National Archives, Kew

British Coal Corporation
Coal Research Establishment

COMPARISON OF DILUTION TUNNEL AND ELECTROSTATIC PRECIPITATOR METHODS FOR THE MEASUREMENT OF SMOKE MASS EMISSION RATE FROM MANUFACTURED SOLID FUELS FOR DOMESTIC OPEN FIRES

January 1992

65

BRITISH COAL COROPRATION

COAL RESEARCH ESTABLISHMENT

ANALYSIS AND TESTING BRANCH

COMPARISON OF DILUTION TUNNEL AND ELECTROSTATIC PRECIPITATOR METHODS FOR THE MEASUREMENT OF SMOKE MASS EMISSION RATE FROM MANUFACTURED SOLID FUELS FOR DOMESTIC OPEN FIRES

by

J W Keeling
D Wilkins

SUMMARY

Work previously carried out by CRE at the request of the DoE Warren Spring Laboratory (WSL) has compared three methods for the measurement of particle mass concentration ($mg.m^{-3}$) in flue gases from the combustion of manufactured fuels on domestic open fires. The report concluded that whilst the three methods were in reasonable agreement on a concentration basis, proposals to use one of the methods: a gravimetric sampled filtration technique, sampling directly from the chimney, to obtain the mass emission rate ($g.h^{-1}$) were unsound, due to difficulties in obtaining an accurate measure of the low flue gas volume flow in the chimney. It was recommended that further work should be undertaken to investigate incorporation of the sampling equipment in a Dilution Tunnel located above the chimney, which would increase the flue gas velocity and improve the homogeneity of the particulate in gas suspension.

These recommendations were accepted by WSL, and CRE were requested to carry out further work to assess the new arrangement. This report describes testwork to compare the new method, referred to as the Dilution Tunnel (DT) method with the Electrostatic Precipitator (ESP) described in BS 3841:1972 for mass emission rate measurement.

After commissioning of the equipment, five replicate tests have been carried out by each of the two methods on two fuels currently authorised for use in smoke control areas. One has a smoke emission of approximately 2.0 $g.h^{-1}$ and the other approximately 4.5 $g.h^{-1}$. The limit for authorisation purposes is 5 $g.h^{-1}$. Testwork was carried out following the firing procedures described in BS 3841.

The results show very good agreement in the mean smoke emission obtained by the two methods. For Fuel A the mean mass emission rate obtained by the ESP method was 4.43 $g.h^{-1}$ and for the DT method was 4.45 $g.h^{-1}$. With Fuel B the figures were 2.03 $g.h^{-1}$ and 1.96 $g.h^{-1}$ respectively. The standard deviation in results were also similar.

Deposits collected in the probe of the DT sampling equipment was around 25% of the total weight of deposit collected. Consequently the report concludes that procedures for removing and weighing the probe deposit need to be as carefully controlled as for that collected on the filter paper.

Guidelines are given for nozzle diameters, sample volume flow rates and other test parameters appropriate to this application. However it is likely that in due course the DoE may wish to specify the DT method in a British Standard for coal burning smoke reducing domestic appliances. The operating conditions in this application will be significantly different from those reported here and it is recommended that further work would be necessary to assess the equipment for this purpose.

The report concludes that the Dilution Tunnel is a suitable method for inclusion in the forthcoming revision of BS 3841 alongside the current Electrostatic Precipitator method. The DT method is more labour intensive and is likely to be more expensive to operate than the ESP, but would incur less capital expenditure for a laboratory with no existing facilities. The need for cleaning of the precipitator with a toxic solvent wash would also be avoided with the DT method.

Report No. FAT 65
January 1992

Approved by:
Dr N Paterson

CONTENTS PAGE

1. INTRODUCTION

CRE have undertaken work previously at the request of Warren Spring Laboratory (WSL) to compare two new sample filtration techniques with the BS 3841[1] Electrostatic Precipitator (ESP) for the measurement of particle mass concentration in flue gas emissions from manufactured fuels burned on an open fire. The two sampling techniques were the Dichotomous Gravimetric Sampler (DGS) and the Domestic Particulate Sampler (DPS). Whilst reasonable agreement was obtained between the three techniques when measuring concentration, proposals to use the DGS concentration measurement along with in-stack velocity measurements to obtain the mass emission rate were thought to be unsound, due to potential error in measuring the very low flue gas velocity ($<5 m.s^{-1}$) and possible sampling bias. The potential for positional sampling bias when sampling directly from the stack would be even greater if the method were to be subsequently adopted for PD 6434 measurements on closed appliances, where the flue gas velocity is even lower ($<1 m.s^{-1}$) and the flow may be laminar, leading to an increased risk of stratification.

It was recommended in the report[2], that WSL should consider incorporation of the DGS sampling equipment in the dilution tunnel as a means for determining the mass emission rate. This approach would combine the reliability and practicality of the DGS apparatus with the benefits of sampling from the dilution tunnel, ie improved homogeneity of the flue gas/air mixture and increased gas velocity (typically around 10 $m.s^{-1}$). The proposed system is effectively a hybridisation of the previous DPS and in-stack DGS methods.

These proposals were accepted by WSL, and CRE were requested to carry out further work to assess the new arrangement which shall hereinafter be referred to as the Dilution Tunnel (DT) method. The equipment used in previous work was modified to accept the DGS sampling equipment as shown in figs 1 and 2. Five replicate tests were carried out using the DT equipment to obtain the mass emission rate, and five using the ESP, on each of two fuels; a total of 20 replicate tests.

2. METHODS

2.1 Apparatus

The equipment was arranged as shown in fig 1. A sample of flue gas was extracted from the dilution tunnel at a point 1.67m (9.8 diameters) downstream of entry and 0.92m (5.4 diameters) upstream of a right angled bend at entry to the exhaust fan. The sample which was taken from the centre of the duct, passes through the nozzle (see below) and along a 415 mm long, 9 mm id stainless steel probe before entering a heated filter housing, maintained at a temperature of 70°C. A 6.5 mm dia. nozzle was used in the majority of tests (see section 4). Particulate material was separated from the sample gas in the housing using a Whatman EPM 2000 glass microfibre filter paper with a claimed collection efficiency of 99.999% for 0.6μm particles at a face velocity of 2.5 $cm.s^{-1}$. The cleaned sample gas then passes through a series of gas wash bottles filled with silica gel to dry the gas prior to measurement of its volume in a calibrated dry gas meter. The temperature of the gas at the gas meter was also recorded.

The Dilution Tunnel is a stainless steel duct, 170 mm in diameter and incorporates a collecting cowl at entry and tubulator plates fitted approximately 320 mm downstream of entry which create a free cross sectional area, similar in shape to a Maltese cross (see fig 1).

Pitot velocity measurements of the velocity at the centre of the duct were made approximately 75 mm upstream of the sample nozzle just prior to each test and the pitot was then removed. This measurement was then used to set the sample volume flow rate for isokinetic sampling, which was maintained at the predetermined level for the duration of the test. For measurement of the volume flow in the duct a pitot velocity measurement was made 710 mm upstream of the sample nozzle. In this case, a pitot survey across one diameter of the measurement section was made prior to each test and the pitot was then positioned at a point representative of the mean velocity for the duration of the test. The mean velocity obtained at that position over the test period was then used to determine the overall mean velocity and volume flow. It was decided to carry out separate velocity measurements for isokinetic sampling and volume flow measurement purposes after it was

found that the velocity profile at the nozzle was different to that further upstream at the volume flow measurement point.

Filters were conditioned prior to weighing at the start and end of the test in a desiccator containing silica gel drying agent. A clean control filter was also weighed along with the set of filters for each test to correct for any weight change due to absorbtion of atmospheric moisture. All weighings were carried out in a temperature controlled (but not humidity controlled) room.

The filter probe was washed out with acetone using a burette brush at the end of each test, and the acetone allowed to evaporate to dryness from a beaker at ambient temperature to obtain the weight of deposit collected in the probe. An equal volume of clean acetone was also evaporated to obtain a control weight for correction.

The electrostatic precipitator was the modified version described in BS 3841:1972 comprised of a honeycomb of 85 hexagonal aluminium tube collecting electrodes, 30 mm across the flats and 0.45 m long, each with an axial 0.15 mm diameter stainless steel wire discharge electrode. In use the precipitator wires are connected to a high negative voltage (typically 7 to 8 kV) and the tubes earthed, under which conditions a current flow of approximately 30 to 35 mA occurs between the electrodes. The method is tried and tested in this application and has been demonstrated capable of collecting over 95% by weight of the particulate material carried in the flue gas, as required in the standard.

The precipitators were conditioned prior to weighing at the start and end of test by the hot room method, in which the precipitator is allowed to stabilize - at a temperature of 30°C prior to weighing. This method is not specified in the 1972 revision of BS 3841, but is being incorporated in a forthcoming revision.

2.2 Calculation

2.2.1 Dilution Tunnel method

After correction for weight change in the control filter the mass of deposit collected on the filter (M_f) was added to that washed from the sample probe (M_p) to give the total mass of deposit collected (M_t).

The volume of gas sampled (V_g) was obtained from gas meter readings and corrected in accordance with a calibration factor provided by WSL. This was then corrected to NTP (25°C, 1 atm) using:

$$V_{g(NTP\ dry)} = V_{g(gas\ meter\ TP,\ dry)} \times \frac{298}{T_g + 273} \quad m^3$$

Where T_g is the temperature of the sample gas at the meter.

(Note: the pressure of the sample gas at the gas meter is taken to be approximately atmospheric and the gas is dry having previously passed through a drying agent).

The volume of moisture V_m in the sample obtained from gas wash bottle weight increases is given by:

$$V_{m\ (NTP)} = 22.4 \times weight\ of\ moisture\ in\ bottles/18000 \quad m^3$$

and the percentage moisture in the sample on a wet basis by:

$$\% \, moisture = 100 V_{m\,(NTP)} / V_{m\,(NTP)} + V_{g(NTP,\,dry)} \qquad m^3$$

The volume of gas sampled at the Tunnel temperature (T_tK) and moisture content may then be obtained from:

$$V_{g\,(tunnel\ TP,\ wet)} = V_{g(NTP,\ dry)} \times \frac{T_t}{298} / (1 - \frac{\% \, moisture}{100}) \qquad m^3$$

and the particle mass concentration (C_m) at Tunnel TP, wet from:

$$C_{m\,(tunnel\ TP,\ wet)} = 1000\ M_t / V_{g\,(tunnel\ TP,\ wet)} \qquad mg.m^{-3}$$

The velocity in the Dilution Tunnel (v_t) is obtained from mean pitot pressure measurements (h, mm.wg) and the mean Tunnel temperature (T_t,K) using the equation:

$$v_t = 0.0754 \sqrt{9.803 \times h} \times \sqrt{T_T} \qquad m.s^{-1}$$

from which the actual volume in the Tunnel (at Tunnel TP, wet) is obtained using:

$$Q_{t\,(tunnel\ TP,\ wet)} = v_t \times A_t \qquad m^3.s^{-1}$$

where A_t is the cross sectional area of the duct at the plane of pitot measurements in m^2. In this case the Tunnel diameter was 170 mm and therefore the cross sectional area was 0.0227 m^2.

Finally the mass emission rate is calculated from the product of volume flow and mass concentration using:

$$\dot{m} = Q_{t\,(tunnel\ TP,\ wet)} \times C_{m(tunnel\ TP,\ wet)} \times \frac{3600}{1000} \qquad g.h^{-1}$$

2.2.2 Electrostatic precipitator method

With the electrostatic precipitator, since all of the deposit (>95%) in the flue gas is collected, the mass emission rate is simply calculated from the increase in weight of the precipitator during the test period divided by the test duration.

3. TESTWORK

Five replicate tests were carried out by the two methods on each of two currently authorised 'smokeless' fuels: A and B. The fuels were burned in a Fulham grate open fire beneath a 4.6m high test chimney as described in BS 3841, following the test procedures also described in the standard. Individual tests are defined as valid if the second peak of the radiation output falls within ±0.15 kW of 2.05 kW and if the mean result of a series of replicate tests falls within ±0.06 kW of 2.05 kW. By this means it can be ensured that combustion takes place under conditions which are as nearly as possible reproducible from test to test and from fuel to fuel. Consequently even though it was not possible to obtain simultaneous measurements by the two methods results obtained can still be compared.

4. RESULTS AND DISCUSSION

1. Summarised test results are presented in Tables 1 and 2, which show very good agreement between the mean results of the two methods on both fuels. For fuel A the mean results obtained by the ESP was 4.43 $g.h^{-1}$ with a standard deviation of 0.299 $g.h^{-1}$ and by the DT method was 4.45 $g.h^{-1}$ with a standard deviation of 0.474. For Fuel B the mean ESP result was 2.03 $g.h^{-1}$ with a standard deviation of 0.288 and the mean DT result was 1.96 $g.h^{-1}$ with a standard deviation of 0.211 $g.h^{-1}$.

Tables 3 and 4 give intermediate values used in obtaining the final results given in Tables 1 and 2.

2. Deposit washed from the probe was 25.4% of the total weight of deposit collected in the case of Fuel A and 25.5% with Fuel B (mean results). Consequently the systems for collecting and weighing this deposit need to be as carefully controlled as for that collected on the filter.

Deposits were washed from the probe by rinsing with acetone and brushing with a clean burette brush. The resulting solution was then allowed to evaporate to dryness at room temperature in a beaker, leaving behind the residual solids. Evaporation takes typically 4 to 5 days to complete at room temperature, which means that final results are delayed. It may be possible to accelerate this process significantly by even a moderate warming of the acetone, leading to a faster turn round of results. However the effect on deposit weight would need to be investigated.

3. A check was made to determine how quickly filters begin to absorb moisture on removal from the desiccator prior to weighing. One clean and one dirty filter were weighed immediately after removal and at time increments thereafter as indicated in Table 5. It can be seen that each filter did gain weight slightly during the period, reaching equilibrium some 3 to 5 mins after the start time before beginning to lose weight again after about 15 mins. However the maximum weight increase was only 0.07 mg, ie 0.7% for a filter with 10 mg of deposit. Consequently the effect is very small, but it would be worthwhile stipulating that filters should be weighed within say 1 minute of removal from the dessicator to avoid this effect. Furthermore, if different filter media were to be used, it would be adviseable to carry out a similar check in case they are more hygroscopic.

4. A control test was carried out, running the DT equipment with no fire burning to determine by how much particles in the 'clean' laboratory air contribute to the deposit weight. In this single test, 0.42 mg of deposit were collected over a period of 5h (the length of a typical test period), which represents 0.9% of the total weight of deposit collected during tests on Fuel A and 1.4% for Fuel B. It is not clear however, whether this material entered the system through the chimney, or at the Dilution Tunnel inlet. If the former is true then the material would also have been collected in the precipitator and would therefore need to be included in the dilution tunnel measurement for the purposes of comparison. If the latter is true then strictly speaking a correction to the dilution tunnel measurement would be necessary. In practice, it is likely that the material enters by both routes, and therefore it would be difficult to make a valid correction.

If the DT was being used in isolation, ie not for the purpose of comparison with ESP measurements, it could be argued that a correction should be made since this material does not represent smoke emission from the fuel. The quantity is however small and could vary

from day to day depending on other laboratory activities. It could also be that some or most of the material is being scoured from the internal surfaces of the chimney, dilution tunnel and probe, and is not actually present in the laboratory air. Further measurements would be necessary to confirm this.

5. In order to obtain a reasonable number of filter changes per test ie 2 or 3, and a total weight of deposit in the region of 20 to 40 mg, a 6.5mm diameter nozzle was found suitable. With a velocity of around 8.5 $m.s^{-1}$ (Volume flow of 0.195 $m^3.s^{-1}$) in the Dilution Tunnel, the corresponding isokinetic sample volume flow is approximately 2.8×10^{-4} $m^3.s^{-1}$ or 16.9 litres. min^{-1}. The inlet area of a 6.5mm diameter nozzle is 0.15% of the cross sectional area of the 170mm diameter dilution tunnel.

For a sample volume flow of 16.9 litres.min^{-1} and a filter face area of 15.9 cm^2 (45 mm dia presented area) the velocity at the face would be 17.7 $cm.s^{-1}$. The manufacturers claim a maximum face velocity of 80 $cm.s^{-1}$ and a collection efficiency of 99.999% for 0.6 μm particles at 2.5 $cm.s^{-1}$ face velocity.

The above system parameters are convenient for measurement of the necessary components and provide satisfactory guidelines for setting up the DT for this application.

5. CONCLUSIONS

1. Good agreement has been obtained between the WSL Dilution Tunnel and BS 3841 Electrostatic Precipitator methods for measurement of smoke emission from two manufactured smokeless fuels (both currently DoE authorised) burned on an open fire. The mean results obtained from five replicate tests were in very close agreement and the standard deviations were also similar (see Table 1).

These results substantiate proposals to incorporate the Dilution Tunnel method into a forthcoming revision of BS 3841 as an alternative to the Electrostatic Precipitator method.

2. Approximately 25% of the total weight of deposit collected in the DT sampling system was deposited in the probe. Consequently the procedures for removing and weighing this deposit need to be as carefully controlled as those for the filter.

3. The Dilution Tunnel system is more labour intensive to operate than the ESP. The latter requires less attention in use, less weighing time and less data analysis. This would be partially compensated for with the DT, by there being no requirement for cleaning of the filter between tests, but overall the DT method is likely to be more expensive to operate.

The ESP method requires a toxic solvent for cleaning (currently a dichloromethane based solvent is used), which would be avoided with the DT method.

6. RECOMMENDATIONS

1. The DT method is recommended as suitable for inclusion in the forthcoming revision of BS 3841, for the measurement of smoke mass emission rate from manufactured fuels burned on an open-fire, as an alternative to the ESP method currently specified.

2. Further work is recommended if the technique were subsequently to be adopted for measurement of smoke from coal burning smoke reducing appliances, as covered by BS PD 6434[3]:1969. These appliances produce deposits of a significantly different physical nature to those of 'smokeless' fuels and the flue gases carrying the particles are less diluted with air and are consequently hotter and have lower volume flow. The system parameters (dilution ratio, nozzle sizes, sample volume flow etc) are therefore likely to be different in this application and would need to be determined.

7. REFERENCES

1. BS 3841:1972: Method for the Measurement of Smoke From Manufactured Solid Fuels for Domestic Open Fires.

2. "A Comparison of three methods for the measurement of particulate mass concentration in flue gases from the combustion of solid fuels in an open fire". CRE Analysis and Testing Branch report no 63, by J W Keeling and D Wilkins. Dec 1991.

3. BS PD 6434: 1969: Recommendations for the Design and Testing of Smoke Reducing Solid Fuel Burning Domestic Appliances.

TABLE 1. Fuel A summarised test results

Test number	3	4	5	6	7	Mean	SD
ESP measured mass emission rate, $g.h^{-1}$	4.72	4.54	4.65	4.22	4.02	4.43	0.299
Second peak radiant output kW	2.18	2.02	2.02	1.93	2.02	2.03	0.090
Test number	**8**	**9**	**10**	**11**	**12**	**Mean**	**SD**
DT measured mass emission, $g.h^{-1}$	4.98	4.92	4.13	3.94	4.26	4.45	0.474
Second peak radiant output, kW	2.07	2.04	1.97	2.16	1.90	2.03	0.099

TABLE 2. Fuel B summarised test results

Test number	13	14	15	16	17	Mean	SD
ESP measured mass emission rate, $g.h^{-1}$	1.75	2.49	2.09	1.84	1.99	2.03	0.288
Second peak radiant output, kW	2.05	2.04	2.19	2.23	2.05	2.11	0.091
Test number	18	19	20	21	22	Mean	SD
DT measured mass emission rate, $g.h^{-1}$	1.87	1.90	1.75	1.96	2.31	1.96	0.211
Second peak radiant output, kW	2.07	2.07	2.04	2.15	2.10	2.09	0.042

TABLE 3 - Fuel A intermediate values

Dilution Tunnel								
Test number		8	9	10	11	12	Mean	SD
Volume gas sampled @ NTP, dry	m^3	8.6482	7.0985	6.5434	6.8505	6.5816	7.1444	0.8700
Moisture in gas	%	0.73	0.85	0.98	1.06	1.04	0.93	0.14
Mean gas temperature in DT	°C	30.6	30.5	33.9	33.7	35.4	32.8	2.2
Volume gas sampled @ tunnel TP, wet	m^3	8.8755	7.2915	6.8055	7.1260	6.8829	7.3963	0.8492
Mass of deposit collected on filter	mg	43.72	37.55	32.19	29.32	32.03	34.96	5.73
Mass of deposit collected in probe	mg	16.90	12.80	9.40	10.40	10.10	11.92	3.06
Particle mass concentration @ tunnel TP, wet	$mg.m^{-3}$	6.83	6.91	6.11	5.57	6.12	6.31	0.56
Velocity in DT	$m.s^{-1}$	8.92	8.72	8.27	8.65	8.51	8.61	0.24
Volume flow in DT @ DT TP, wet	$m^{-3}s^{-1}$	0.2025	0.1979	0.1877	0.1964	0.1932	0.1955	0.0055
Mass emission rate	$g.h^{-1}$	4.98	4.92	4.13	3.94	4.26	4.45	0.474
BS 3841 2nd peak radiant output	kW	2.07	2.04	1.97	2.16	1.90	2.03	0.099
ESP								
Test number		3	4	5	6	7	Mean	SD
Mass of deposit collected	g	27.3	25.1	27.1	23.0	21.1	24.7	2.7
Test duration	h	5.78	5.53	5.83	5.45	5.25	5.57	0.24
Mass emission rate	$g.h^{-1}$	4.72	4.54	4.65	4.22	4.02	4.43	0.474
BS 3841 2nd peak radiant output,	kW	2.18	2.02	2.02	1.93	2.02	2.03	0.090

TABLE 4 - Fuel B intermediate values

Dilution Tunnel								
Test number		18	19	20	21	22	Mean	SD
Volume gas sampled @ NTP, dry	m^3	7.6991	11.2443	10.7601	10.7442	10.8903	10.2676	1.4499
Moisture in gas	%	0.80	0.65	0.72	0.47	0.61	0.65	0.12
Mean gas temp in DT,	°C	37.1	36.1	35.6	32.2	32.4	34.7	2.2
Volume gas sampled @ tunnel TP, wet	m^3	8.0763	11.7394	11.2231	11.0558	11.2292	10.6648	1.4695
Mass of deposit collected on filter	mg	15.91	21.88	22.07	23.66	27.29	22.16	4.11
Mass of deposit collected in probe	mg	6.40	9.35	5.95	7.40	8.90	7.60	1.34
Particle mass concentration @ DT TP, wet	$mg.m^{-3}$	2.76	2.66	2.49	2.81	3.22	2.79	0.27
Velocity in DT	$m.s^{-1}$	8.29	8.74	8.60	8.53	8.79	8.59	0.20
Volume flow in DT @ DT TP, wet	$m^{-3}s^{-1}$	0.1882	0.1984	0.1952	0.1936	0.1995	0.1950	0.0044
Mass emission rate	$g.h^{-1}$	1.87	1.90	1.75	1.96	2.31	1.96	0.211
BS 3841 2nd peak radiant output,	kW	2.0	2.07	2.04	2.15	2.10	2.09	0.042
ESP								
Test number		13	14	15	16	17	Mean	SD
Mass of deposit collected	g	11.6	14.9	13.7	11.9	13.7	13.2	1.4
Test duration	h	6.63	5.98	6.57	6.47	6.90	6.51	0.34
Mass emission rate	$g.h^{-1}$	1.75	2.49	2.09	1.84	1.99	2.03	0.288
BS3841 2nd peak radiant output	kW	2.05	2.04	2.19	2.23	2.05	2.11	0.091

TABLE 5: Weight Change in filters due to atmospheric moisture absorbtion

Time, mins	Test 1		Test 2	
	Clean filter weight, g	Dirty filter weight, g	Clean filter weight, g	Dirty filter weight, g
0	0.14927	0.16381	0.14929	0.16369
0.5	30	85	29	71
1	30	86	31	71
2	31	87	30	72
3	31	88	32	72
4	31	87	32	73
5	30	87	32	73
6	30	87	32	72
7	30	87	32	72
8	29	87	32	72
9	29	87	32	72
10	30	87	32	71
15	28	85	31	70
20	28	85	31	69

Note: only the last two decimal places are given for weights after the start time to aid comparison.

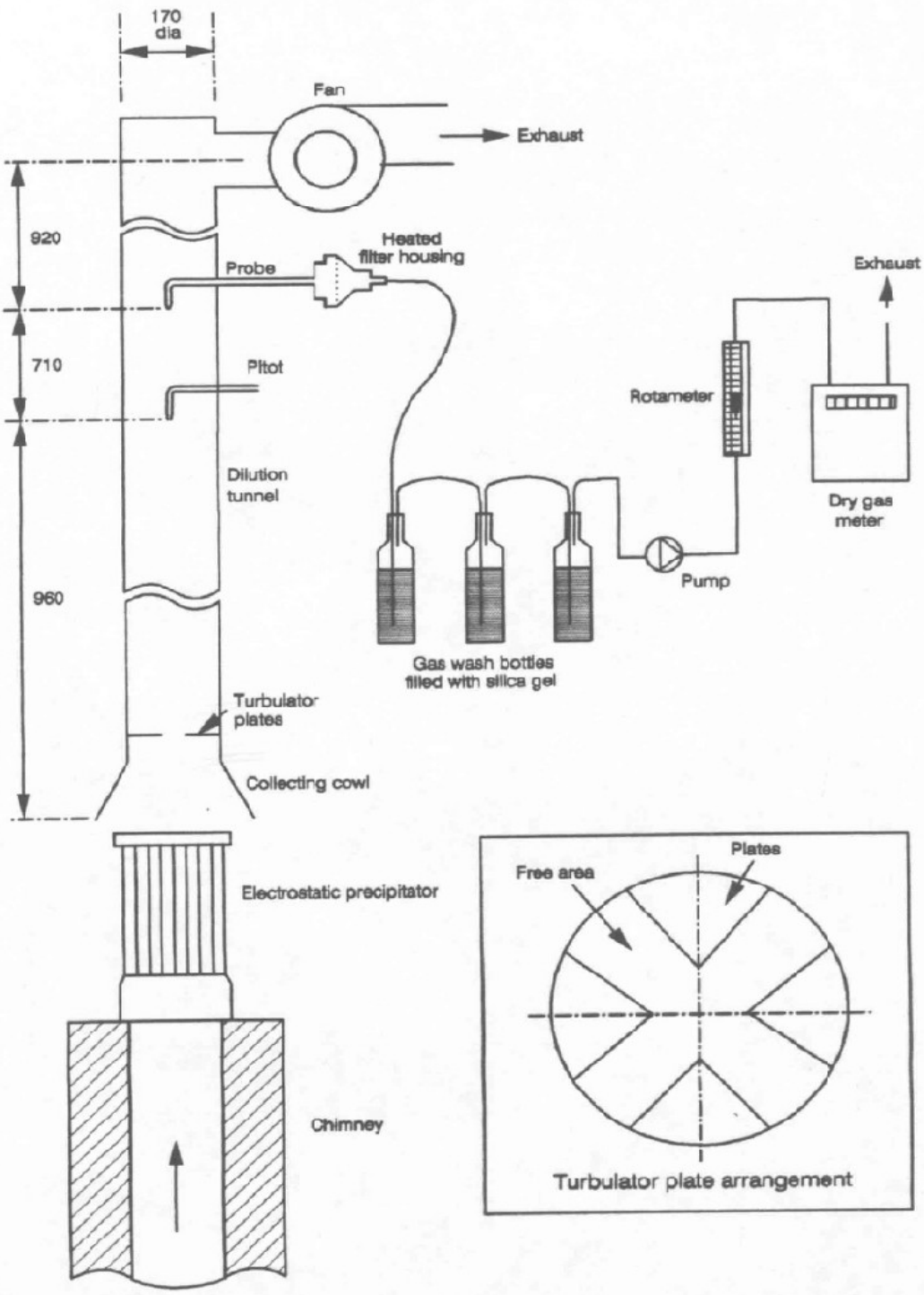

Fig.1 Dilution tunnel and Electrostatic precipitator.
Arrangement of test apparatus

DISTRIBUTION LIST

Mr P Clayton (3)	-	Warren Spring Laboratory
Dr J C Whitehead	-	CRE
Mr S G Dawes	-	"
Dr J M Topper	-	"
Dr N Paterson	-	"
Mr P W Jenkins	-	"
Mr D Wilkins	-	"
Mr J W Keeling	-	"
Branch File	-	"
Library (3)	-	"

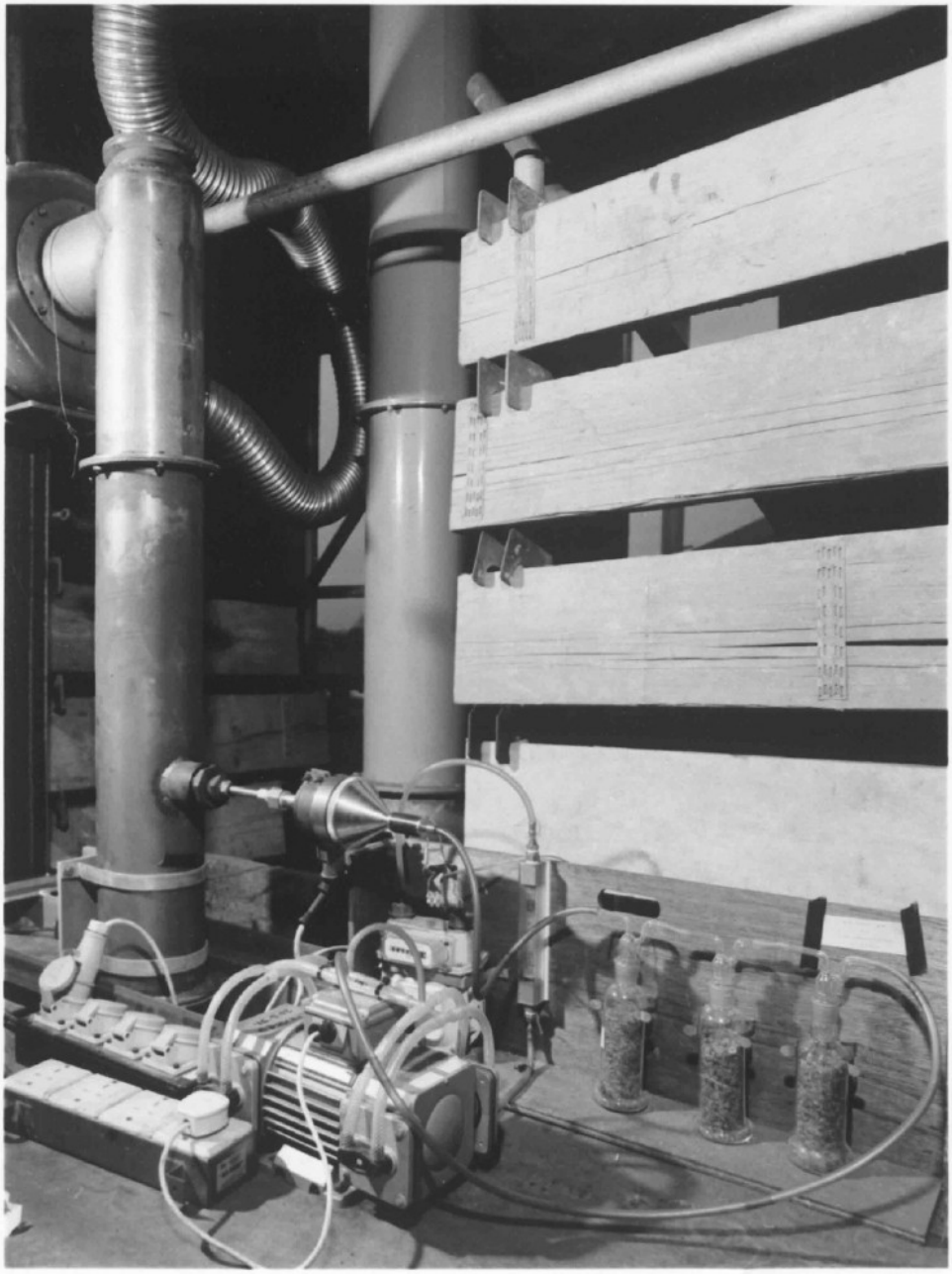

Fig 2 Dilution tunnel Sampling apparatus.