SECRET

Porton Note No.188

THE LONG DISTANCE TRAVEL OF PARTICULATE CLOUDS

(Prog.10/58 Carried Out August 18th 1959)

By

A.R. Laird and R.A. Titt

INTRODUCTION

This report deals with one of a series of trials carried out under Programme 10/58 to investigate the feasibility of engagement of a specified target area (10^4 sq. miles) from a line source of inert tracer and to obtain information on the relation between cloud trajectories and air movements indicated by synoptic charts.

The series of experiments under Prog.10/58 were carried out on a fixed date basis using the meteorological data available on each occasion to give the best chance of successfully attacking the central region of England. Previous experiments have been reported in P.N's 68, 138, 139, 145, 185, 186, 187.

In this trial the aerosol cloud was generated off the S.E. coast of England in the expectation that it would drift N.W. over the country. In the event part of the cloud passed over the extreme east of the country and the remainder appeared to cross the extreme S.W.

GENERAL ARRANGEMENTS

A line source of fluorescent pigment (F.P.) was released from an aircraft flying from a point off Cromer, south-west to the Straits of Dover, and then westwards close inshore to a point south of Swanage.

The resulting cloud was sampled at ground level by a total of 63 stations of which 34 were operated by the Meteorological Office, 3 by U.S.A.F., 17 by M.O.S. outstations, and 9 by mobile teams despatched from C.D.E.E.

In addition an attempt was made to sample the cloud by means of a sampler mounted in an Anson aircraft, flying between Boscombe Down and Selsey Bill.

SOURCE

The F.P. used in this experiment was U.S. Radium 2267, Lot. H.206, magnesol treated (to improve flow properties).

The F.P. was hand poured into a Venturi operated dispenser mounted in a Valetta aircraft.

The source line was selected off the southeast coast from Yarmouth to Dover then along the English Channel to a point about 2 degrees W. The winds in these regions were expected to be light, so, to avoid long times of travel over the sea, it was decided that the source should be laid as near the coast as possible. Safety regulations prevented any close approach to the east coast, but along the Channel, where the emission had to be made almost alongwind, it was found possible to follow a line reasonably close to the south coast.

The relevant flight details were as follows:-

Time G.M.T.

1055 Airborne Boscombe Down - Valetta 264

1131 Start Emission - Posn. 52$\frac{1}{4}$ N 0252 E
Track 206° True
G/S 155 knots
Distance 150 st. mi
Altitude 1000 ft.

1221 1st Turn - Posn. 50$\frac{1}{4}$ N 0120 E
Track 258° True
G/S 155 knots
Distance 60 st. mi
Altitude 1000 ft.

1241 Alter Track Posn. 50$\frac{3}{4}$ N 0000
Track 264° True
G/S 170 knots
Distance 89 st. mi
Altitude 1000 ft.

1308 Stop Emission - Posn. 50$26\frac{1}{2}$ N 0202 W

Total Distance = 299 st. mi.

1415 Land Boscombe Down

Weight of F.P. dispenser 279 lbs (= 0.93 lb/st. mile)

Wind Velocities found:-

W/V	Time effective	Altitude
135/10	1015-1040	2500 ft
145/10	1040-1120	3000 ft
105/13	1120-1140	3000 ft
050/12	1140-1150	1000 ft
060/13		
070/15	1150-1215	1000 ft
055/12	1215-1230	1000 ft
060/18		
040/16	1230-1250	1000 ft
080/25		
095/25	1250-1310	1000 ft

SAMPLING

(a) Ground

The locations of the sampling stations are shown in Fig.1. The Meteorological Office and U.S.A.F. stations are identified by their 3 figure met. station numbers and the Ministry of Supply stations by the letter "S" and a two figure number.

These stations were controlled from C.D.E.E. via the Meteorological Office teleprinter service and G.P.O. land line telephones.

This sampling network was reinforced by 9 mobile sampling stations sent out from C.D.E.E. to areas where the fixed stations were rather far apart. These stations are identified in Fig.1 by letters A to K.

As in other experiments of this series, sampling was by means of drum impactors aspirated by electrically driven vacuum pumps, with flow rates controlled by critical orifices. With the exception of a few stations (indicated in the tabular summary of data) the sampling period for the fixed stations was 30 minutes. The mobile stations, manned from C.D.E.E., operated duplicate samplers with a 15 minute interval.

The times of starting and stopping sampling were calculated to give ample scope for errors in the estimates of times of arrival and clearance of the cloud.

(b) Airborne

The cloud was sampled by a sampler mounted in the nose of an Anson aircraft flying from Bosqombe Down to a point 16 mi

south of Selsey Bill and back to Boscombe.

The aircraft sampled at 1000 ft ASL on the outward journey and at 3500 ft on the return.

RESULTS

(a) Meteorological conditions

During August 18th, 1959, an anticyclone, centred at 1200 GMT near Heligoland, drifted slowly eastwards and by midnight it was centred over southern Denmark. From this centre a weak and rather broad ridge extended across East Anglia to north Devon and remained virtually stationary throughout the experiment. The situation at 1200 GMT while the source was being laid is shown in fig.2. The situation at midnight is shown in outline in fig.3.

The vertical temperature distribution at the beginning of the experiment is indicated in figs. 4a and c by ascents at 1100 GMT at Crawley and Hemsby. Both show an isothermal layer base about 3800 feet. This also appears in the ascent (see fig. 4(b)) made at 1100 GMT at Camborne to the west of the region initially traversed by the cloud. It may be assumed, then, that this isothermal layer was a widespread feature of the situation in southern and southeastern England.

The surface temperature appropriate to the particulate cloud during the initial hours of travel was about 64°F (18°C), the sea temperature. At 1500 GMT when the cloud had just reached land, the surface temperatures along the exposed east coast were reported about 66°F (19°C), but on that part of the south coast where particles were collected, comparable temperatures were reported only at exceptionally exposed places like Portland Bill. A few miles inland in the east and generally along the sourth coast, temperatures increased to about 73°F (23°C). As the cloud progressed inland the tendency for the surface temperature to increase further was counter-acted by the diurnal decrease of solar heating, and even in favourable places temperatures had begun to fall by 1600 GMT, at first slowly to maybe 71°F (22°C) around 1700 GMT with a more rapid fall from 1800 GMT.

When these temperatures are substituted in fig.4 for the observed surface temperatures it can be seen that the air was stable over the sea but convective turbulence would start as the air moved inland and eventually, with a surface temperature of 23°C, could develop to just above 4000 feet.

The vertical temperature distribution at the end of the experiment is indicated in figs. 5(a), (b) and (c) by ascents at 2300 GMT at Crawley, Camborne and Hemsby. The night-time surface inversion is well-developed at those places where the air has had an appreciable track over land (Local records show that at Porton this inversion began about 1750 GMT). It will be noted that the base of the isothermal layer at the inland stations is somewhat higher than it was in the early morning as might be expected if daytime heating had extended to 4000 feet.

Weather reports from the source-laying aircraft are given in table 1(a) and (b). No other aircraft reports were received. The wind reports included in table 1(a) are of special interest in that they suggest that initially there was movement of the cloud away from the coast between Dover and Brighton. Upper wind measurements from selected stations are given in table 2.

Synoptic surface weather observations are available in the Meteorology Research Division, C.D.E.E., Porton.

The height of the mixing layer at the various stages of the experiment may be inferred from the above and from the aircraft reports of table 1. Vertical diffusion of the particulate cloud in the stable air over the North Sea would be slow, though the very slight bumpiness reported in table 1(a), suggests that mixing down to the surface could easily have occurred. The upper limit was probably the haze top, reported at 1200 to 1500 feet just before the emission started (table 1(b)). Over the Channel bumpiness was nil and vertical diffusion should have been very slow indeed.

Over land by day convection would rapidly extend the top of mixing layer to 4000 feet, a height in agreement with the reported tops of fragmentary cumulus at 3500 to 4000 feet (table 1(b)ii). (It may be noted that humidity was low enough for convection to proceed through this layer without the formation of any but the most short-lived clouds).

Inland, from around 1800 GMT, conditions became progressively more stable, with the surface wind falling calm over wide areas towards midnight.

(b) Particle Counts

A summary of the particle counts giving the estimated time of passage of the cloud median and its duration is given in table 3. In this the particle counts are all corrected to a sampler flow rate of 20 l/min.

Full details of all the sampling are given in table 4.

Although there were reports of fog and mist from a number of sampling stations, there was little interference with sampling on this account as in almost all cases the cloud had passed the sampling position before the development of mist or fog.

The results of the aircraft sampling are tabulated below:-

Sample No.	Time GMT	Location	F.P. Count	Height
1	1400-1409	2 mi S. Stockbridge	3 (1 spurious)	1000 ft
2	1409-1415	2 mi W. Bishops Waltham	2	"
3	1415-1421	1 mi E. Horndean	1	"
4	1421-1427	2 mi W. Bognor	1	"
5	1427-1434	16 mi S. Selsey Bill	1	"
6	1434-1436	Climbing	0	3500 ft
7	1436-1442	2 mi S. Chichester	0	"
8	1442-1448	1 mi S. Winchester	1	"
9	1448-1459	C.D.E.E. Ranges	0	"
10	1459-1500	Boscombe Down	0	Descend

It was estimated from observations of haze levels that the top of the imersion was about 3700 ft ASL.

Aircraft - Anson VS 562. Sampler No.5.

ANALYSIS OF THE PARTICLE-COUNTS

Two diagrams have been prepared from the data given in table 3. The first, fig.6, shows the number of particles collected at the various stations at a standard sampling rate of 20 litres per minute. An isopleth of dosage, 10, has been suggested and this demonstrates clearly the bifurcation of the cloud. The second, fig.7, shows the observed time of passage of the cloud median with isochrones based on these figures or estimated from other observations.

Several points from this latter diagram are to be noted. First, the usual procedure for calculating the time of passage of the cloud median had to be modified in the case of three stations - Chivenor (707), Exeter (839) and Dorchester (H) - where it appeared that two distinct particulate clouds had been sampled. The times entered against these stations refer to these separate clouds. The three earlier times together with the observations from Bridgwater (S.42) and Pembrey (S.31) form a sequence suggestive of the expected northward movement of a cloud oriented east-west. The later times together with the observations from Mount Batten (827) and St. Mawgan (817) form a sequence suggestive of the westward movement of a cloud oriented north-south. The simplest combination of these two clouds gives a wave-form as shown with a crest which passed southwest of Wincanton (G) about 1900 GMT (1 particle collected ?), over Bridgwater and over Pembrey. The trajectory of particles released from the end, B, of the source-line must have passed between the pairs Mount Batten - Exeter and St. Mawgan - Chivenor. The path shown by the dashed line has in addition the following properties. First, at B, its direction agrees with a wind of 090 degrees as reported by the source laying aircraft.

Secondly, its direction at 1700 GMT agrees with a wind of 135 degrees averaged between that reported at Camborne to the WSW and Porton to the ENE. Lastly its final direction tends towards that appropriate to the more southerly wind reported at Aberporth.

The collection at Mount Batten (827) extended over a long period and the cloud may even have continued to pass after sampling stopped. It is therefore probable that the cloud recurved in this area, the trough moving on later to the vicinity of St. Mawgan as indicated. The mechanism by which such a wave would be formed requires an initial southerly movement of the cloud over much of the eastern part of the Channel. This is supported directly by observations from the source-laying aircraft and indirectly by the failure to find any particle on the surface at a large number of stations apparently opposite the middle of the source-line. A possible link between the cloud sampled in the southwest and that sampled in the east has been suggested.

The remaining section of the emission line over the North Sea must then have been the source of the particles found at all the other sampling stations northeast of the line Isle of Wight/Cardigan Bay. All the collection times form a pattern in reasonable agreement with this assumption. It is a little surprising that there should have been any appreciable number found at Thorney Island (871) in view of the smaller collections to the east. Nevertheless the time of arrival of the particles and the argument that has gone before would indicate that the collection could hardly be associated with the Channel emission.

The sampling aircraft, probing at 1000 ft southward from Selsey Bill at 1530 GMT almost to the source line found very few particle. This supports the suggestion that the cloud had largely moved southwards and the few particles found seem not to be associated with the larger concentration found at Hayling Island very much later.

(Sgd.) F. Pasquill,
Supt., Meteorology Research Division.

ARL/RAT/MC

(Sgd.) K.F. Sawyer,
Supt., Munitions Research Division.

Table 1

Weather Reports from Aircraft on 18th August, 1959

(a) Weather report from source-laying aircraft during period of emission 1131 to 1308 GMT - aircraft height 1000 feet above m.s.l.

Time GMT	Cloud amount and estimated height of base (feet)	Bumpiness	Mean Wind
1132	1/8 Ci	Nil	
1135-1145	1/8 Ci	Very slight	1140-1150 050/14 mph
1150	1/8 Cu 2500	" "	
1155-1215	Nil, hazy	" "	1150-1215 065/16
1215-1230	" "	" "	055/12
1230-1250	" "	Nil	050/19
1250-1308	" "	"	090/28

Table 1(b)

Miscellaneous Reports

(i) Source laying aircraft in vicinity Lowestoft, 1050-1120 GMT, altitude 3000 feet.

1/8 Ci, 1/8 Cu 2500 ft. over land near coast, haze top c. 2500 ft. over land lowering to c. 1500 ft over sea.

(ii) Source laying aircraft in vicinity Bournemouth, 1315-1330 GMT, altitude 4500 feet.

1/8 Ci, 2/8 Cu tops 3500-4000 feet. Haze top 3000 feet. Bumpiness nil becoming moderate below 3500 feet during descent.

Table 3

Summary of particulate cloud data on 18-19th August, 1959

(a) Stations at which fluorescent particles were found

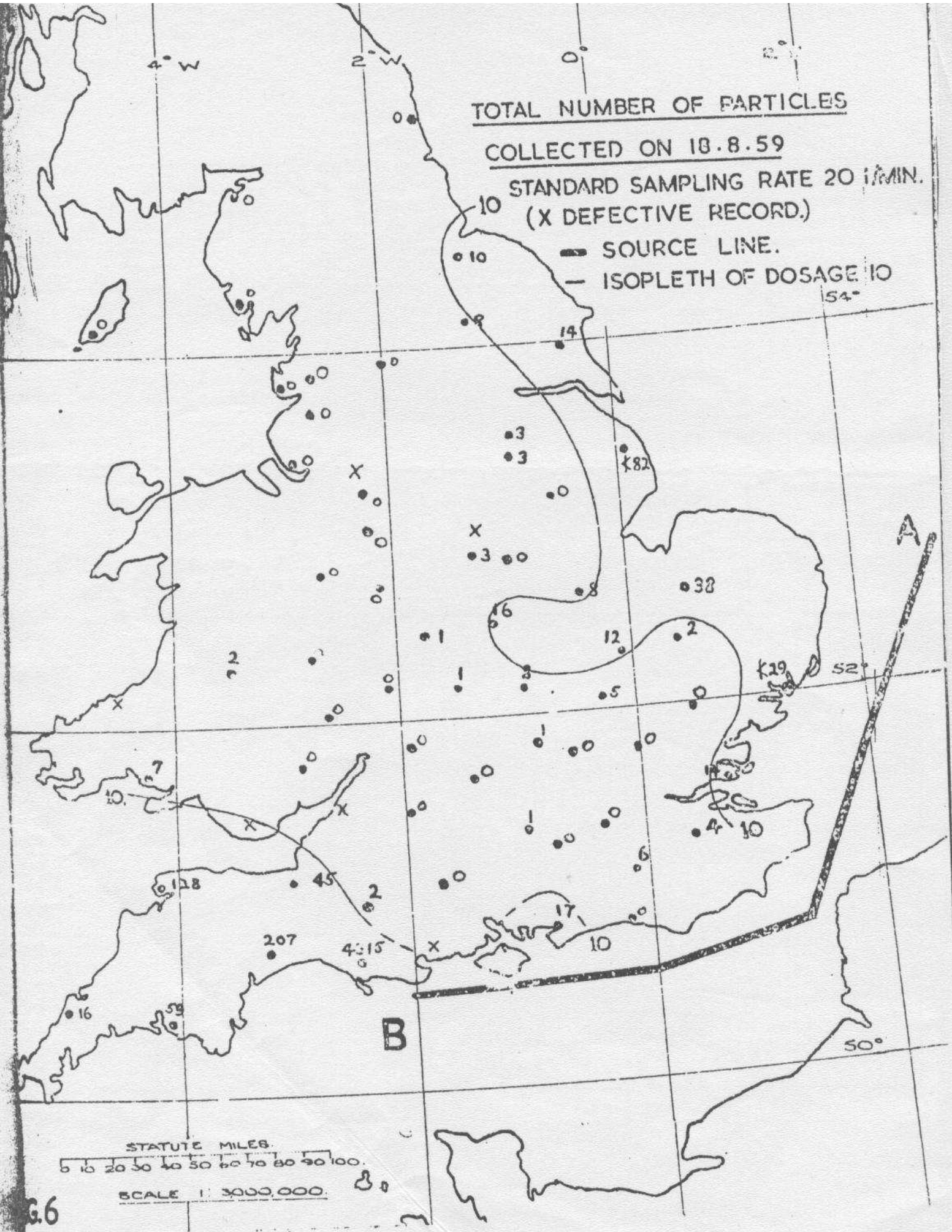
Sampling Station Identification No. (see fig.1)	Period bracketing cloud sample Time of incidence of cloud median (GMT)	No. of particles (corrected to sampling at 20 l/min)	Remarks (All times GMT)
Dishforth 261	19/0100 - 0359 (0240)	8	Patches of ground fog from 19/0400 becoming general from 0500 dispersing 0830. Fog top at 0738 reported at 500 ft.
Middleton St. George 263	19/0133 - 0400 (0210)	10	No mist or fog
Finningley 360	18/2325 - 19/0226 (0010)	3	Mist 19/0442 becoming fog 0530 cleared 0730
Leconfield 383	18/2200 - 19/0100 (2325)	14	Patches of ground fog from 19/0140, becoming general from 0205 dispersing 0845
Manty 395	1856 - 2254 (2020)	$\leq$ 82	Particles arriving during first sampling interval. Fog 19/0300 thinning to mist about 0630 clearing 0815.
Wittering 462	2027 - 2154 (2130)	8	Fog and mist 19/0425 - 0840
Marham 482	1750 - 2025 (1840)	38	-
Elmdon 534	19/0230 - 0301 (0245)	1	-
Cardington 559	1930 - 2100 (2035)	5	-
Wyton 566	1900 - 2100 (2000)	12	Fog formed 0425

Table 3(a) Cont'd

Sampling Station Identification No. (see fig.1)	Period bracketing cloud sample Time of incidence of cloud median (GMT)	No. of particles (corrected to sampling at 20 l/min)	Remarks (All times GMT)
Mildenhall 578	2053 - 2155 (2130)	2	Fog 19/0230 - 0708
Shoeburyness 693	1514 - 1545 (1530)	14	-
Felixstowe 697	1432 - 1500 (1445)	< 29	Sampling stopped 1432-1437
Chivenor 707	1830 - 2230 (1955)	81 } 128	-
	2258 - 19/0256 (0055)	47 }	
Gatwick 776	1744 - 1912 (1820)	6	19/0100 - 0300 ground fog patches
West Malling 787	1630 - 1730 (1710)	4	-
St. Mawgan 817	19/0022 - 0429 (0210)	16	-
Mount Batten 827	2228 - 19/0300 (0055)	59	-
Exeter 839	1600 - 1759 (1645)	185) 207	-
	2101 - 19/0001 (2150)	22)	
Thorney Island 871	1800 - 2230 (1955)	17	-
Ranskill S.17	2300 - 19/0030 (2345)	3	Particle found in first sample but it is not believed that any arrived before sampling started (cf. 360). Mist 19/0300 - 0500

Table 3(a) Cont'd

Sampling Station Identification No. (see fig.1)	Period bracketing cloud sample Time of incidence of cloud median (GMT)	No. of particles (corrected to sampling at 20 l/min)	Remarks (All times GMT)
Kings Newton S.26	2359 - 19/0100 (0040)	3	-
Pembrey S.31	2359 - 19/0200 (0040)	7	-
Bridgwater S.42	1930 - 2359 (2120)	45	-
Westcott S.37	2230 - 2300 (2245)	1	-
Burghfield S.45	2130 - 2200 (2145)	1	light ground mist 19/0100 - 0500
Rhayader A	0230 - 0330 (0300)	2	-
Lutterworth C	2145 - 2300 (2225)	16	-
Kineton D	2130 - 2200 (2145)	1	-
Towcester E	2115 - 2315 (2135)	8	-
Wincanton G	1915 - 1930 (1920)	1 } 2	-
	2315 - 2330 (2320)	1 }	
Dorchester H	1500 - 1630 (1520)	3893 } 4315	Particles still arriving when sampling stopped
	1700 - 1900 (1815)	< 422 }	



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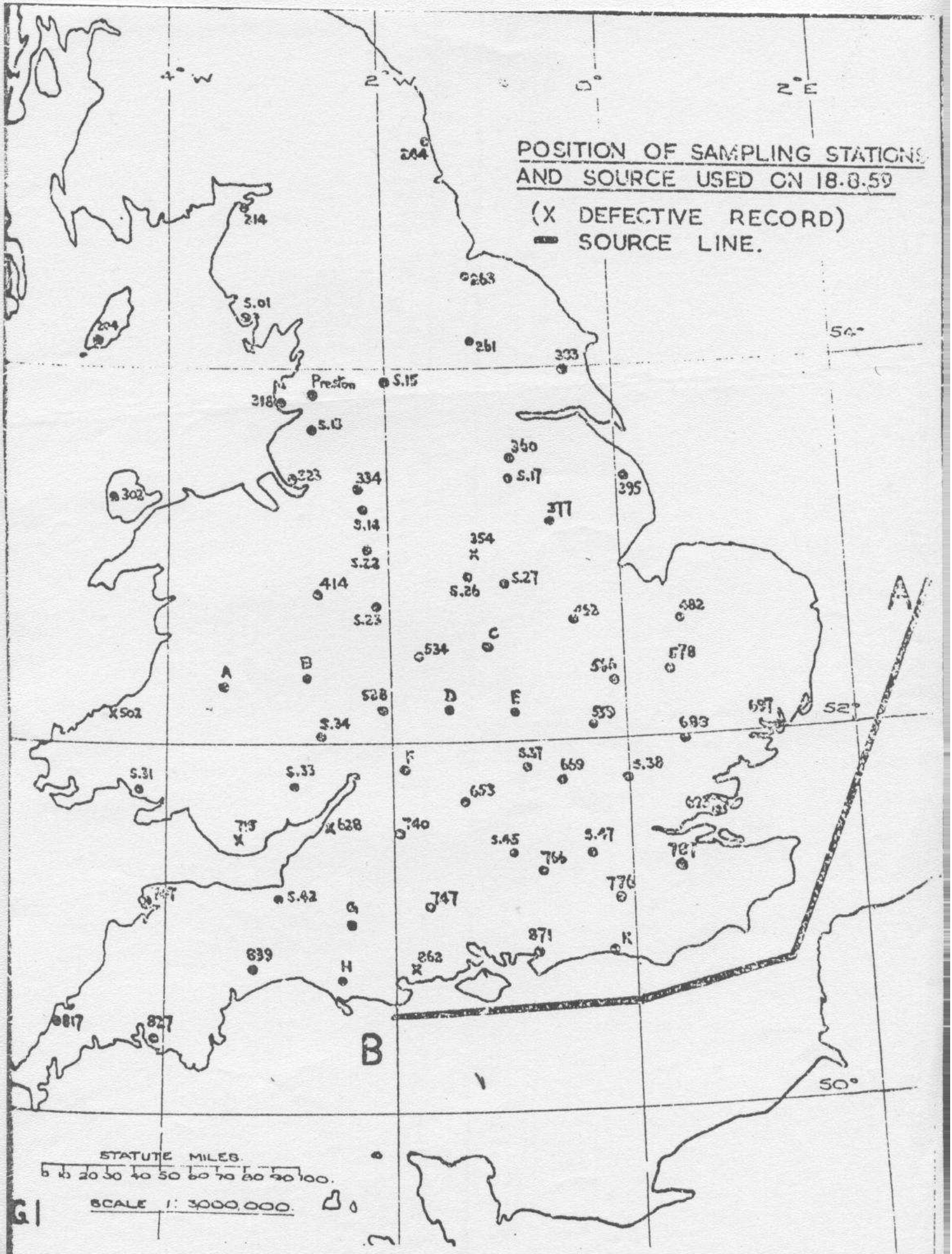

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