
Not filtered -	·0331	·0153	·0148	·0283	·0198	·0472	·0283	·0166
Filtered - -	·0496	·0198	·0369	·0399	·0198	·0826	·0397	·0331
Hydrochloric acid:—								
Not filtered -	·0219	·0036	·0164	·0282	·0328	·0219	·0109	·0028
Filtered - -	·0365	·0036	·0219	·0356	·0372	·0273	·0087	·0036

To collect the rain the bottles were kept out of doors ready, and, as soon as there was enough water for analysis, the sample was brought in and examined; when the storm lasted long enough two samples of the same downpour were analysed. At other times the rain was only collected after a considerable interval of dry weather.

E 14137. 50.—9/84. Wt. 9364. E. & S.

The principal impurities in the rain of towns are no doubt sulphates and chlorides, and it is the amount of these salts present in the London rain which has been systematically determined, and, at present, only in certain cases have other impurities been looked for. In the following experiments the amounts of sulphates and chlorides present are expressed as so much sulphuric acid (H_2SO_4), and so much hydrochloric acid (HCl) in a litre of rain. Both determinations were made volumetrically. The sulphates were determined by a method similar in principle to that proposed by Angus Smith for determining the carbonic acid in the air, viz., by fixing on a particular amount of cloudiness, that most easily remembered and imitated by the operator, and using this as a standard in all cases. It was produced when 2 c.c. of a centinormal solution of sulphuric acid, diluted with 50 c.c. of water, was added to 10 c.c. of a barium chloride solution made from a saturated solution of barium chloride diluted with an equal volume of water, and acidulated with hydrochloric acid. Two tall cylinders, 12 inches high, with a diameter of 1 inch, were used for the experiments.

In one cylinder the standard amount of cloudiness was produced; in the other, after adding the regulation amount of acid barium chloride solution, the rain water was run in until, on standing, a like amount of cloudiness was obtained, the same amount of dilution being brought about in each case. A black mark below the plate-glass bottom of the cylinders helps very materially to show the amount of cloudiness. From experiments with a solution of sulphates of known strength and of about the same degree of dilution as the rain water, it was found that results of considerable accuracy could be obtained by the above method, and I have, through the kindness of Messrs. Lawes, Gilbert, and Warington, had the opportunity of checking my method against their more elaborate one. In their case large quantities of rain could be operated on, and the amount of sulphates determined by the gravimetrical method.

This volumetric method seems to give results which are fairly accurate, and are rapidly and easily obtained. The amount of chlorides present was determined by a centinormal solution of silver nitrate, using about 100 c.c. of the rain water. A little chromate of potash was used as an indicator, and the experiment was made in a white porcelain basin. The rain water was always filtered before the amount of sulphates and chlorides were determined. To determine the ammonia present the rain water was Nesslerized in the ordinary way.

Three principal stations have been used for collection of the rain. One station was in the City, at St. Bartholomew's Hospital; here the collecting bottle was placed on some leads about 10 feet from the ground in an open situation, so that the samples collected are probably rather above than below the average of purity for this neighbourhood. Another station was on the north-west of London, in an open garden in Upper Hamilton Terrace, the collecting bottle standing on the ground. The nearest chimney was at a distance of 50 yards, and lay to the east; on the west there were no houses for a considerable distance. This station is about 3¾ miles in a direct line from St. Bartholomew's Hospital. The third station was at Shacklewell Green, Hackney, which, in a direct line, is about 3 miles from St. Bartholomew's Hospital, and lies on the north-east of London. Here also the bottle was placed on the ground in an open garden, and it was also fully 50 yards from any chimney. A good many samples have also been collected at other places, but these will be noticed separately.

First, with regard to the rain collected at St. Bartholomew's, it was always more or less dirty from soot floating in it, and disagreeable in taste. As before mentioned, the samples were collected and analysed as soon as enough rain had fallen to furnish the required amount of water. The amount of rain which fell I had not the means of accurately determining; the time and the direction of the wind, when the rain occurred, have been put into the following table from observations made at the time, but these have been supplemented and checked by the observations taken at Lloyd's, which have, through the kindness of Mr. Fowler, been put at my disposal. The following numbers express, then, as far as the sulphates and chlorides are concerned, the composition of each individual sample of rain.

I think there is a general impression that London rain is acid, and the first sample collected at St. Bartholomew's Hospital certainly was so—in fact so acid that I easily determined with a decinormal solution of carbonate of soda, the amount of acid present.

After this preliminary experiment and the systematic collection began, I did not find any sample of rain to be acid; by this I mean that none would, with our most delicate indicators, litmus, or methyl orange, give the least indication of acidity.

At the City station 38 samples of rain have been collected, at Hamilton Terrace and at Hackney 32. The results obtained from the analysis of these samples are given in the following table:—

TABLE II.

St. Bartholomew's Hospital, E.C.

	1882.						1883.						
DATE	Oct. 15–21.	Oct. 21–26.	Oct. 26–28.	Oct. 28 to Nov. 6.	Nov. 6–13.	Nov. 15–16.	Nov. 18–23.	Nov. 24 to Dec. 6.	Dec. 6 to Jan. 8.	Jan. 8–16.	Jan. 16–28.	Jan. 28 to Feb. 3.	Feb. 3–12.
Sulphuric acid	·0266	·0211	·0165	·0268	·0216	·0139	·0248	·0198	·0248	·0168	·0283	·0132	·0147
Hydrochloric acid	·0075	·0073	·0053	·0155	·0164	·0146	·0120	·0153	·0198	·0135	·0373	·0087	·0069
Total	·0281	·0284	·0218	·0423	·0380	·0285	·0368	·0351	·0446	·0303	·0656	·0219	·0186
Proportion	1:2·9	1:2·9	1:3·1	1:1·7	1:1·3	1:0·9	1:2·1	1:1·7	1:2·7	1:1·2	1:1	1:1·5	1:1·7

	1883.												
DATE	Feb. 17–18.	Mar. 8.	Apr. 2.	Apr. 20–24.	Apr. 28.	May 7–8.	May 11–12.						
Sulphuric acid	·0236	·0165	·0827	·0661	·0392	·0320	·0348						
Hydrochloric acid	·0080	·0084	·0466	·0310	·0073	·0131	·0066						
Total	·0316	·0249	·1293	·0971	·0465	·0451	·0414						
Proportion	1:3·0	1:2·1	1:1·8	1:2·1	1:4·1	1:2·4	1:3·6						

Upper Hamilton Terrace, N.W.

	1882.						1883.						
DATE	Oct. 15–21.	Oct. 21–26.	Oct. 26–28.	Oct. 28 to Nov. 6.	Nov. 6–13.	Nov. 15–16.	Nov. 18–23.	Nov. 24 to Dec. 6.	Dec. 6 to Jan. 8.	Jan. 8–16.	Jan. 16–28.	Jan. 28 to Feb. 3.	Feb. 3–12.
Sulphuric acid	·0101	·0083	·0099	·0101	·0124	·0198	·0090	·0062	·0105	·0083	·0090	·0079	·0121
Hydrochloric acid	·0080	·0058	·0054	·0082	·0182	·0124	·0073	·0065	·0058	·0058	·0065	·0062	·0058
Total	·0181	·0141	·0153	·0243	·0306	·0322	·0165	·0127	·0223	·0141	·0155	·0141	·0179
Proportion	1:1·3	1:1·4	1:1·8	1:3·0	1:1·7	1:0·6	1:1·2	1:1	1:2·8	1:1·4	1:1·2	1:1·3	1:2·1

	1883.												
DATE	Feb. 17–18.	Mar. 8.	Apr. 2.	Apr. 20–24.	Apr. 28.	May 7–8.	May 11–12.						
Sulphuric acid	·0461	·0221	·0248	·0090	·0090	·0090	·0141						
Hydrochloric acid	·0340	·0101	·0043	·0087	·0044								
Total	·0701	·0322	·0291	·0285	·0185								
Proportion	1:1·9	1:2·2	1:0·2	1:2·2	1:3·2								

Milton House, Hackney, E.

	1882.						1883.						
DATE	Oct. 15–21.	Oct. 21–26.	Oct. 26–28.	Oct. 28 to Nov. 6.	Nov. 6–13.	Nov. 15–16.	Nov. 18–23.	Nov. 24 to Dec. 6.	Dec. 6 to Jan. 8.	Jan. 8–16.	Jan. 16–28.	Jan. 28 to Feb. 3.	Feb. 3–12.
Sulphuric acid	·0240	·0184	·0141	·0248	·0090	·0090	·0090	·0079	·0121				
Hydrochloric acid	·0053	·0095	·00 3	·0095	·0055	·0102	·0065	·0062	·0058				
Total	·0293	·0279	·0214	·0343	·0145	·0362	·0155	·0141	·0179				
Proportion	1:0·7	1:1·9	1:2·0	1:2·5	1:1·6	1:2·5	1:1·4	1:1·3	1:2·1				

	1883.												
DATE	Feb. 17–18.	Mar. 8.	Apr. 2.	Apr. 20–24.	Apr. 28.	May 7–8.	May 11–12.						
Sulphuric acid	·0461	·0221	·0248	·0090	·0090	·0090	·0141						
Hydrochloric acid	·0340	·0101	·0043	·0087	·0044								
Total	·0701	·0322	·0291	·0285	·0185								
Proportion	1:1·9	1:2·2	1:0·2	1:2·2	1:3·2								

TABLE II.—*continued.*

ST. BARTHOLOMEW'S HOSPITAL, E.C.

1883. DATE	May 26.	June 18–22.	June 22–28.	June 28.	July 10–13.	July 14.	July 14–22.	Oct. 1–31.	Nov. 30.	Jan. 26–28.	Jan. 29–28.	Jan. 31.	Feb. 1–2.	Feb. 2–10.	Feb. 19–26.	Mar. 3–4.	Mar. 4–9.	Mar. 9.	Mean.
	W.	S.W.	S.W.	S.W.	S.	S.	S.W.	S.W.	W.	S.W.	S.W.	S.W.	S.W. and E.	S.W.	S.W.	E. to S.	S.W.	S.W.	
Sulphuric acid - -	·0962	·1984	·0396	·0496	·0661	·0396	·0396	·0661	·0331	·0153	·0331	·0153	·0148	·0283	·0198	·0472	·0283	·0166	·0362
Hydrochloric acid - -	·0306	·0467	·0401	·0292	·0365	·0127	·0189	·0302	·0073	·0032	·0219	·0036	·0219	·0282	·0328	·0219	·0109	·0028	·0178
Total - - -	·1268	·2451	·0797	·0788	·1026	·0523	·0585	·0963	·0404	·0185	·0550	·0189	·0367	·0565	·0526	·0691	·0392	·0194	·0540
Proportion - - -	1:2·6	1:4·2	1:0·9	1:1·7	1:1·8	1:3·1	1:2·1	1:2·1	1:4·5	1:4·8	1:1·5	1:4·2	1:0·7	1:1	1:0·6	1:2·1	1:2·3	1:6·0	1:2·0

UPPER HAMILTON TERRACE, W.

Sulphuric acid - -	·0359	·0248	·0099	·0248	·0331	·0248	·0248	·0331	·0369	·0150	·0198	·0165	·0248	·0166	·0283	·0331	·0110	·0201	
Hydrochloric acid - -	·0073	·0087	·0014	·0073	·0525	·0054	·0043	·0047	·0109	·0127	·0051	·0248	·0168	·0153	·0054	·0036	·0014	·0101	
Total - - -	·0432	·0283	·0113	·0321	·0856	·0302	·0291	·0378	·0378	·0277	·0249	·0413	·0416	·0319	·0337	·0367	·0124	·0302	
Proportion - - -	1:4·8	1:4·2	1:7·0	1:3·4	1:0·6	1:4·6	1:5·7	1:7·1	1:3·4	1:2·2	1:3·8	1:0·7	1:1·5	1:1·0	1:5·2	1:9·7	1:7·8	1:2·0	

MILTON HOUSE, SHACKLEWELL GREEN, E.

Sulphuric acid - -	·0331	·0165	·0248	·0099	·0496	·0165	·0198	·0331	·0248	·0320	·0180	·0198	·0283	·0248	·0331	·0397	·0132	·0214	
Hydrochloric acid - -	·0659	·0073	·0059	·0014	·0073	·0014	·0036	·0248	·0036	·0076	·0040	·0152	·0186	·0219	·0073	·0058	·0028	·0081	
Total - - -	·0990	·0238	·0307	·0113	·0338	·0312	·0234	·0579	·0284	·0396	·0220	·0350	·0469	·0467	·0404	·0455	·0160	·0295	
Proportion - - -	1:5·5	1:2·2	1:4·0	1:7·0	1:14·1	1:14·1	1:5·5	1:1·4	1:6·9	1:4·2	1:4·5	1:1·3	1:1·5	1:1·1	1:4·5	1:6·8	1:4·7	1:2·6	

The numbers, as before explained, express in grammes the weight of sulphates and chlorides present, supposing them to exist as the hydrogen salts (H_2SO_4 and HCl). Further, in the above tables is given the total weight of sulphuric and hydrochloric acid found in each experiment, and the proportion which the sulphates bear to the chlorides, the amount of chloride present being taken as 1. All the samples of the same date were collected at the same time and in the same manner, so they are, as far as possible, comparable. The arithmetical mean of each set of experiments is as follows:—

TABLE III.

——	St. Bartholomew's.	Hamilton Terrace.	Shacklewell.
Sulphuric acid - -	·0388	·0196	·0207
Hydrochloric acid - -	·0179	·0088	·0078
Total - - -	·0567	·0307	·0285
Proportion of chloride to sulphate.	1:2·2	1:2·2	1:2·6

These results show:—First, that the City rain contains twice as much impurity as that collected at the suburban stations. Second, that the impurities at all the stations are in the same proportion. Dilute the City rain with very nearly an equal bulk of water, and you have the rain of the suburbs. If the City rain was so far diluted as to have the same weight of sulphates and chlorides as are found in the suburban samples, then the Hamilton Terrace sample would contain sulphates ·0189, instead of ·0196, and ·0095 chlorides instead of ·0088; the Shacklewell Green would have ·0182, instead of 0·209 sulphates, and ·0091, instead of ·0089 chlorides, so that it appears on the average that the composition of the London rain differs very largely in amount of impurity, but very little with regard to the composition of the impurity. On comparing the three simultaneous experiments, it is also evident that, speaking generally, when the impurities, either sulphates or chlorides, are high or low at one station they are similarly affected at all of the stations. The following tables [Tables IV. (represented graphically in Plates A. and B.), and V.], in which the three simultaneous results are joined together, shows to the eye this general character, that, for instance, the sulphates as a rule at the different stations increase and diminish together, and that the same thing occurs with the chlorides.

Of course exceptions occur, but there certainly is much greater uniformity in composition between the simultaneously collected samples on the east and west of London than I should have anticipated. Again, if the results be grouped according to the time of year, a curious result is obtained. Calling October to March the winter months, and April to September the summer months, then at the three stations the winter and summer rain is as follows:—

TABLE V.

——	Winter, 1882–83.	Summer, 1883.	Winter, 1883–84.
St. Bartholomew's Hospital.			
Sulphuric acid - -	·0200	·0631	·0289
Hydrochloric acid - -	·0117	·0266	·0167
Total - - -	·0317	·0897	·0456
Proportion - -	1:1·7	1:2·4	1:1·7
Hamilton Terrace.			
Sulphuric acid - -	·0116	·0252	·0225
Hydrochloric acid - -	·0083	·0117	·0101
Total - - -	·0199	·0369	·0326
Proportion - -	1:1·4	1:2·1	1:2·2

TABLE V.—*continued.*

——	Winter, 1882–83.	Summer, 1883.	Winter, 1883–84.
Shacklewell Green.			
Sulphuric acid - - -	·0139	·0222	·0265
Hydrochloric acid - - -	·0073	·0071	·0099
Total - - -	·0212	·0293	·0364
Proportion - -	1 : 1·9	1 : 3·1	1 : 2·6

These three half-years are not sufficient for establishing general conclusions, but they seem to indicate that summer rain is more impure than winter rain. If the winter of 1882–83 and following summer, that of 1883, be compared, this is most strikingly the case. The total amount of salts at St. Bartholomew's was nearly three times, and at the other two stations nearly twice as much in the summer as in the winter six months; again, there is in the summer at each station an increase in the amount of sulphates over the chlorides. Evaporation must be the principal cause of the increase of impurity, but the increase of the proportion of sulphates to chlorides in the summer is remarkable, and it appears is not caused by evaporation, for on evaporating over a water-bath 150 c.c. of rain to only 75 c.c. the proportion between the sulphates and chlorides was unchanged, and on evaporating some of the same rain at ordinary temperatures, by exposing it in a basin freely to the air in a room until reduced to half its bulk, it increased in strength, but gave no indication of loss of hydrochloric acid :—

——	Original Rain.	After evaporation at 100° C.	After evaporation at ordinary temperatures.
Sulphuric acid - -	·0248	·0496	·0661
Hydrochloric acid - -	·0087	·0175	·0219
	1 : 3·0	1 : 3·0	1 : 2·9

The most probable explanation of this increase of the sulphates in the summer, is, that it arises from the decomposition of animal and vegetable matter, volatile sulphur compounds being eliminated and afterwards oxidised. The samples collected during the past winter 1883-84 are, however, more impure than those of the previous winter, and contain proportionally more sulphates; in fact, at the Hackney station during the last winter, there was a greater amount of impurity than in the previous summer, but that is the only exception, and the great prevalence of South-west winds during last winter may be the cause of this; in fact it is reasonable to suppose that the exceptional winter we have had may have caused exceptional results. From comparatively so short a series of observations, one cannot with certainty learn much, but the differences indicated in these tables are of interest and importance.

That an increase in the amount of sulphates in rain also occurs in the summer months in the country is shown by the experiments of Messrs. Lawes, Gilbert, and Warington, for they found that at Rothamsted on the average for two years in the winter the sulphates amounted to ·0027, while in the summer there was ·0032 present. The chlorides were, however, much less in the summer than in the winter. At all the stations the variations of amount of sulphates and chlorides are very considerable. At St. Bartholomew's the amount of sulphates varied from 0·1984 grammes in the litre which was contained in the rain falling between the 18th and 22nd June to 0·0117, which was in the rain falling between the 3rd and 12th February 1883, and the maximum amount of chlorides was coincident with that of the maximum of sulphates, while the smallest amount was during a storm on March 9th, 1884, when only ·0028 grammes were present and a very small, but not quite the smallest, amount of sulphates. On two occasions, April 2nd and April 20th, 1883, both the sulphates and the chlorides were above the average at all the stations. On five occasions, April 3rd, 20th, May 26th, June 22nd, and March 3rd, the amount of sulphates present was above the average at all stations. That a greater difference in the amount of impurity should not exist between the rain collected simultaneously on the east and west of London is

curious, but the results show that the average amount is much the same at the two places. Still the sample from Hamilton Terrace, containing the smallest amount of sulphates, was collected when a west wind was blowing, and the smallest amount of sulphates at Shacklewell Green was collected when an East wind blew. It would be interesting to have other and well-selected stations round London, specially some on the south-west side. Probably in most cases when it rains, a high wind is not blowing, and what may be called the normal atmosphere of London predominates. The analyses of the samples collected on March 4th to 9th and on the 9th show the purifying effect of a good downpour of rain. A sample of rain was collected early on the 9th March, the rain continued most of the day and another sample was collected by the evening. These two samples from each station gave :—

TABLE VI.

——	St. Bartholomew's.		Hamilton Terrace.		Shacklewell Green.	
Sulphates - -	·0397	·0331	·0331	·0110	·0397	·0132
Chlorides - -	·0087	·0036	·0036	·0014	·0058	·0028

In fact it is only necessary to collect London rain in order to be convinced of its beneficial action as a washing agent.

In order to determine the amount of solid matter present in the rain collected at St Bartholomew's, two samples were evaporated to dryness over a water-bath and the residue weighed; in the first sample 0·17 grammes and in the second, 0·14 grammes were found per litre. The latter residue on ignition left only ·055 of incombustible matter.

A few samples of rain have also been collected at the same time and in the same manner as the foregoing ones, but at different places. One set was collected at St. Bartholomew's, but nearer to the ground, and in a yard at a distance of about 100 yards from the former collecting place. These results were intended simply as a check on the former ones, and to determine what amount of difference in composition would arise from this difference of position. The two sets of experiments are given in Table VII., and it will be seen that the differences are small and unimportant :—

TABLE VII.

ST. BARTHOLOMEW'S HOSPITAL.

On the leads over Dispensary :—

——	1883. Feb. 3–12.	Feb. 17–18.	April 2.	April 20–24.	April 28.	May 7–8.	May 11–12.	May 26.	June 12–18.	June 28.	July 10–13.	July 14.	July 15–22.	Oct. 1–31.	Mean.
Sulphuric acid - -	·0117	·0236	·0827	·0661	·0292	·0320	·0248	·0902	·0396	·0496	·0661	·0396	·0396	·0661	·0471
Hydrochloric acid - -	·0069	·0080	·0466	·0310	·0073	·0131	·0066	·0306	·0401	·0292	·0365	·0127	·0189	·0292	·0226
Total - - -	·0186	·0316	·1293	·0971	·0365	·0451	·0314	·1208	·0797	·0788	·1026	·0523	·0585	·1053	·0697
Proportion - -	1 : 0·7	1 : 3·0	1 : 1·8	1 : 2·1	1 : 4·1	1 : 2·4	1 : 3·6	1 : 2·6	1 : 0·9	1 : 1·7	1 : 1·8	1 : 3·1	1 : 2·1	1 : 2·4	1 : 2·1

In the yard :—

Sulphuric acid - -	·0049	·0290	·0992	·0584	·0331	·0368	·0261	·0496	·0496	·0496	·0708	·0331	·0331	·0708	·0495
Hydrochloric acid - -	·0069	·0102	·0263	·0393	·0124	·0240	·0073	·0175	·0116	·0292	·0584	·0102	·0131	·0109	·0213
Total - - -	·0118	·0392	·1255	·0977	·0455	·0608	·0334	·0671	·0612	·0788	·1292	·0433	·0462	·0817	·0708
Proportion - -	1 : 0·7	1 : 2·8	1 : 3·6	1 : 1·5	1 : 2·7	1 : 1·5	1 : 3·5	1 : 2·8	1 : 4·2	1 : 1·7	1 : 1·2	1 : 3·2	1 : 2·5	1 : 6·5	1 : 2·3

Another set of simultaneous samples was collected at Denmark Hill, and the interest of these is in their showing how local circumstances may cause great differences in the amount of rain impurities. These samples were collected on the ground in a garden and at about 20 yards from any chimney, but on the side of a hill, and although the situation was open, and therefore regarded as likely to give a fair sample of the rain of this district, still it will be seen from the following experiments, which extend from November 1882

till the end of July 1883, that the amount of both sulphates and chlorides is much greater than in the rain collected at St. Bartholomew's, the average total for the corresponding samples being, for St. Bartholomew's ·0567, and for Denmark Hill ·0789. Dividing them into summer and winter experiments, the same relation exists between them as in the former experiments, the summer rain being much more impure than the winter, in fact in this case three times as impure; but here the sulphates are in proportion to the chlorides in greater amount in the winter than in the summer.

TABLE VIII.

Denmark Hill.	Winter.	Summer.
Sulphuric acid - -	·0236	·0622
Hydrochloric acid -	·0119	·0442
Total - -	·0355	·1064
Proportion - -	1:2·0	1:1·4

However, there is still a certain relationship between these experiments and the others. In the sample collected on June 18th–22nd, the rain was excessively impure, far more so than on any other occasion, but on comparing it with the St. Bartholomew's rain of the same date, we find that it also contains the largest amount of sulphates ever found, together with a very large amount of chlorides. The conclusion seems to be that this collecting station at Denmark Hill, although it was an open space, still, owing to local circumstances, must give an unfair average for the district.

The best series of analyses of country rain are those of Messrs. Lawes, Gilbert, and Warington of the rain collected during the last 13 months at Rothamsted, near St. Albans. The mean of these experiments is as follows:—

Sulphates - - - -	·0040
Chlorides - - - -	·0033
Total - -	·0073
Proportion -	1:1·2

That is, there is about one-fifth the amount of sulphate and less than one half the amount of chloride in Rothamsted rain than there is in the rain of the suburbs, and only about one ninth the amount of sulphate and half the chloride that there is in the City rain.

Again, seven samples of rain have been collected at Slinfold, near Horsham, Sussex. The mean of these experiments gives—

Sulphates - - - -	·0048
Chlorides - - - -	·0041
Total - -	·0089
Mean - -	1:1·2

These numbers do not differ much from the Rothamsted numbers, but evidently the amount of chloride is increased by proximity to the sea. A single sample of rain collected on Dartmoor during a storm from the south-west gave the following results:—

Sulphates - - - -	·0005
Chlorides - - - -	·0087

The sulphates present were really only a trace, the number does not mean more than that; in fact, in this case, the air is uncontaminated by either the products of combustion or by the decomposition of animal or vegetable matters, the sulphates and chlorides in this air coming simply from sea water.

The question before alluded to of the acidity of London rain is interesting and important. At first sight the results which have been obtained are conflicting, but can, I think, be readily explained. As far as my experiments go, London rain, when collected as above described, is never acid, but if the rain be collected in an open vessel, which is left exposed for a considerable length of time, then the water will, I believe, always be acid. I am speaking now of City rain. This acidity, however, arises, not from acid washed directly out of the air, but from acid washed out of the soot which is always abundantly present in London air.

That the mere evaporation of the rain is not sufficient to cause this acidity seems proved by the following experiment: 150 c.c. of rain was evaporated under an air pump over calcium chloride, and from time to time tested, even when the 150 c.c. was reduced to only 15 c.c. it gave no signs of acidity. On the other hand, soot collected from the top of several chimnies yielded to water a solution distinctly acid, as shown both to litmus and methyl orange, and the amount of acidity was sufficient to be determined quantitatively. The following determinations were made by treating 2 grammes of the soot with water, and determining the acid by a decinormal carbonate of soda solution, using the methyl orange indicator:—

TABLE IX.

SOOT.—PERCENTAGE AMOUNTS OF ACID, &c.

Samples.	1.	2.	3.	4.	5.	6.	7.	8.	9.
Sulphuric acid - -	1·6	3·9	7·8	4·9	9·8				
Hydrochloric acid -	3·1	2·1	3·3	4·0	8·9				
Total - -	4·7	6·0	11·1	8·9	18·7				
Proportion - -	1:0·52	1:1·8	1:2·4	1:1·2	1:1·1				
Acidity - - -	1·4	0·5	7·2	0·0	0·0	4·9	0·8	1·2	2·3
Ammonia - - -	0·6	0·4	1·8	1·8	8·0				

Two samples of soot, it will be seen, were not acid, but it is very difficult to collect such samples absolutely free from mortar, and judging from appearance in both these cases some was present, but the analyses were made and the results are given. It is also of interest to see the amount of sulphates and chlorides present in the soot; in one case there is only one half as much sulphate as chloride, in another two and a half times as much. One sample of rain collected in the city and examined after long exposure to the air was not acid, but this seems to confirm what is said above, for it was singularly free from soot The sample was collected on the top of the Star Works of Messrs. De la Rue & Co., in Bunhill Row. If the soot in the London air be generally acid, its adherence to bodies and subsequent moistening by rain will tend to corrode those bodies, and as the surface becomes roughened so will the soot more readily and more firmly adhere and the disintegrating action will proceed with increased rapidity.

It seemed, at least, of scientific if not of practical interest, to ascertain whether arsenic could be found in London rain, or rather in London rain and soot. For this purpose simply open vessels were used to collect the rain, and some five or six litres were used. This amount was slightly acidulated with pure hydrochloric acid evaporated over a water-bath to a quarter of a liter, and filtered.

On adding 70 c.c. of this liquid to a bottle in which hydrogen generated from pure zinc with platinum attached, and which was proved to be perfectly free from arsenic, gave at once, as the hydrogen passed through a very small heated tube, an arsenic mirror, and on comparing this mirror with one similarly obtained from a known quantity of arsenic, a fair indication of the amount of arsenic in the rain water was obtained.

Two different samples of water collected in the City gave—

1st experiment - -	0·00021	grains of arsenious acid (As_2O_3)
2nd „ - -	0·00020	„ „

in a gallon of rain.

There also appeared to be a trace of copper present in this same solution.

Another way of ascertaining the amount of impurities in the air, and one more under immediate control, is to condense and collect the moisture in air. For this purpose I had a large conical tin vessel constructed, 3 feet 6 inches high which could be filled with ice and suspended, cone downward, from a stand. The moisture as it trickled from it was collected and then treated as a rain water.

The following five experiments were made with this apparatus. It was placed out of doors and close to where the St. Bartholomew's rain specimens were collected. The last of these experiments was made on a day when there was a fog during the morning.

1883.	——	Jan. 15.	Jan. 30.	March 11.	April 28.	Mean.
Sulphates - - -	·1101	·1652	·0827	·0661	·2480	·1344
Chlorides - - -	·0353	·0219	·0196	·0547	·1215	·0506
Total - - -	·1454	·1871	·1023	·1208	·3695	·1850
Proportion - -	1 : 3·1	1 : 7·5	1 : 4·2	1 : 1·2	1 : 2·0	1 : 2·7
Ammonia - - -	0·005	0·004	0·01	—	—	0·006

Comparing the mean of these five experiments with the mean of the St. Bartholomew's rain, it will be seen that the sulphates and chlorides in the dew is very nearly in the same proportion as in the rain, but the dew contains about three times as much impurity as the rain. In the first three experiments the amount of ammonia was determined; these give as a mean six milligrammes to the litre. The rain collected on May 11th, 1883, at the three stations was tested for ammonia, and the amounts found were, at St. Bartholomew's, ·0038; at Hamilton Terrace, ·0009; and at Shacklewell Green, ·0024 milligrammes to the litre. The mean amount found during the last year at Rothamsted is 0·00057.

My assistant, Mr. W. J. Orsman, junr., has rendered me most efficient aid in carrying on the above experiments. They are really only tentative. In order to study more fully the composition of London rain, means for collecting larger quantities, so that more frequent analyses could be made, should be adopted, and to each specimen should be attached a full account of the direction and velocity of the wind at the time of collection, as well as of the amount of the rain which fell.

Monthly Weather Report. April 1884.

APPENDIX II.

On the Amount of Carbonic Acid in London Air.—By W. J. Russell, Ph.D., F.R.S.

The following experiments were commenced in connexion with other experiments undertaken to determine the chemical composition of London fogs. The absence of fogs of late has, however, delayed the completion of this work.

I therefore give, as desired, an account of the carbonic acid determinations, which have an interest of their own, and are really complete in themselves.

All the samples of air treated of in the following report were collected at St. Bartholomew's Hospital, in the City of London, in an open space, and at a height of 12 feet from the ground. Pettenkofers' method for the estimation of the carbonic acid was in all cases used. The bottles in which the samples were collected held between 9 and 10 litres, and were filled by means of a large aspirator, which drew a steady current of air through them for nearly 25 minutes. This was proved by experiment to be sufficient to expel the original contents of the bottle.

The experiments were commenced at the beginning of 1882, and were made at first entirely in relation to the fog experiments, the special object being to determine whether the amount of other impurities in the air at the time of the fog increased in the same proportion as the carbonic acid did.

During the first year, the samples of air were collected whenever there was a fog, and only occasionally and at irregular intervals when the weather was clear. In 1883 the samples of air began to be collected with tolerable regularity once a week, in the middle of the day, irrespective of weather, and this has been continued to the present time. In addition to this regular collection, other samples have been taken whenever during the day there was a fog or mist.

These determinations, 159 in number, are given with description of weather, temperature, direction of wind, &c., in Table I.

TABLE I.

Date.	Weather.	Temperature. C.		Barometer in m.m.	Direction of Wind.	Vols. of CO_2 in 10,000 of Air.	
		Wet Bulb.	Dry Bulb.			1st Experiment.	2nd Experiment.
1882.							
January 7	Dull - - - - -	—	7·2	765	S.E.	5·2	5·4
„ 16	Dull - - - - -	—	8·	782	S.	5·9	6·0
„ 17*	Dense black fog - - - -	—	10·	786	S.	6·4	6·7
„ 18*	Dense black fog - - - -	—	4·	786	S.	5·6	5·7
„ 19*	Slight white fog - - - -	—	6·	768	S.	4·8	—
„ 25*	Dense black fog - - - -	—	3·5	780	S.	10·5	10·3
„ 26	Fine - - - - -	—	3·	775	S.W.	5·1	4·9
„ 28	Fine - - - - -	—	11·	770	S.W.	5·6	5·6
„ 31	Dull - - - - -	6·	8·	778	S.E.	4·8	4·8
February 1	Very fine - - - -	3·	5·	780	N.W.	4·7	5·1
„ 3*	Slight fog - - - -	3·	4·4	781	S.	6·2	6·9
„ 4*	Dense black fog - - - -	4·	5·	775	S.	10·7	10·2
„ 9	Clear - - - - -	2·7	4·4	773	S.E.	4·4	4·8
„ 14	Very fine - - - -	10·	15·	768	S.W.	4·1	—
„ 18	Dull - - - - -	9·	11·5	766	W.	4·3	4·8
„ 20	Dull - - - - -	6·	8·9	780	W.	4·7	4·9
„ 21	Dull and misty - - - -	10·	12·	777	N.W.	4·6	5·0
„ 22	Very fine - - - -	9·	12·	775	N.W.	4·5	4·6
„ 27	Very bright after much rain - -	10·	12·	742	W.	6·0	—
March 1	Very fine - - - -	8·	12·	737	S.W.	4·0	4·1
„ 11	Dull - - - - -	11·	12·5	773	N.E.	4·2	—
„ 15*	White fog (9.30 a.m.) - - -	9·	11·	775	N.E.	5·0	5·6
„ 20	Very fine - - - -	6·	9·	763	N.	3·8	—
„ 27	Very fine - - - -	8·	13·	764	N.W.	3·9	—
„ April 4	Very fine - - - -	9·	14·	761	N.E.	4·4	—

TABLE I.—*continued.*

Date.	Weather.	Temperature. C. Wet Bulb.	Temperature. C. Dry Bulb.	Barometer in m.m.	Direction of Wind.	Vols. of CO_2 in 10,000 of Air. 1st Experiment.	Vols. of CO_2 in 10,000 of Air. 2nd Experiment.
1882.							
April 19	Dull	13·5	14·5	761	S.W.	4·5	4·2
„ 20	Very fine	15·5	19·5	761	E.	4·5	4·5
„ 21	Very fine	12·	17·8	767	S.E.	4·4	4·3
„ 24	Dull, showery	10·	14·4	750	S.W.	4·4	4·4
May 2	Dull, showery	13·	13·5	755	S.E.	4·5	—
„ 12	Very fine	13·5	20·	768	W.	4·0	—
„ 22	Dull	16·	19·	756	S.E.	3·4	—
June 27	Very fine	19·	26·6	763	N.W.	3·6	—
„ 28	Dull	18·5	25·	765	N.W.	3·8	4·0
July 20	Fine	20·5	31·	761	S.W.	3·5	3·6
„ 21	Fine	14·4	22·2	762	S.W.	3·3	3·4
„ 27	Very fine	26·6	28·8	770	S.W.	3·4	3·5
„ 29	Very fine	21·6	25·5	766	N.E.	3·3	—
„ 31	Very fine	17·2	30·5	770	N.W.	4·0	3·9
August 1	Dull	18·3	22·2	766	N.W.	3·2	3·6
„ 7	Very fine (Bank Holiday)	18·5	22·5	765	N.E.	3·0	3·1
October 4	Dull	15·7	16·1	773	S.E.	3·7	3·9
„ 9	Very fine	14·4	18·3	765	S.	3·4	3·5
„ 10	Dull	15·0	17·2	765	S.	3·9	—
„ 12	Dull after much rain	11·1	12·7	748	N.W.	3·5	—
„ 16	Dull after much rain	8·3	8·8	753	S.E.	3·5	—
„ 17	Dull after much rain	9·4	10·5	760	N.	4·0	—
„ 18	Dull	10·5	11·6	768	N.E.	5·1	—
„ 21	Dull, with rain	12·7	13·8	748	S.E.	4·1	—
„ 23	Fine	8·8	12·7	748	W.	6·4	—
„ 24	Dull; strong gales	5·5	7·2	735	N.W.	3·8	4·0
„ 25	Very fine	8·8	11·1	750	W.	4·6	—
„ 26*	White fog (10.30 a.m.)	6·6	7·7	750	W.	9·9	—
„ „	Very fine (12.30)	8·3	11·1	751	W.	5·0	—
„ 28	Dull	9·4	10·5	747	N.E.	3·7	3·8
November 1	Fine	9·5	11·3	748	N.W.	3·8	3·4
„ 4	Fine after heavy gale	9·4	12·7	754	W.	3·7	—
„ 8	Very fine after rain	7·7	11·6	746	W.	3·6	—
„ 13	Dull	5·5	7·2	760	E.	3·7	—
„ 17	Fine, after snow	3·3	5·0	759	N.	3·2	—
„ 18*	Dense black fog	2·2	2·7	760	S.E.	9·6	—
„ „	Fine. Sun 1½ hours after above	2·5	5·5	760	S.E.	5·0	—
„ 23	Dull	3·3	6·1	750	S.E.	4·1	—
„ 29	Dull, after much rain	7·2	8·3	755	N.W.	4·1	—
December 1*	Thick white fog (11 a.m.)	1·6	2·2	765	S.	5·5	—
„ „	Dull and misty (3.30 p.m.)	0·5	1·1	765	S.	4·1	—
„ 2*	Slight mist	1·1	1·6	766	S.E.	5·1	—
„ 5	Very dull	6·1	8·6	740	S.	5·0	—
„ 8	Fine	2·2	3·3	747	N.	4·0	—
„ 10*	Thick white fog	0·5	1·1	755	S.W.	9·4	—
„ 11*	Thick white fog. Darker, 12 a.m.	0·0	0·5	755	S.W.	11·0	—
„ „*	Thick white fog. Very dark, 5 p.m.	0·0	0·5	755	S.W.	14·1	—
„ 12	Dull and hazy	0·0	1·1	760	S.W.	4·7	—
„ 13	Fine	6·1	8·3	760	W.	4·5	—
„ 14*	White fog (wet)	4·4	4·4	755	S.E.	6·2	—
„ 15*	White fog	5·	6·1	753	S.E.	5·4	—
„ „*	Overhead fog, white	3·3	4·4	760	S.E.	4·8	—
„ 17	Dull	8·3	9·4	752	S.	3·8	—
„ 19	Dull and hazy	8·8	10·	760	S.E.	4·4	—
„ 20*	Thick black fog at 10.30 a.m.	4·4	4·7	767	S.	8·1	—
„ „	Fine (at 12)	4·4	4·7	767	S.	5·2	—
„ 21	Very fine	4·4	4·8	761	W.	4·0	—

TABLE I.—*continued.*

Date.	Weather.	Temperature. C. Wet Bulb.	Temperature. C. Dry Bulb.	Barometer in m.m.	Direction of Wind.	Vols. of CO_2 in 10,000 of Air.
1883.						
January 8	Very fine	3·8	5·2	764	N.E.	4·8
„ 11	Dull	5·5	7·1	749	E.	3·9
„ 16	Fine after rain	7·7	10·5	758	S.W.	4·1
„ 17	Dull, hazy	10·	11·1	765	S.W.	4·7
„ 19*	Foggy	10·	8·8	763	S.W.	5·0
„ 22	Very fine	3·3	5·2	777	N.E.	3·8
„ 24	Very fine	4·4	7·2	751	W.	3·7
„ 25	Fine	3·6	6·1	763	W.	4·1
„ 30	Dull	5·	7·2	752	W.	5·0
February 6	Fine	5·	7·2	755	E.	3·7
„ 14	Dull, rain	6·	7·1	755	S.E.	4·2
„ 22	Fine	10·	11·	775	N.W.	4·2
„ 27	Dull	6·1	7·7	773	N.W.	3·9
March 6	Very fine	1·6	5·0	765	N.E.	3·8
„ 13	Fine	2·7	5·5	752	N.E.	4·3
„ 15	Fine	1·1	3·3	750	N.E.	4·0
„ 21	Fine	1·6	4·4	751	N.E.	3·9
„ 27	Dull	2·7	6·1	761	N.W.	3·8
„ 31	Fine	6·1	8·8	758	N.W.	3·7
April 3*	Very foggy	10·	12·2	762	W.	13·3
„ 5	Overcast	14·4	18·3	759	S.E.	4·8
„ 8*	Dull, slight fog	7·7	11·1	756	S.E.	4·7
„ 13	Dull	9·4	15·5	758	S.	4·1
„ 17	Dull	5·5	7·2	752	S.E.	4·0
„ 20	Fine	2·2	4·4	762	S.E.	4·0
„ 28	Fine	10·0	15·0	754	N.W.	3·6
„ 30	Very fine	11·6	16·1	756	N.W.	3·7
May 6	Fine	12·2	18·3	761	W.	3·6
„ 12	Dull	12·2	13·8	765	S.W.	4·0
„ 14	Dull (Whit Monday)	14·4	17·7	758	S.E.	3·3
„ 16	Very fine	16·1	20·5	758	N.W.	3·6
„ 20	Very fine	15·5	20·1	761	W.	3·5
„ 24	Very fine	15·0	23·3	764	N.W.	3·4
„ 31	Very fine	15·1	21·6	765	S.	3·8
June 6	Very fine	16·6	21·6	756	W.	3·6
„ 13	Very fine	17·2	23·3	760	N.W.	3·5
„ 20	Dull, with rain	13·3	16·6	758	S.E.	3·5
August 5	Dull, after rain (Bank Holiday)	15·0	17·2	762	N.W.	3·3
October 10*	Dull, yellowish fog	12·2	13·8	760	N.W.	4·5
„ 11*	Dense black overhead fog, 10.30 a.m.	11·6	12·7	758	S.E.	7·6
„ „	Fine sun after, 3.30 p.m.	12·2	13·3	758	N.W.	5·1
„ 18	Very fine	8·8	12·2	756	N.W.	3·8
„ 25	Dull	14·4	16·6	757	W.	5·1
„ 30	Dull and misty	11·1	12·2	772	S.E.	3·9
November 6	Dull	7·2	8·5	739	N.E.	4·2
„ 15*	Dull and foggy	5·5	7·7	761	W.	6·6
„ 22	Dull	9·4	11·6	753	S.E.	3·7
„ 29	Very fine	7·2	10·0	752	N.E.	3·8
December 4	Very fine	3·8	6·6	754	N.W.	3·4
„ 6	Dull and snowstorms	0·5	2·2	764	N.E.	4·5
„ 7	Fine	1·1	3·3	763	N.E.	4·5
„ 10	Dull and misty	6·6	8·8	758	N.W.	4·3
„ 12	Dull, stormy	7·2	9·4	756	W.	3·9
1884.						
January 16*	Dull, slight fog	6·1	7·2	776	N.W.	5·5
„ 17	Very dull	6·3	7·6	771	W.	4·2
„ 18*	Dull and foggy	6·6	8·3	775	S.W.	4·5
„ 22	Dull and stormy	8·8	11·1	762	W.	3·3
„ 24	Very fine	3·3	6·1	758	N.W	4·1
„ 26	Dull and rainy	6·1	7·2	763	S.W.	4·1

TABLE I.—*continued.*

Date.	Weather.	Temperature. C. Wet Bulb.	Temperature. C. Dry Bulb.	Barometer in m.m.	Direction of Wind.	Vols. of CO_2 in 10,000 of Air.
1883.						
January 28	Very fine	5·0	7·2	763	N.W.	3·7
February 7	Dull	5·6	7·0	768	S.W.	4·1
„ 8*	Black fog, 10.30 a.m.	6·1	7·7	747	S.E.	4·5
„ „	Black fog, 2 p.m.	6·1	7·7	747	S.E.	5·1
„ „	Black fog, 6 p.m.	6·1	7·7	747	S.E.	5·5
„ 16	Very fine	3·8	6·1	762	S.E.	3·5
„ 18	Very fine	6·1	8·3	761	E.	4·0
„ 21	Dull and rain	6·1	8·3	763	S.E.	4·0
„ 28	Dull	6·1	7·7	760	S.E.	3·8
March 6	Fine	8·3	10·5	759	S.E.	3·9
„ 13	Fine	11·1	13·8	765	S.W.	3·7
„ 27	Dull	2·7	6·1	764	E.	3·7
April 25	Dull	6·1	8·3	750	N.E.	4·1
„ 27*	Overhead fog, 11.30 a.m.	7·2	8·3	754	S.E.	5·3
„ „	After, clear at 2 p.m.	7·2	8·3	754	S.E.	4·6
„ 28	Yellowish fog (slight)	8·8	10·0	753	S.E.	4·8
May 9	Dull	9·4	11·6	762	S.E.	3·8
„ 15	Dull	12·7	15·3	757	S.E.	4·1

From this table are taken out all the special determinations made during a fog or even a mist, and these are put together in Table II. At the commencement of the investigation, when two experiments were made, the samples of air were in a few cases collected simultaneously, but generally the second sample was collected about an hour after the first one. Omitting, then, from Table I. all the fog experiments (marked by an asterisk), and in the case of where there are two experiments, taking the mean, then the mean of all these determinations is 4·03; this represents the volume of carbonic acid in 10,000 volumes of London air.

Taking the years separately, the mean for 1882 is 4·10; for 1883, 3·98; and for 1884 up to May, 3·92.

It appears, then, that the average amount of carbonic acid in the City in ordinary weather is not appreciably above four parts in 10,000 of air, and if we take the results of 1883 and the first half of the present year, and these are the more systematically carried out experiments, then the average amount is only 3·96.

This number seems to compare favourably with other towns. Dr. Angus Smith, in Manchester in ordinary weather, found 4·03, in Perth 4·14, and in Glasgow 5·02 parts of carbonic acid in 10,000 of air.* Roscoe and McDougall found in Manchester air 3·92 of carbonic acid. With regard to previous experiments on London air, and it is to be remembered that all the experiments here given are from the very centre of London, those of Angus Smith are, as far as I know, the only systematic ones recorded. He found in 1864, as the mean of five experiments, that the amount of carbonic acid in the air of the parks of London was 3·01, and in the streets 3·80;† and in 1869 as the mean of 35 analyses of air from different parts of London he found 4·39.

It has been generally assumed that the normal amount of carbonic acid in pure air is four parts in 10,000, but the elaborate and careful experiments that have of late been carried out on the Continent, seem clearly to show that this number is much too high.

The extensive series of experiments carried on by F. Schultze, at Rostock, who analysed the air daily for four years (1868–71), give as a mean only 2·9197, the maximum being 3·44, and the minimum 2·25 parts per 10,000.

Schultze also deduces from his experiments that the amount of carbonic acid does not vary with the time of year.

Thorpe,‡ from a series of 77 very carefully conducted experiments, concludes that the air over the sea contains 3·011 parts of carbonic acid, while he assumes, from the experiments of others, that air over the land contains 4·04.

G. F. Armstrong§ found in the air at Grasmere 2·96 parts during the day and 3·30 parts during the night, and assumes that the land air contains 3·5 parts in 10,000.

Reiset at Dieppe obtained in 1872–73 as the mean of 92 experiments 2·942 parts per 10,000 of air.

Further, the elaborate experiments made at the Montsouris Observatory give as a mean of the determinations from 1877–82, 3·000,‖ and, lastly, the mean of the experiments of Angus Smith, made in

* "Air and Rain."—Angus Smith. † "Air and Rain," p. 8. ‡ "Chem. Soc. Jour.," Vol. XX.
§ Proceedings of Royal Soc, 1880. ‖ Annuaire de l'observation de Mountsouris 1883, p. 379.

1865 of the air on the Scotch hills, is 3·36 parts per 10,000 of air. These appear to be the most important determinations of the amount of carbonic acid in pure air the difference between them is not great; and on taking the mean of these five sets we get the number 3·036, which probably fairly represents the amount of carbonic acid in the purest air.

On comparing this amount with that found in the centre of London, we see that the increase is only 1 part in 10,000 of air. On examining Table I. it will also be seen that it very often happens that the amount of carbonic acid is very considerably below the average, and that when this is the case the weather is fine with bright sun. The diminution of the amount of carbonic acid in bright weather in the country has been assumed to arise from the increased activity of the chlorophyll in vegetation. In the City the diminution probably arises from the production of an active circulation in the air. The smallest amount of carbonic acid found in the City air was 3·0 and this was on a Bank Holiday, August 7, 1882; in fact, it appears that the amount is usually low on these holidays, for on both Whit Monday and the August Bank Holiday of last year, the carbonic acid only amounted to 3·3 parts.

In country air, as before mentioned, it appears that the amount of carbonic acid does not vary with the time of year in London as we should naturally expect it does. The following are the results obtained by taking the mean of the summer (April—September) and of the winter (October—March) observations separately:—

	Vols. of CO_2 per 10,000 of Air.	
	Winter.	Summer.
1882	4·70 (Jan.–Mar. only.)	3·86
1882–83	3·94	3·72
1883–84	4·01	

Which give as a mean for the three winters 4·22, and for the two summers 3·79 parts per 10,000 of air.

Turning now to the cases in which the average amount of carbonic acid has been exceeded, we find this is always the case when there is any fog or mist. Evidently, then, the products of combustion and respiration cannot pass freely away, but accumulate often to a very considerable extent in the lower air. The cases when there is no fog and the carbonic acid is above the average are when the weather is dull and gloomy and the air still. Table II. gives exclusively the results of experiments made when there was either a fog or a mist, and shows very well the great accumulation of carbonic acid which often occurs. The results of the experiments are shown graphically in Plates C. and D.

TABLE II.

FOG AND MIST EXPERIMENTS.

Date.	Weather.	Temperature. C. Wet Bulb.	Temperature. C. Dry Bulb.	Barometer in m.m.	Direction of Wind.	Vols. of CO_2 in 10,000 of Air.
1882.						
January 17	Dense black fog	—	10·	786	S.	6·7
„ 18	Dense black fog	—	4·	786	S.	5·7
„ 19	Slight white fog	—	6·	768	S.	4·8
„ 25	Dense black fog	—	3·5	780	S.	10·5
February 3	Slight fog	3·	4·4	781	S.	6·9
„ 4	Dense black fog	4·	5·	785	S.	10·7
March 15	Slight white fog	9·	11·	775	N.E.	5·6
October 26	White fog	0·6	7·7	750	W.	9·9
November 18	Dense black fog	2·2	2·7	760	S.E.	9·6
December 1	Thick white fog	1·6	2·2	765	S.	5·5
„ 2	Slight mist	1·1	1·6	766	S.E.	5·1
„ 10	Thick white fog	0·5	1·1	755	S.W.	9·4
„ 11	Thick white fog, darker noon	0·0	0·5	755	S.W.	11·0
„ „	Thick white fog, very dark 5 p.m.	0·0	0·5	755	S.W.	14·1
„ 14	White fog, slight	4·4	4·4	755	S.E.	6·2
„ 15	White fog, slight	5·	6·1	753	S.E.	5·4

TABLE II.—*continued.*

Date.	Weather.	Temperature, C. Wet Bulb.	Temperature, C. Dry Bulb.	Barometer in m.m.	Direction of Wind.	Vols. of CO_2 in 10,000 of Air.
1882.						
December 15	Overhead fog, white	3·3	4·4	760	S.E.	4·8
„ 20	Dense black fog	4·4	4·7	767	S.	8·1
1883.						
January 19	Slight fog	10·	8·8	763	S.W.	5·0
April 3	Fog, dense	10·	12·2	762	W.	13·3
„ 8	Slight white fog	7·7	11·1	756	S.E.	4·7
October 10	Slight yellow fog	12·2	13·8	760	N.W.	4·5
„ 11	Dense black fog	11·6	12·7	758	S.E.	7·6
November 15	Slight yellow fog	5·5	7·7	761	W.	6·6
1884.						
January 16	Slight yellow fog	6·1	7·2	776	N.W.	5·5
„ 18	Slight fog	6·6	8·3	775	S.W.	4·5
February 8	Black fog	6·1	7·7	747	S.E.	5·5
April 27	Overhead fog	7·2	8·3	754	S.E.	5·3
„ 28	Yellowish fog, slight	8·8	10·0	753	S.E.	4·8
						29)207·3
					Mean	7·2

The largest amount of carbonic acid found was 14·1 parts, this was on December 11th, 1882, and was during a long-continued fog. On referring to the table it will be seen that the fog had begun on the previous day, when there was a "thick white fog," and the carbonic acid had then increased to 9·4; at noon on the 11th there were 11·0 parts, and at 5 p.m. the carbonic acid had increased to 14·1 parts in the 10,000 of air, that is, there was more than three and a half times the normal amount present. Supposing, then, this had been an increase of only pure carbonic acid, such a change in the composition of the atmosphere would be felt by most people, but an accumulation of carbonic acid means, certainly, a very large accumulation of other bodies, which probably are more, rather than less, deleterious than carbonic acid itself.

In Table I. will be seen several instances of the rapid change in the composition of the air with the clearing off of a fog. The following are instances:—

Date.	Vols. CO_2 per 10,000 of Air during Fog.	Vols. CO_2 per 10,000 of Air when Fog had cleared.
October 26, 1882	9·9	5·0 (2 hours after)
November 18, 1882	9·6	5·0 ($1\frac{1}{2}$ „)
December 1, 1882	5·5	4·1 ($4\frac{1}{2}$ „)
„ 20, 1882	8·1	5·2 ($1\frac{1}{2}$ „)
October 11, 1883	7·6	5·1 (5 „)
April 27, 1884	5·3	4·6 ($2\frac{1}{2}$ „)

Table II. contains 29 experiments, and the mean of all these is 7·2; the maximum, as above stated, being 14·1, and the minimum 4·7. With regard to the time of year when these 29 experiments were made—

7	were made in January.	3	were made in October.
3	„ February.	2	„ November.
1	„ March.	9	„ December.
4	„ April.		

The above experiments certainly confirm the impression that the carbonic acid in a town air is a very important indication of its purity.

Table IV. *Plate A.*

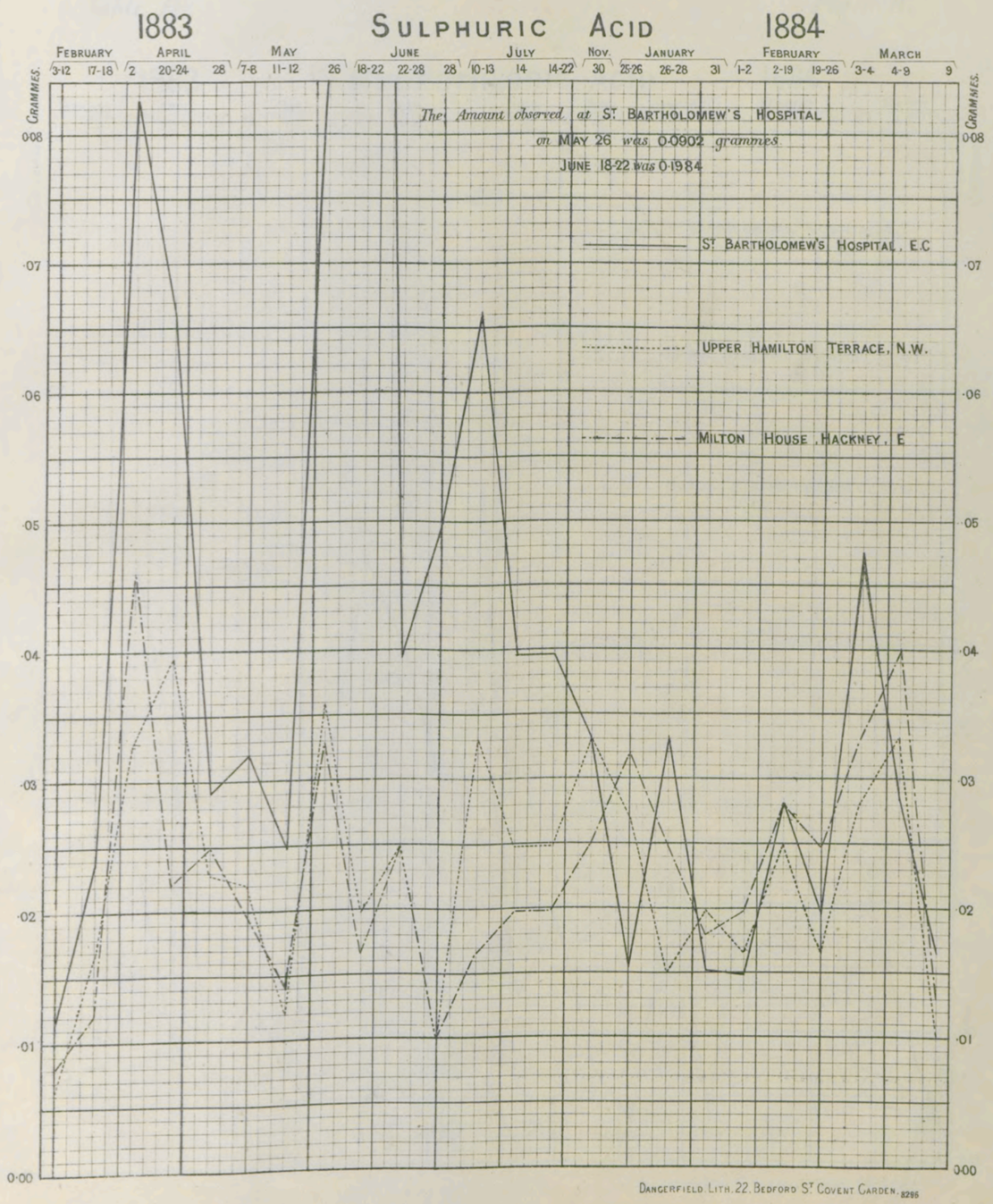


Table IV. *Plate B.*

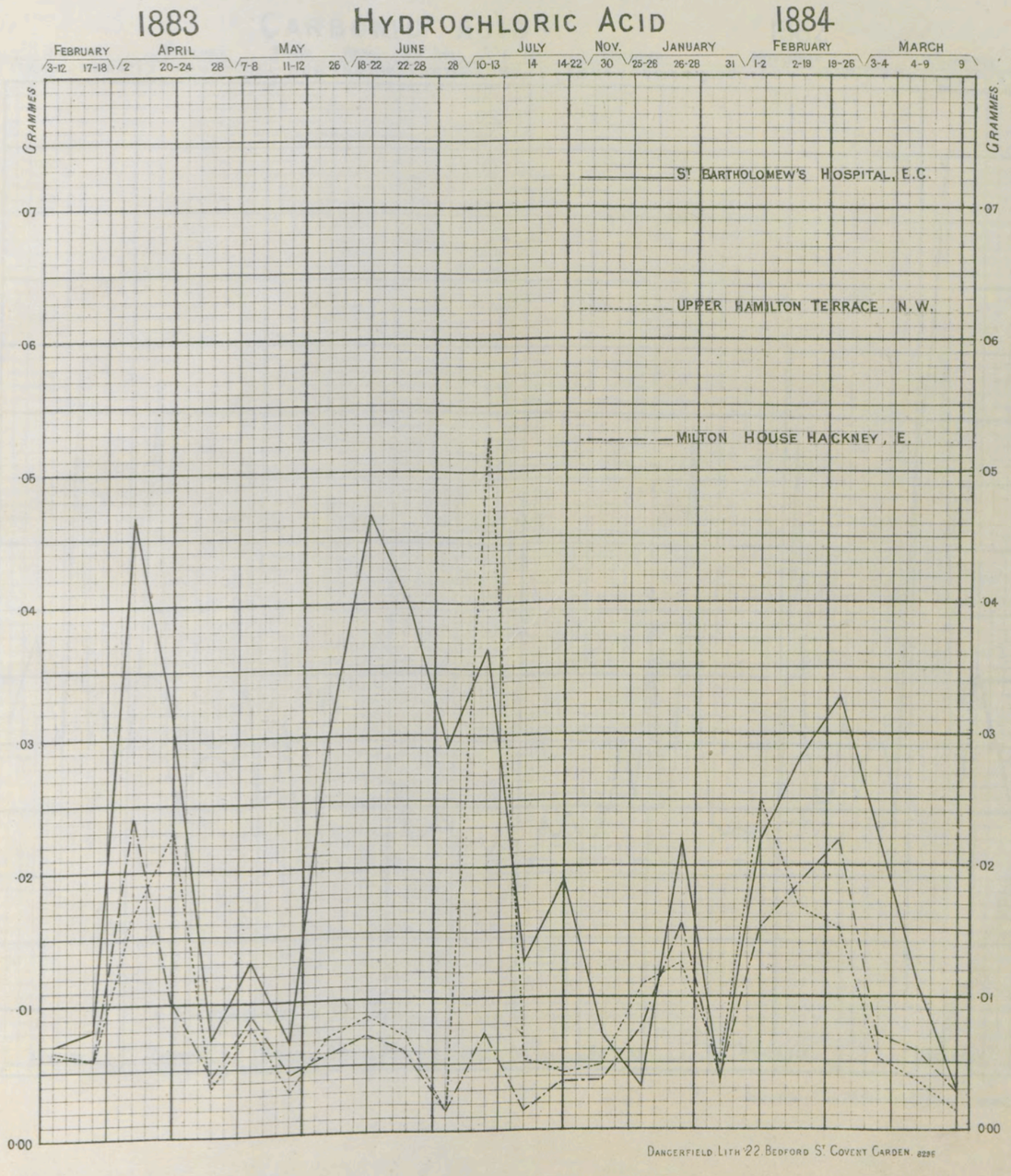


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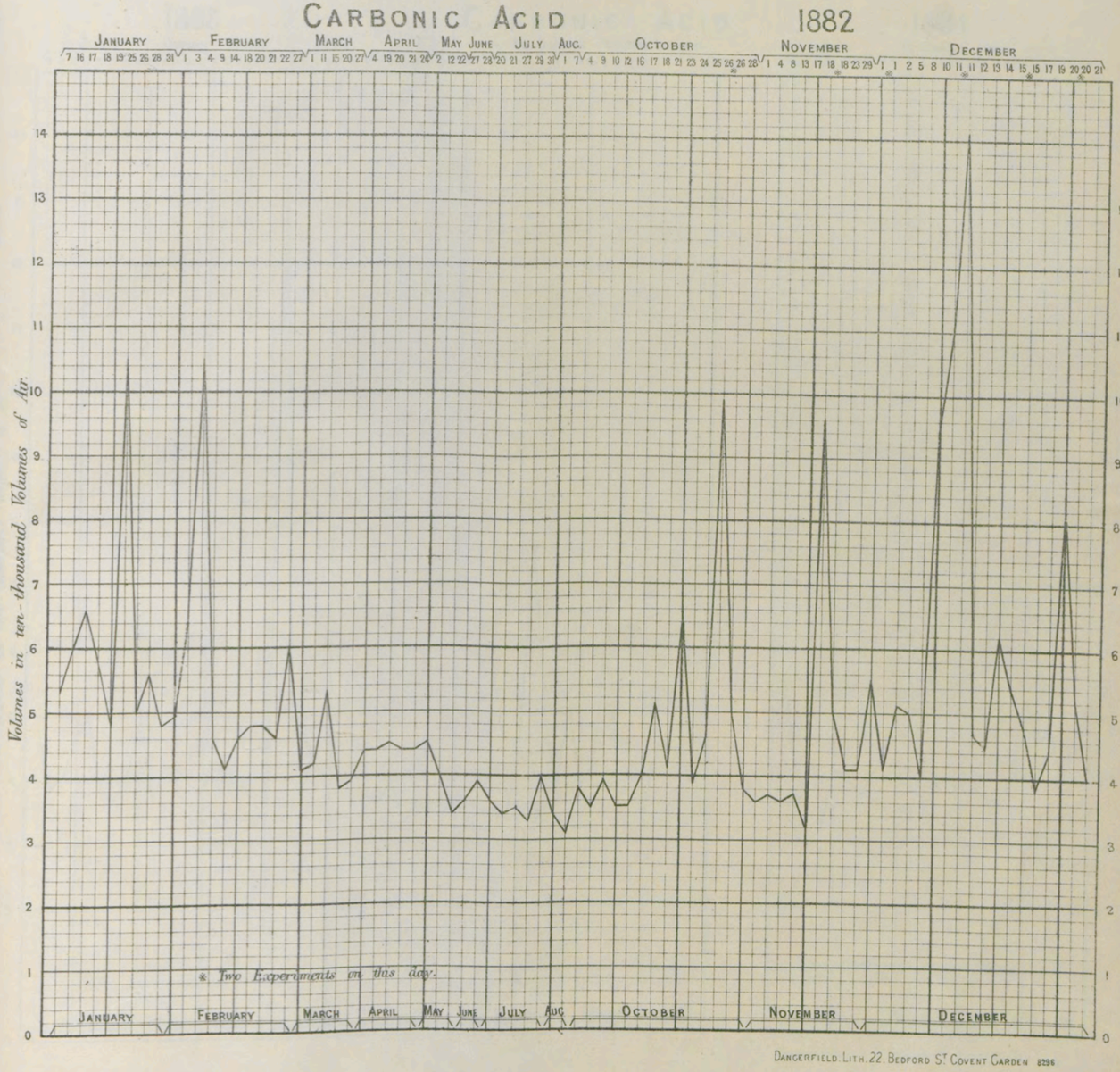
Plate C.



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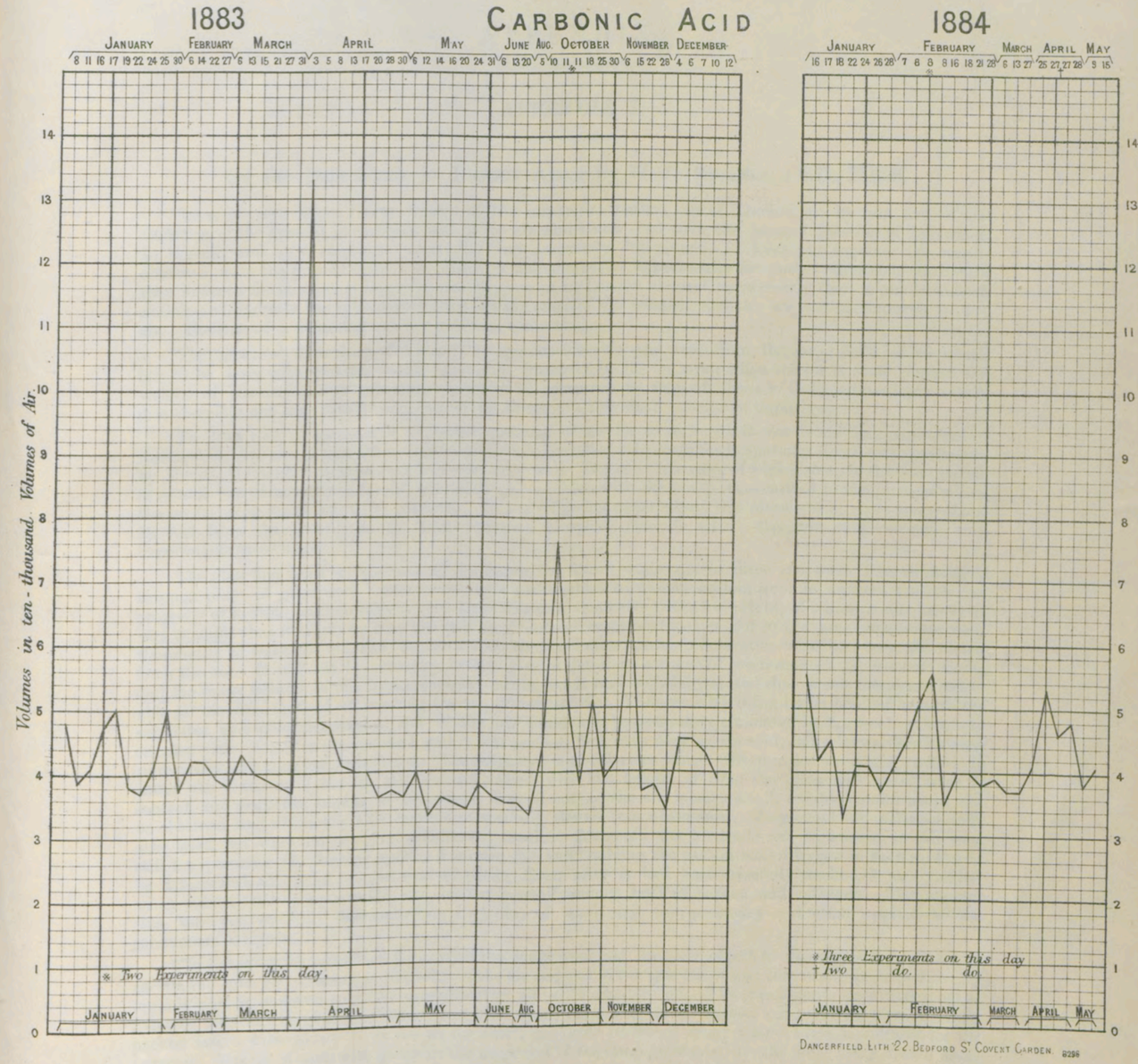

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Monthly Weather Report, August, 1885.

APPENDIX.

APPENDIX I.

On the Impurities in London Air.—By W. J. Russell, Ph.D., F.R.S.

In a previous report I have treated of the impurities washed out of London air by rain, and of the variation of the amount of carbonic acid in the air, and I now deal with the general question of impurities in the air, and how they can be readily and accurately determined. I have put together the results obtained up to the present time, and although the number of experiments for such a subject is small, still they indicate the amount of impurity usually present in London air, and, more clearly than might have been anticipated, indicate the relationship between the state of the weather and the amount of impurity in the air. The case of a dense fog has not yet been examined.

The practical difficulties of this inquiry are considerable, and arise from the large bulk of air which has to be dealt with, and the small amount of impurity in it, for even when the air is most impure the weight of the extraneous substances present is, compared to that of the air itself, exceedingly small, it is therefore not easy rapidly and completely to remove this small amount of impurity.

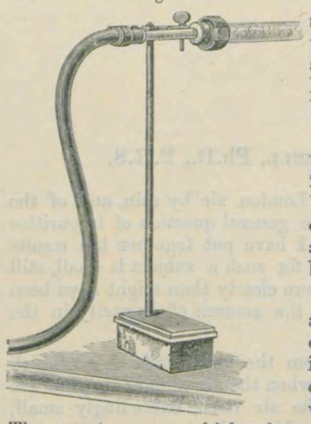
To draw and to measure a sufficient quantity of air for experiment it was found that aspirators of manageable size would not answer; a large double-barrelled air pump, made specially for these experiments by Messrs. Owens & Co., answered, however, very well. The cylinders were of such size as to draw a quarter of a cubic foot of air at each stroke. Metal tubes connected with the pump were carried to the place at which the air for experiment was to be collected. In the following experiments this place was an open space about 12 feet from the ground at St. Bartholomew's Hospital, close to where the rain and carbonic acid experiments were made.

The plan first tried for abstracting the impurities from the air was to filter and wash it by drawing it through plugs of glass wool. Glass wool, which resembles so closely cotton wool in appearance, has the property of holding mechanically a very large amount, about five times its weight, of water, consequently it was thought that it would be easy not only to remove all suspended matter, but in the same experiment very thoroughly to wash the air, and, by examining the wool afterwards, to determine what had been abstracted from the air. It will not be necessary here to give in detail an account of the numerous experiments made, and the many failures to obtain satisfactory results, but it may be briefly stated that it was found impracticable to use this method of washing the air, not on account of the washing being imperfect, but because the sulphates and chlorides washed out of the air could not be accurately estimated in the wool. Carefully selected glass wool was always used, and it was washed first with very dilute acid, and afterwards with very pure water and then carefully dried. The sulphates and chlorides which this purified wool still yielded to water was determined, but as this amount varied with the length of time the glass and water were in contact, and since the amount of these salts washed out of the air is very small, reliable results could not be obtained, and ultimately this method of washing the air was abandoned. Slag wool and asbestos were also tried, but they did not give satisfactory results. Although the air could not be washed in this way, still for removing the floating matter from the air, and enabling the carbon and nitrogen in such matter to be determined, this wool seemed well adapted. Even after it had been carefully washed, it still yielded, when mixed with copper oxide and heated, a small amount both of carbon and nitrogen. The amount was, however, carefully determined in each lot of wool, and the necessary correction applied to the subsequent analyses.

The following experiments, then, with the glass wool had for their object to determine the amount of carbon and nitrogen existing as impurity in the air and not in the gaseous state; this would include different organic matters, soot and such like products, from imperfect combustion. The experiments were carried out as follows: 13 grams of glass wool which had been washed and assayed for carbon and nitrogen, were carefully packed into a tube about 1½ inches in diameter, and 9 or 10 inches long; a lamp glass is suitable for the purpose. A piece of wide wire gauze in the large end of the lamp glass prevents the wool being drawn along by the current of air, and the metal tube from the air pump is also fastened into this end of the glass by an india-rubber plug (Fig. 1 p. [2]). The above amount of glass wool, when so used, seemed able to withdraw the organic matter from the air passed through it, if not with absolute completeness, still very thoroughly. An experiment made to test this point by using two plugs and analysing them separately was carried out

under the most trying circumstances,—that of a fine day. In the first plug ·0043 of carbon and ·0005 nitrogen were found, and in the second plug ·0009 carbon and ·0003 nitrogen,—amounts which are really within the error of observation. The reason in the first instance for selecting this amount of glass wool was, that it is the largest quantity which can conveniently be heated in the combustion tube at one time, and obviously it is very disadvantageous, and liable to lead to error, to have to analyse only a sample instead of the whole of the wool which has been used.

Fig. 1.



To draw the air through this plug of glass wool the pump was usually worked at a rate of about 1,000 strokes in the hour, thus drawing about 250 cubic feet of air, or a little less, in that time. On a fine day at least 1,000 cubic feet of air are required for a single experiment. The amount of carbon and nitrogen abstracted from the air, and representing the organic and carbonaceous impurities floating in the air, was determined by combustion with copper oxide in the ordinary way.

The glass wool, after the experiment, was wetted with sulphurous acid (perhaps an unnecessary proceeding to eliminate the presence of any carbonates), dried, powdered, and intimately mixed with copper oxide, and introduced into a combustion tube, the carbonic acid and nitrogen evolved, carefully collected by a Sprengel pump and then measured. Thus the weight of carbon and nitrogen in the air experimented on was determined. The great power which glass wool has of removing dust from the air is seen by the slight brown colouration which occurs, even on the finest days, where the air and wool first come into contact, and in case of fog a very few cubic feet of air are sufficient to render the wool at this point quite black. The glass wool, owing to its being a lead glass, appears to act as a very delicate test for sulphuretted hydrogen, but it is difficult to distinguish between the brown shade produced by dust and that produced by a trace of lead sulphide.

This method for estimating the organic floating matter in the air was finally arranged in the autumn of 1883, and, omitting all previous experiments as imperfect, the following are all the determinations made since that date. No dense fog that could be experimented on occurred, but on looking through the descriptions of the weather made at the time, the experiments may be classed as occurring in fine, dull, and foggy weather, and that classification of weather has been adopted in arranging all the experiments in this report.

FINE WEATHER.

Grams per 1,000 Cubic Feet of Air.

——	Carbon.	Nitrogen.	Total Organic Matter.
October 20, 1883	·0043	·0005	·0048
June 26, 1884	·0025	None	·0025
June 24, 1885	·0032	None	·0032
Mean	·0033	·0002	·0035

DULL WEATHER.

Grams per 1,000 Cubic Feet of Air.

——	Carbon.	Nitrogen.	Total Organic Matter.
October 30, 1883	·0068	None	·0068
December 8, „	·0092	·0011	·0103
February 18, 1884	·0067	·0004	·0071
March 27, „	·0114	None	·0114
April 28, „	·0115	None	·0115
„ 29, „	·0150	None	·0150
January 20, 1885	·0101	·0003	·0104
Mean	·0101	·0002	·0103

FOGGY WEATHER.

Grams per 1,000 Cubic Feet.

——	Carbon.	Nitrogen.	Total Organic Matter.
January 18, 1884	·0182	None	·0182
February 8, „	·0310	·0010	·0320
January 9, 1885	·0226	·0005	·0231
Mean	·0239	·0005	·0244

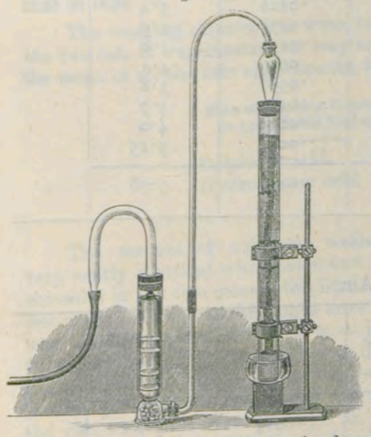
The above experiments very clearly indicate the considerable variation which occurs in the amounts of organic matter in the air, at different times. A very much larger number of experiments should be made, but taking the mean of each set of experiments, the following numbers are obtained, viz.:—

Carbon ·0033, Nitrogen ·0002; for fine weather.
„ ·0101, „ ·0002; for dull weather.
„ ·0239, „ ·0005; for foggy weather.

They indicate that a close relationship exists between the weather and the amount of organic matter in the air.

The method first tried for washing the air, viz., with moist wool, was not, as before stated, successful; another method had therefore to be found in place of it. To wash every trace of soluble matter out of a large bulk of air in a short space of time is all but impossible; all that is feasible is to make the washing as complete as possible. The difficulty of washing the air thoroughly for the present purpose is much increased owing to the necessity for using a small bulk of water, for since the absolute amount of impurity in the air is so little if it be diffused through a large bulk of water, it cannot be accurately determined. Another difficulty is the rapidity with which the washing has to be done. Fig. 2 shows the form of apparatus finally adopted, and it seems to fulfil the above requirements and acts well. It consists of a glass cylinder 2 feet 9 inches long and 2¾ inches in diameter; inside this cylinder and reaching from near the top to within some 4 inches of the bottom two pieces of a somewhat coarse (about 300 meshes to the inch) wire gauze are fixed at right angles to one another, and held in position by the elasticity of the gauze, thus from the centre of the tube four arms radiate out, dividing the inside into equal spaces. This wire gauze is cut into six different lengths, and between each length a disc of wire gauze is placed across the tube. A stopper of pure india-rubber fits into the top of the cylinder and carries a glass adapter, which serves to collect the water carried along by the current of air, and in order still further to prevent this loss of water, a disc of platinum foil is held by a platinum strap, cut out of the same piece of foil, in front and a little below the small end of the adapter, and another disc is placed at the end of the tube passing from the top of the adapter. The lower end of this washing cylinder is open and is placed a little above the bottom of a glass vessel,—a strong glass finger-bowl answers exceedingly well. To use the apparatus, the necessary amount of water, some 400 c.c., is placed in this bowl, then on working the pump the air forces the water up into the tube, some falling back between each stroke; but the strong current of air passing up the tube carries the water gradually higher and higher in the tube, till at last it becomes stationary, and if the upper wire discs be of a little finer gauze than the lower ones, then, as long as the flow of air continues, a layer of water will rest on each disc, and through each of these the air will have to pass in succession, throwing the water into spray, and beating it against the wire gauze uprights,—in fact, the air before it leaves the tube has undergone six distinct washings, and washings in which it has been brought most intimately in contact with the water. As soon as the pump stops, all the water trickles down from cylinder and gauze, and collects again in the bowl. In this way as large an amount of washing as possible is done with this small amount of water, still, soluble salts passed through, and a second washing apparatus was added; it consists simply of a large sized eprouvette of the same diameter as the washing cylinder. The bottom chamber is partly filled with glass marbles to lessen the amount of water necessary, and to break up the air as it enters;

Fig. 2.



four discs of gauze are placed above and act as in the first washing cylinder, they are held in their place by pieces of glass tube cut of different lengths, and of such diameter as to slip inside the éprouvette ; these reach to the cork which holds them all in their places. 200 c.c. of water was usually used in this part of the apparatus, making altogether 600 c.c. of water used for the washing ; through this some 500 to 1,000 cubic feet of air were passed at about the same rate as in the glass wool experiments. The wire gauze should all be of platinum. The discs used in the following experiments were of platinum, but the upright gauze in the first washer was brass thickly nickelled. The whole apparatus before being used was carefully cleaned and soaked in distilled water till the water yielded no trace of sulphates or chlorides. In hot weather very considerable evaporation occurs, and if not obviated by adding more water the washing may become less complete from loss of liquid.

Since the above experiments were completed Mr. Fletcher, chief inspector of alkali works, mentioned to me a case in which the washing power of a given quantity of water used as above had been very considerably increased by suspending in it a solid, in that particular case sulphate of lime. Acting on this idea, I have made a few experiments with pure sand, suspended in the 400 c.c. of water used. In the first experiment the sand did apparently increase the washing power of the water, in the second experiment this is doubtful.

Again omitting the earlier experiments, the following have all been made with the apparatus in the form above described. They are arranged, with regard to weather, under the same three heads: fine, dull, foggy.

Fine Weather.

Grams per 1,000 Cubic Feet of Air.

——	Sulphuric Acid.	Hydrochloric Acid.	Total.	Volumes of Carbonic Acid in 10,000 of Air.
January 26, 1883 - - -	·0078	·0010	·0080	4·1
February 6, „ - - -	·0048	·0002	·0050	3·7
„ 22, „ - - -	·0142	·0014	·0156	4·2
May 1, „ - - -	·0146	·0014	·0160	3·6
„ 24, „ - - -	·0114	·0008	·0122	3·4
July 13, „ - - -	·0142	·0036	·0178	3·9
„ 19, „ - - -	·0142	·0011	·0153	3·8
January 24, 1884 - - -	·0078	·0001	·0079	4·1
„ 28, „ - - -	·0367	·0029	·0396	3·8
June 26, „ - - -	·0119	None.	·0119	3·7
April 29, 1885 - - -	·0095	None.	·0095	4·0
June 24, „ - - -	·0069	None.	·0069	3·15
Mean - - - -	·0128	·0010	·0138	3·78

Dull Weather.

Grams per 1,000 Cubic Feet of Air.

——	Sulphuric Acid.	Hydrochloric Acid.	Total.	Volumes of Carbonic Acid in 10,000 of Air.
January 17, 1883 - - -	·0184	·0029	·0213	4·7
„ 19, „ - - -	·0160	·0028	·0188	4·7
February 27, „ - - -	·0136	·0022	·0158	3·9
August 1, „ - - -	·0179	·0019	·0198	4·1
December 8, „ - - -	·0475	·0066	·0541	4·6
„ 10, „ - - -	·0529	·0021	·0555	4·3
January 22, 1884 - - -	·0213	·0013	·0226	3·3
February 18, „ - - -	·0416	·0012	·0428	4·0
March 27, „ - - -	·0496	·0018	·0514	3·7
April 28, „ - - -	·0363	·0055	·0418	4·8
„ 29, „ - - -	·0360	·0109	·0469	4·8
Mean - - - -	·0319	·0036	·0355	4·5

Foggy Weather.

Grams per 1,000 Cubic Feet of Air.

——	Sulphuric Acid.	Hydrochloric Acid	Total.	Volumes of Carbonic Acid in 10,000 of Air.
February 1, 1883 - - -	·0433	·0029	·0462	5·6
January 16, 1884 - - -	·0535	·0009	·0544	5·5
„ 18, „ - - -	·0476	·0016	·0492	4·5
February 8, „ - - -	·0397	·0058	·0455	5·0
Mean - - - -	·0460	·0028	·0488	5·1

The difference in the amount of sulphates in the air in fine, dull, and foggy weather appears to be considerable. Taking the mean of each set of the above experiments, we find in 1,000 cubic feet of air in the city sulphates which correspond to ·0128, ·0319, ·0460 of sulphuric acid in fine, dull, and in foggy weather respectively.

From the analysis of London rain, it was shown that the amount of chlorides in the air, as judged by the amount found in rain, was much less than the amount of sulphates. With the artificial washing of the air the same of course is the case ; and in fine weather, when some 800 cubic feet of air were washed as above described, the water used did not yield more than the slightest trace of chlorides,—in fact not sufficient to admit of their estimation. The mean amount of chlorides obtained in dull weather, it will be seen, is somewhat higher than the mean of the foggy weather experiments. Although it is not possible to say what amount of air has been washed by falling rain, or how thorough that washing has been, still it is of much interest to compare the relative amount of sulphates and chlorides in the artificial washing of air with that in rain.

The washing experiments were made at irregular intervals, and for the purpose of roughly comparing the two sets of experiments we may take the mean of all the washing experiments and compare them with the mean of all the rain experiments, both sets having been carried on at the same place :—

Mean of Washing Experiments. In 1,000 Cubic Feet of Air.		Mean of Rain Experiments. In 1 Litre.	
Sulphuric acid	·0184	Sulphuric acid	·0388
Hydrochloric acid	·0023	Hydrochloric acid	·0179
	1 : 8		1 : 2·2

The amount of sulphates washed out of a 1,000 cubic feet of air, by a curious coincidence, is very nearly identical with that found in a litre of rain, but there is considerable difference in the amount of chlorides in the two cases,—the litre of rain water containing three or four times as much as the 1,000 cubic feet of air. Of course this might arise from the artificial washing being either more perfect, and thus taking more sulphates out of the air, or more imperfect, and leaving more chlorides in the air ; or it might be that in the higher atmosphere there are more chlorides present than in the lower. From experiments made with dew, to be mentioned further on, it would seem that the proportion between chlorides and sulphates in the rain is most probably the correct one, but it is not obvious why, if the sulphates are washed out completely, the chlorides should, to so large an extent, remain behind. It seemed possible that during the washing hydrochloric acid might be formed and be removed by the large quantity of air passing through the washing water ; to test whether this was the case two experiments were made in which the washing water was made alkaline, in one case by a very small quantity of sodium carbonate, in the other by a very small quantity of caustic soda ; in neither case was there an increase in the proportional amount of chlorides.

Some samples of this washing water were also examined for ammonia salts and for organic matter, but water through which so much air has been driven is not suitable for their determination.

Dew.—In my report on the London rain waters I mentioned having made a few experiments on the impurities found in dew. These experiments have been continued, and the following results obtained In order to collect a sufficient amount of dew a large conical metal vessel, previo usly described, was first

used, but was abandoned in favour of a large glass funnel, about 10 to 12 inches in diameter the tube end of it was sealed up and drawn out to a point. From such a funnel more moisture was collected than from the metal vessel; this apparently arises from the fact that when the metal funnel was filled with ice the surface became studded all over with drops of dew, which do not unite and flow off, and consequently preventing to a considerable extent any further condensation taking place, whereas on the glass the moisture as it forms into drops runs down the side of the funnel, and fresh moisture takes its place. This artificial formation of dew may be looked upon as another way of washing the air, and has many advantages: it is local, apparently thorough, and goes on without constant attention. On the other hand, it cannot practically be carried on in a very dry atmosphere and of course there is the inconvenience in many places of obtaining considerable quantities of ice. The following experiments were made as above described, and the dew was condensed at the same place where the rain had been collected, and where the washing of the air had been carried on, so far as possible to make the experiments comparable with the former ones. The dew thus collected is diluted with water, and the sulphates and chlorides determined in it by the same process as that adopted with the rain water.

The dew thus formed is also well adapted for indicating other important impurities in the air, specially ammonia, which, as being a product of the decomposition of nitrogenous bodies, it is important to recognise and to estimate, and also the organic and other oxydisable matter contained in it. The ammonia was estimated by the Nessler test, and the oxygen required to oxydise the organic matter by the permanganate test as described by Dr. Tidy. The numbers given below indicate the weight of oxygen required to oxydise the organic matter in a litre of dew; the weight of ammonia is also expressed per litre of dew. The dew is at times more or less dilute according as the air is more or less moist, and consequently the numbers are not absolutely comparable.

A record of the length of time taken to from the dew was in all cases kept, but it does not appear worth adding to the table.

DEW.

Grams per Litre of Dew.

——	Sulphuric Acid.	Hydrochloric Acid.	Ammonia.	Tidy.
October 14, 1884 - -	·0413	·0149	·0020	—
„ 15, „ - -	·0268	·0182	·0030	—
„ 17, „ - -	·0248	·0122	·0040	—
„ 18, „ - -	·0165	·0091	·0036	—
„ 22, „ - -	·0583	·0365	·0080	—
„ 24, „ - -	·0248	·0084	·0035	—
„ 25, „ - -	·0331	·0219	·0050	—
November 5, „ - -	·0354	·0237	·0080	—
December 1–2, „ - -	·1417	·0405	·0175	—
„ 4, „ - -	·0197	·0148	·0060	—
„ 8, „ - -	·0198	·0146	·0030	—
„ 10, „ - -	·0496	·0234	·0050	—
„ 11, „ - -	·0331	·0131	·0020	—
„ 12, „ - -	·0221	·0146	·0060	—
January 9, 1885 - - -	—	—	·0080	·0230
„ 26, „ - - -	·0331	·0168	·0100	·0420
„ 26 (night), 1885 - -	·0248	·0102	·0100	·0280
„ 27, 1885 - - -	·0141	·0116	·0040	·0250
„ 27–28, „ - - -	—	—	·0080	·0280
„ 29–30, „ - - -	—	—	·0130	·0265
„ 29, „ - - -	·0331	·0331	·0066	·0220
February 17, 1885 - -	—	—	·0150	·0314
„ 17–18, 1885 - -	—	—	·0300	—
Mean - - - -	·0382	·0188	·0079	·0282

The amount of sulphates and chlorides in the dew, it will be seen, is very considerable, and is curiously near to the amount which I have, in my former report, shown to be present in London rain. These impurities vary much in the same kind of way in dew as in rain; the most impure dew collected was that

on the night between December 1st and 2nd, the weather being then dull, moist, and foggy. Again, if these results be arranged according to the description of the weather recorded at the time of the experiments, they show in a remarkably clear and definite way how considerable is the variation of impurity in the air in different states of the atmosphere.

——	Fine Weather.	Dull Weather.	Foggy Weather.
Sulphuric acid - -	·0237	·0392	·0832
Hydrochloric acid -	·0145	·0197	·0245

With regard to the sulphates and chlorides, the following numbers, which are the mean of all the rain and all the dew experiments made at St. Bartholomew's, will show how singularly near in composition the dew is to that of the rain:—

——	Rain.	Dew.
Sulphuric acid - - -	·0388	·0382
Hydrochloric acid - - -	·0179	·0188
Total - - - -	·0567	·0570
Proportion of chloride to sulphate -	1:2·2	1:2·0

These natural ways, by rain and dew, of washing the air appear complete and satisfactory, and probably are better than the artificial washing, and it certainly seems that considerable information can be obtained of the impurities in the air by examining the dew. It is worthy of note that the ammonia varies with the weather in the same marked way as the other impurities do. The following table gives the weight of ammonia in grams per litre of dew collected at St. Bartholomew's:—

——	Fine Weather.	Dull Weather.	Foggy Weather.
Mean -	·0034	·0055	·0110

The estimation of the organic matter in the dew as represented by the amounts of oxygen required to oxidise it was only commenced in the present year, consequently very few results have been obtained, but these seem to indicate that the determination is of interest and worth carrying on.

GRAMS of OXYGEN required to OXIDISE the ORGANIC MATTER in LITRE of DEW.

Fine Weather.	Dull Weather.	Foggy Weather.
·0265	·0420	·0314

The total number of these experiments is only five, and only one of them was made on a day recorded as foggy.

This process of examining the air by the dew obtained from it has also been tested in other cases. Taking first the remaining out-of-door experiments. Two simultaneous experiments were made on December 12, 1884, at St. Bartholomew's, to see whether a variation of place would make much difference in the composition of the dew. One experiment was made at the usual place, the other on the ground in an open space at the distance of about 100 yards. In all respects except position the two experiments were similar. The samples of dew thus obtained gave on analysis the following results:—

——	Leads.	Ground.
Sulphuric acid - - -	·0221	·0283
Hydrochloric acid - - -	·0146	·0109
Ammonia - - -	·0060	·0080

Evidently the composition of both samples were nearly the same.

Two other experiments were made in a garden at Hackney where the samples of rain had been collected. The dew was collected on November 12 and on the 13th, both days being fine.

The two samples gave on analysis the following results:—

—	Nov. 12.	Nov. 13.
Sulphuric acid - - -	·0099	·0099
Hydrochloric acid - -	·0036	·0037
Ammonia - - - -	·0040	·0040

The two samples are then identical in composition and as might naturally be expected, are far purer than dew collected at St. Bartholomew's.

With the object of ascertaining what results would be given by an exceptional pure air, dew was condensed on Dartmoor in the same way, by means of ice and large glass funnels, as in London. Three experiments were made with the following results:—

Grams per Litre.	Dec. 31.	Jan. 1.	Jan. 2.
Sulphuric acid - - - -	trace.	trace.	trace.
Hydrochloric acid - - -	·0146	·0097	·0193
Ammonia - - - -	·0003	·0002	·0003
Oxygen required to oxydise organic matter.	·0056	·0031	·0051

Except the chlorides present ther were only traces of the other substances, and the organic matter present proved on miscroscopic examination to be only dead vegetable matter, grass and seeds blown against the funnels by the wind, and then washed into the collecting bottles.

This absence of organic matter may possibly account for what is very noticeable in this and some other pure airs, namely, the feeling of freshness which they excite even when saturated with moisture.

It certainly appears that the composition of dew may be fairly taken as indicating correctly the relative purity of the air; but still further to test the method a few experiments were made on the air of rooms and closed spaces. The following experiments show in a very marked way the composition of dew in different situations:—

——	Sulphuric Acid.	Hydrochloric Acid.	Ammonia.
In an empty cellar - - -	·0198	·0044	·0080
In an empty cellar - - -	·0099	·0015	·0025
In room with people waiting, but windows open.	·0708	·0219	·0175
In room with people waiting, but windows open.	·0248	·0018	·0085
In a dissecting room - -	·0763	·0073	·0450
In a stable (Dew collected during the night. Stable closed and smelt strongly of ammonia.)	trace.	·0061	·1000
Large room filled with children at Hoxton.	·0354	·0044	·0125
Same room after ventilating -	·0198	·0073	·0125
Same room, children present -	·0248	·0043	·0143
Water condensed from gas flame -	·2480	·0037	·0150

The above analyses are too few in number to do more than indicate the amount of the variation which may be looked for in the impurities in air from different sources, but this variation appears to be so considerable and characteristic that the examination of the dew may lead to more definite knowledge with regard to the impurity of an air, and may also indicate the nature and source of the impurity.

Before placing together the results obtained by these different methods of analysis I would add, as a supplement, the former experiments on rain, and as connecting the composition of rain with those of dew some further analyses lately made of rain, in which not only the amount of sulphates and chlorides has been determined, but also the ammonia and oxygen required to oxidise the organic matter, in fact rain water which has been examined in exactly the same way as the dew. These samples of rain were collected simultaneously at St. Bartholomew's and at Hamilton Terrace, St. John's Wood, two of the stations previously used.

Grams per Litre.	St. Bartholomew's.	Hamilton Terrace.	St. Bartholomew's.	Hamilton Terrace.	St. Bartholomew's.	Hamilton Terrace.	St. Bartholomew's.	Hamilton Terrace.
	January 10–12.		January 29–30.		January 30–31.		January 31–February 2.	
Sulphuric acid -	·0331	·0198	·0198	·0124	·0331	·0248	·0165	·0165
Hydrochloric acid -	·0124	·0081	·0112	·0083	·0251	·0164	·0167	·0167
Ammonia - -	·0040	·0020	·0030	·0034	·0040	·0034	·0024	·0030
Oxygen - -	·0080	·0053	·0073	·0056	·0057	·0063	·0044	·0055

	February 4.		February 16.		February 16–17.		Mean.	
Sulphuric acid -	·0198	·0066	·0271	·0066	·0191	·0082	·0241	·0135
Hydrochloric acid -	·0095	·0073	·0073	·0036	·0095	·0048	·0131	·0093
Ammonia - -	·0014	·0020	·0020	·0012	·0026	·0014	·0028	·0023
Oxygen - -	·0063	·0063	·0104	·0044	·0142	·0090	·0080	·0061

The results are interesting, for they show very clearly that the ammonia and organic matter, like the sulphates and chlorides, increase in amount very appreciably in the town as compared to the country air, and that ammonia and organic matter in rain are important constituents as indicators of the purity of an atmosphere.

Chemical tests can then readily distinguish town and country air, and even town from suburban air, and can strikingly show the difference in the composition of the air at the same place in different weathers. The extreme case, that of dense fog, the case in fact for which these experiments were instituted, has not yet been examined, and it will no doubt give far more marked results than any of the foregoing experiments. In a former report I showed the great variation which occurs in the amount of carbonic acid in London air at different times, and then pointed out that probably the special interest of determinations of carbonic acid in the air would be as indicating the amount of general impurities present. These later experiments quite confirm this, and the amount of carbonic acid in air appears to vary exactly with the amount of floating matter in the air, and with the amount of soluble matter which can be washed out of it. This is seen in the following table, which contains all the complete experiments made at the same time and place:—

FINE WEATHER.

Grams per 1,000 Cubic Feet of Air.

—	Carbon.	Nitrogen.	Total Organic Matter.	Sulphuric Acid.	Hydrochloric Acid.	Total Sulphuric and Hydrochloric Acid.	Carbonic Acid, per 10,000 Vols. of Air.
June 26, 1884 - - -	·0025	None	·0025	·0119	None	·0119	3·7
June 24, 1885 - - -	·0032	None	·0032	·0069	None	·0069	3·2

DULL WEATHER.

Grams per 1,000 Cubic Feet of Air.

—	Carbon.	Nitrogen.	Total Organic Matter.	Sulphuric Acid.	Hydrochloric Acid.	Total Sulphuric and Hydrochloric Acids.	Carbonic Acid, per 10,000 Vols. of Air.
December 8, 1883 - -	·0092	·0011	·0103	·0475	·0066	·0541	4·6
February 18, 1884 - -	·0067	·0004	·0071	·0416	·0012	·0428	4·0
March 27, „ - -	·0114	None	·0114	·0496	·0018	·0514	3·7
April 28, „ - -	·0115	None	·0115	·0363	·0055	·0418	4·8
„ 29, „ - -	·0150	None	·0150	·0360	·0109	·0469	4·8

FOGGY WEATHER.

Grams per 1,000 Cubic Feet of Air.

—	Carbon.	Nitrogen.	Total Organic Matter.	Sulphuric Acid.	Hydrochloric Acid.	Total Sulphuric and Hydrochloric Acids.	Carbonic Acid, per 10,000 Vols. of Air.
January 18, 1884 - -	·0182	None	·0182	·0476	·0016	·0582	4·5
February 8, „ - -	·0310	·0010	·0320	·0397	·0058	·0455	5·0

My assistant, Mr. W. Lapraik, has much aided me in the above work, and has made for me all the determinations of carbon and nitrogen.