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Environmental Protection Act
Pollution Prevention & Control

PARTICULATE EMISSION TEST
(BS EN 13284-1:2017)

on

AGGREGATE DRYING PLANT
BAG FILTER EXHAUST

for

CPI MORTARS LTD
29 MEAD PARK
RIVERWAY
HARLOW
ESSEX   CM20 2SE

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Tested By: *[signature]*   Date Of Test : 03.12.18
                                                      Date Of Report : 16.12.18
        A. Yelland   Report No :   2953
MCERTS Level 2 Team Leader (MM 02 130)

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EXECUTIVE SUMMARY

EMISSIONS SUMMARY				
Determined	**Units**	**Results**	**Uncertainty** +/-	**Limit**
Particulate Concentration (STP)	mg/m^3	6.08	0.17	25
Mass Emission (STP)	kg/hr	0.19	5.07	-
Stack Temperature	ºC	62	-	-
Gas Velocity	m/s	16.19	-	-
Stack Volume Flow Rate (Actual)	m^3/hr	37076	-	-
Stack Volume Flow Rate (STP)	m^3/hr	29901	-	-

All results are reported at reference conditions of 273K, 101.3kPa, wet gas.

EXECUTIVE SUMMARY

MONITORING TIMES				
Determined	**Sampling Date**	**Sampling Times**	**Sampling Duration**	
Total Particulate Matter Run 1	03.12.18	14.00 - 14.32	32	minutes
Total Particulate Matter Run 2	03.12.18	14.38 - 15.10	32	minutes
Preliminary Stack Traverse	03.12.18	13.55	-	

EXECUTIVE SUMMARY

PROCESS DETAILS	
Determined	**Process Details**
Process description	AGGREGATE DRYING PLANT
Continuous or Batch	Continuous - Sand @ 35tph.
Particulate type	Sand
Abatement	Bag filter
Appearance of plume	No visible discharge.

EXECUTIVE SUMMARY

MONITORING METHODS				
Determined	**Method**	**Technical Procedure**	**Limit of Detection**	**Calculated MU +/-%**
TPM	BS EN 13284-1	EL18	0.06	5.9%
Velocity	BS EN ISO 16911-1	EL20	-	-
Volumetric Flow	BS EN ISO 16911-1	EL20	-	-

1. BACKGROUND INFORMATION

Particulate emission testing was undertaken by SJG Environmental Limited, on the sand drying plant exhaust at CPI Mortars, Harlow site.

The purpose of the emission testing was to ensure compliance with the requirements of the permit issued by the Local Authority under The Environmental Permitting (England and Wales) Regulations 2010.

2. MONITORING PROTOCOL

2.1 Test Method and references

Isokinetic sampling of the contained emission sources was undertaken using the APEX Instruments Inc Method Five isokinetic sampling apparatus in accordance with the main procedural requirements within the following British Standards and Technical Guidance Notes:-

*   BS EN 13284-1:2017 - Stationary source emissions. Determination of low range mass concentration of dust.

*   Environment Agency - Technical Guidance Document (Monitoring) M1 Sampling requirements for monitoring stack emissions to air from industrial installations; and

*   Environment Agency - Technical Guidance Document (Monitoring) M2 Monitoring of Stack Emissions to Air.

2.2 Sampling procedure

The work carried out was, as far as was reasonably practical, in accordance with BS EN 13284-1:2017.

Isokinetic flow means that sample gases laden with particulates are drawn off at the same velocity as the free stream velocity in the flue. Isokinetic sampling thus avoids possible inertial effects of particulates approaching the vicinity of the inlet nozzle which may result in significant error.

The Apex Instruments test equipment was designed to meet the sampling requirements of US EPA Method 5 and with a modified nozzle design, meets the sampling requirements of BS EN 13284-1.

The principle of the standard is to draw a known volume of dust laden gas isokinetically through a filter. The weight gain on the filter, after sampling, divided by the gas sample volume equates to the particulate concentration, which in turn can be used to calculate a mass emission.

2.3 Sampling equipment

The test equipment is inspected prior to use and it's calibration status observed. This includes:-

* *Pitot Tube* - All pitot tubes are checked for damage, alignment and that there are no blockages;

* *Manometer* - Check of oil levels, connectors and orientation level;

* *Thermocouple* - Temperature is measured using k type thermocouples. Each thermocouple is inspected for calibration and damage. Digital temperature meters are used in conjunction with k type thermocouples which are also checked for calibration dates;

* Gas meter - The calibration of the gas meter is checked before and after sampling using a critical orifice.

* *Nozzles* - All nozzles used have been constructed in accordance with BS EN 13284-1. Each nozzle is checked for damaged and measured using a Vernier calliper on at least 3 planes. Non conforming nozzles will be rejected.

* *Balance* - A Mettler Toledo balance is used to weigh filters. It is calibrated yearly by the manufacturer and checked daily by in-house weights.

* *Filters* - Quartz membrane filters with a collection efficiency of >99.5% at 0.3microns.

2.4 Preparation for sampling

2.4.1 Filter preparation

Filters are pre-conditioned before arrival on site. The filters are dried in an oven at $180^{o}C$ for a period of at least one hour and then placed to cool in a desiccator for at least four hours. The filters are then weighed on a five figure balance and placed in individual transport containers. Spare Filters are prepared to obtain blank values.

2.4.2 Sampling location

No site visit was undertaken prior to undertaking the sampling procedure, as monitoring had previously been undertaken at the site, during which time the sampling position, working platform, sampling ports, access and safety precautions were found to be satisfactory.

The internal dimension of the flue was known from previous monitoring undertaken. However, further measurements were taken to check that the internal diameter had not changed.

2.4.2 Sampling location - cont.

Prior to sampling a pressure and temperature survey, using a pitot static tube, a micromanometer, a digital thermometer and a nickel-chromium/nickel-aluminium thermocouple, is carried out to check whether the flow conditions meet with the requirements of BS EN 16911. From this initial survey sample locations, isokinetic flow rates, nozzle size, and sample period can be worked out.

2.5 Sample collection

A leak check is carried out before and after sampling to confirm all the suction is drawn through the nozzle.

With the required isokinetic flow rates known the sample probe is inserted into the stack at 90° to the gas flow, this is to stop any particulate matter impinging on the filter before sampling.

The filter head and probe were allowed to obtain the stack gas temperature.

The initial gas meter reading was noted and the suction device and timer started. The correct flow rate for isokinetic sampling was set and the nozzle positioned to face parallel to the gas flow.

Sampling was then carried out for the planned duration and number of sample points, recording all the necessary data for final calculations. On completion, the suction device and timer were stopped and the final gas meter volume recorded.

The probe was removed from the process stack and a further leak test carried out prior to removal of the filter, which was subsequently removed and placed in a storage container.

Any residual particulates upstream of the filter was washed with acetone into an appropriate beaker.

Repeat all of the above procedures to obtain duplicate samples.

At all times during the sampling procedure the sampling technicians were in contact with the process operator to ensure that the plant was in full production and there were no changes in the process that might affect the representative nature of the samples collected.

2.6 Analysis of samples

On returning to the laboratory, the used filters were dried in an oven at 160°C for a minimum of one hour and then desiccated and weighed as before. The water/acetone washings are first evaporated, without boiling, then dried and weighed as above. The total particulate mass is the sum of the differential filter weight added to the differential water/acetone rinsings component.

2.7 Calculation of results

The calculations were made using the formula specified in BS EN 13284-1.

The recorded filter weights, velocity, temperature, sampling duration and internal flue dimensions were then used to calculate:-

* the mass rate of solids emission in kg/hr; and
* the solids concentration in mg/m^3.

3. QUALITY ASSURANCE

3.1 Location

SAMPLING LOCATION					
Determined	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest differential pressure	112	Pa	>= 5Pa	Yes	BS EN 15259
Highest differential pressure	184	Pa	-	-	
Ratio of gas pressures	1.6	Pa	<9:1	Yes	BS EN 15259
Mean gas velocity	16.2	m/s	-	-	-
Temperature deviation	335	K	<10%	Yes	BS EN 13284
Max angle of flow	<15	°	<15°	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259

Duct Details		
	Value	Units
Shape	Circular	-
Depth	0.90	m
Width	-	m
Area	0.64	m^2
Port	0.08	m

Duct Details	
	Isokinetic
Sample port size	4" BSP
Number of lines used	2
Number of points/line	2
Duct orientation	Vertical
Filtration for TPM	In stack

3.2 Methods

MONITORING METHODS		
Determined	**Method**	**Technical Procedure**
TPM	Gravimetric	EL18
H2O	Gravimetric	EL5

3.3 Test Team

MONITORING TEAM						
Personnel	**MCERTS Number**	**MCERTS**		**TE/H&S Qualifications**		
		Level	**Expiry**	**TE1**	**H&S**	
Andrew Yelland	MM 02 130	MCERTS Level 2	Jul-19	Apr-23	Jul-19	
Ryan Carkeek	-	-	-	-	-	

4. ON-SITE SUMMARY/MEASURMENTS

TOTAL PARTICULATE MATTER SUMMARY				
Determined	Sampling Times	Concentration mg/m^3	Uncertainty mg/m^3	Limit mg/m^3
Run 1	14.00 - 14.32	5.27	0.17	50
Run 2	14.38 - 15.10	6.89	0.19	50
Blank	-	0.06	-	-

FILTER SUMMARY					
Determined	Filter No	Filter Start Weight g	Filter Start Weight g	Acetone Rinse Weight g	Combined Mass Gained g
Run 1	4	0.05609	0.05874	0.00002	0.00267
Run 2	5	0.05625	0.05978	0.00003	0.00356
Blank	6	0.05593	0.05595	0.00001	0.00003

STANDARD UNCERTAINTY SUMMARY						
Measured Quantities	Value	Standard uncertainty		Uncertainty %	Requirement of std	
Sampled Volume - V_m	0.5801	uV_m 0.001	m^3	0.17		<=2% Pass
Sampled gas Temp - T_m	291	uTm 2	k	0.69		<=1% Pass
Sampled gas Pressure - ρm	100.1	$u\rho_m$ 0.5	kPa	0.50		<=1% Pass
Sampled gas Humidity - Hm	4.33	uH_m 1	% by vol	0.23		<=1% Pass
Oxygen content - O2,m	18.6	$uO_{2,m}$ 0.1	% by vol	0.54		<=5% Pass
Mass particulate - m	2.67	um 0.01	mg	0.37	0.04	<5% of limit val
Note - Sampled gas humidity, temperature and pressure are values at the gas meter						Pass
Leak - L	0.49		%	0.49		<=2% Pass
Uncollected Mass - UCM (Instack filter - no rinse)	0.03		mg	1.12		<=10% Pass

MOISTURE SUMMARY					
RUN	Trap Start Weight g	Trap End Weight g	Difference g	Volume sampled m^3	Bwo %
Run 1	538.6	557.1	18.5	0.5068	4.33
Run 2	541.3	560.4	19.1	0.5167	4.38

4.1 Preliminary stack survey

On Site Velocity and Flow Data

Company	CPI MORTARS LTD	Stack Diameter	0.90	m
Site	29 MEAD PARK	Area	0.64	m²
Location	AGGREGATE DRYING PLANT	Sample points required	4	
Job No	2953	Barometric Pressure	100.1	kPa
Operators	AJY/RJC	Stack Pressure	0.03	kPa
		Pitot Tube Coefficient	0.997	

Preliminary readings taken before sampling				
	Pitot Traverse A		Pitot Traverse B	
Pitot Settings	Δ P pa	Temp °C	Δ P pa	Temp °C
1	156	61	116	62
2	152	62	123	62
3	129	62	127	62
4	123	61	119	62
5	112	61	114	62
6	115	61	119	62
7	132	62	144	61
8	138	62	172	61
9	161	62	178	61
10	167	62	184	61
Mean	139	62	140	62

4.2 Leak check results

PITOT LEAK CHECK

Run	Pre traverse leak rate			Post traverse leak rate		
	Start value Pa	End value Pa	Difference %	Start value Pa	End value Pa	Difference %
Run 1	250	250	Pass	250	250	Pass
Run 2	250	250	Pass	250	250	Pass

S-TYPE STAGNATION CHECK

Run	Stagnation Pa	Reference Pa	Difference Permitted +/- 10 Pa
Run 1	45	45	Pass
Run 2	45	45	Pass

SAMPLE TRAIN LEAK CHECK

Run	Mean Sampling Rate litres/min	Pre-sampling Leak Rate litres/min	Post-sampling Leak Rate litres/min	Acceptable Leak Rate litres/min	Maximum Leak Rate %
Run 1	20.28	0.10	0.10	0.41	Yes
Run 2	20.40	0.08	0.08	0.41	Yes

SAMPLE TRAIN LEAK CHECK

Run	Blank Value mg/m^3	Emission Limit Value mg/m^3	Acceptable Blank Value mg/m^3	Blank Value Acceptable mg/m^3
Blank 1	0.06	25	3	Yes

5. SAMPLING RECORDS

5.1 Process Conditions

Arrestment Plant:	Bag filter
Particulate Type:	Sand
Plant Loading:	Continuous - Sand @ 35tph.
Appearance of plume:	No visible discharge.

5.2 Sampling Results

	Test Run No. 1.	Test Run No. 2.	Average
Time of Test:	14.00 - 14.32	14.38 - 15.10	
Sampling Duration: (mins)	32	32	
Gas Temperature ($^{\circ}$C)	62	62	62
Mean Velocity at Sampling Points: (m/s)	17.21	17.32	17.27
Gas Flow Rate at STP (1): (m^3/min)	506.7	509.1	507.9
Particulate Loading at STP (1): (mg/m^3)	5.27	6.89	6.08
Particulate at Normalised Conditions (2): (mg/m^3)	-----	-----	-----

(1) Particulate stated at 273K, 101.3kPa without correction for water vapour.

(2) State normalised conditions (eg 11% O_2, etc).

5.3 - Calculations Sample Run No. 1

On-site measurements

O2 =	18.6 %	CO2 =	1.3 %	N2 =	80.1 %
Bws =	0.04	Ps =	100.1 kPa	Ts =	334.8 K

Md = Molecular weight of gas at DGM (g/g mole)
Md = $(0.44 \times \%CO_2) + (0.32 \times \%O_2) + (0.28 \times \%N_2)$
    =   28.95 g/g mole

Ms = Molecular weight of gas wet (g/g mole)
    =   28.51 g/g mole

Stack gas velocity at sample points
    V = Kp x Cp x $\sqrt{(Ts.\Delta P/Ps.Ms)}$ Kp =   4.07
      =   17.21 m/s ΔP =   153.5 av. Δp at sample plane
                                         Cp =   1.00 pitot tube coefficient

Stack gas volume at sample points
    Q = V x A x 60   A =   0.64 area of stack m^2
      =   657.1 m^3/min

Volume of water vapour collected, standard conditions (m^3)
Vwstd = 0.00124 x Vlc   Vlc =   19 ml
    =   0.0229 m^3

Volume of gas metered, standard conditions (m^3)
Vmstd = $\underline{2.695 \times Vm \times (Pa + (\Delta H/102)) \times Yd}$ Tm =   18 °C
                    (T + Tm)   Vm =   0.5801 m^3
                                           Pa =   100.1 kPa
    =   0.5068 m^3 ΔH =   26.5 mm H_2O
                                           Yd =   0.940

Moisture content
  Bwo = Vwstd/(Vwstd +Vmstd)
      =   0.0433

5.3 - Calculations Sample Run No. 1 Cont.

Dry total flow of stack gas, standard conditions (m^3/min)

$$Qstd = \frac{Q \times Ps(2.695)(1 - Bwo)}{Ts + 273}$$

$Ts =$ 61.8 ^{o}C

$Ps =$ 100.1 kPa

$= 507 \ m^3$/min

Percent isokinetic

$$\%I = \frac{(6.184 \times 10^5)(Ts + 273) \times Vmstd}{Ps \times V \times Aa \times t \times (1-Bwo)}$$

$Aa =$ 19.6 area of nozzle mm^2

$= 101.3 \ \%$

Filter & rinsing weights sample no. 1

weight gain on filters =   2.65 mg
weight of acetone wash =   0.02 mg
total weight gain (M) =   2.67 mg

Particulate concentration (mg/m^3)

$C = M/Vmstd$

$M =$ 2.67 mg

$= 5.27 \ mg/m^3$

Particulate emission rate (kg/hr)

$E = (C \times Qstd \times 60)/1000000$

$= 0.16$ kg/hr

5.3 - Calculations Sample Run No. 2

On-site measurements

O2 =	18.6 %	CO2 =	1.3 %	N2 =	80.1 %
Bws =	0.04	Ps =	100.1 kPa	Ts =	335.0 K

Md = Molecular weight of gas at DGM (g/g mole)

$Md = (0.44 \times \%CO_2) + (0.32 \times \%O_2) + (0.28 \times \%N_2)$

$\quad = \quad$ 28.95 g/g mole

Ms = Molecular weight of gas wet (g/g mole)

$\quad = \quad$ 28.48 g/g mole

Stack gas velocity at sample points

$V = Kp \times Cp \times \sqrt{(Ts.\Delta P / Ps.Ms)}$ 　　　　Kp = 　4.07

$\quad = \quad$ 17.32 m/s 　　　　　　　　　　ΔP = 　155.0 av. Δp at sample plane

　　　　　　　　　　　　　　　　　　　　　Cp = 　1.00 pitot tube coefficient

Stack gas volume at sample points

$Q = V \times A \times 60$ 　　　　　　　　　　A = 　0.64 area of stack m^2

$\quad = \quad$ 661.0 m^3/min

Volume of water vapour collected, standard conditions (m^3)

$Vwstd = 0.00124 \times Vlc$ 　　　　　　　　Vlc = 　19 ml

$\quad = \quad$ 0.0237 m^3

Volume of gas metered, standard conditions (m^3)

$Vmstd = \dfrac{2.695 \times Vm \times (Pa + (\Delta H / 102)) \times Yd}{(T + Tm)}$ 　　Tm = 　18 ^{o}C

　　　　　　　　　　　　　　　　　　　　　Vm = 0.5914 m^3

　　　　　　　　　　　　　　　　　　　　　Pa = 　100.1 kPa

$\quad = \quad$ 0.5167 m^3 　　　　　　　　　　ΔH = 　27 mm H_2O

　　　　　　　　　　　　　　　　　　　　　Yd = 　0.940

Moisture content

$Bwo = Vwstd / (Vwstd + Vmstd)$

$\quad = \quad$ 0.0438

5.3 - Calculations Sample Run No. 2 Cont.

Dry total flow of stack gas, standard conditions (m³/min)

$$Qstd = \frac{Q \times Ps(2.695)(1 - Bwo)}{Ts + 273}$$

Ts = 62.0 °C
Ps = 100.1 kPa

= 509.1 m³/min

Percent isokinetic

$$\%I = \frac{(6.184 \times 10^5)(Ts + 273) \times Vmstd}{Ps \times V \times Aa \times t \times (1-Bwo)}$$

Aa = 19.6 area of nozzle mm²

= 102.8 %

Filter & rinsing weights sample no. 2

weight gain on filters = 3.53 mg
weight of acetone wash = 0.03 mg
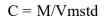total weight gain (M) = 3.56 mg

Particulate concentration (mg/m³)

C = M/Vmstd

M = 3.56 mg

= 6.89 mg/m³

Particulate emission rate (kg/hr)

E = (C x Qstd x 60)/1000000

= 0.21 kg/hr

5.4 - Sample Blank

An overall sample blank was taken after the measurement series, following the sampling procedure in the methodology without starting the suction device and keeping the blank in the duct for 15 minutes with the sampling nozzle 180o from the direction of flow. This leads to an estimation of the dispersion of results related to the whole procedure.

weight gain on filters =   0.00002 mg

weight of acetone wash =   0.00001 mg

total weight gain (M) =   0.00003 mg

Particulate concentration (mg/m^3)

C = M/Vmstd   M =   0.03 mg

=   0.06 mg/m^3

5.5 - Sampling Conditions

	Sample Run No. 1			Sample Run No. 2		
Sample Position	Stack Temp °C	Velocity Pressure ΔP (Pa)	Nozzle Area mm²	Stack Temp °C	Velocity Pressure ΔP (Pa)	Nozzle Area mm²
0.15D	62	152	19.6	63	155	19.6
0.85D	62	161	19.6	62	159	19.6
0.15D	62	123	19.6	62	126	19.6
0.85D	61	178	19.6	61	180	19.6

5.6 - Weighing Results

The below filters and acetone rinsings were weighed on a balance in a temperature controlled room with corrections made for differences in atmospheric pressure. Control parts and blank filters are used to confirm accuracy of weighings.

Sample Run No.1.	Ref No.	Weight gms Before	After	Collected	Sample time at each point (mins)	% weight gain
Filter	4	0.05609	0.05874	0.00265	8.0	4.8%
Acetone	A4	########	121.10664	0.00002		0.0%
Total weight =			0.00267			
Sample Run No.2.	Ref No.	Weight gms Before	After	Collected	Sample time at each point (mins)	
Filter	5	0.05625	0.05978	0.00353	8.0	6.3%
Acetone	A5	########	120.89938	0.00003		0.0%
Total weight =			0.00356			
Sample Blank	Ref No.	Weight gms Before	After	Collected	Sample time at each point (mins)	
Filter	6	0.05593	0.05595	0.00002	n/a	0.0%
Acetone	A6	########	121.21765	0.00001	n/a	0.0%
Total weight =			0.00003			

6. Uncertainty calculation for EN 13284-1:2002

Sample Run No. 1

Measurement Equation

$$c = \frac{m}{V} f_c$$

Limit value	50	mg.m^{-3}	O2 Ref	21	%
Measured conc.	5.27	mg.m^{-3}			

Measured Quantities	Symbol	Value	Standard uncertainty		Units	Uncertainty %		Requirement of std
Sampled Volume	V_m	0.5801	uV_m	0.001	m^3	0.17		<=2%
Sampled gas Tem	T_m	291.0	uTm	2	k	0.69		<=1%
Sampled gas Pressure	ρ_m	100.1	$u\rho_m$	0.5	kPa	0.50		<=1%
Sampled gas Humidity	H_m	4.33	uH_m	1	% by vol	0.23		<=1%
Oxygen content	$O_{2,m}$	18.6	$uO_{2,m}$	0.1	% by vol	0.54		<=5%
Mass particulate	m	2.67	um	0.01	mg	0	0.04	<5% of limit val
Note - Sampled gas humidity, temperature and pressure are values at the gas meter								
Leak	L	0.49			%	0.49		<=2%
Uncollected Mass	UCM	0.03			mg	1.12		<=10%
(Instack filter - no rinse)								

Intermediate calculations

Factor for std conds	fs	0.87		
uncertainty components	symbol	sensitivity coeff	u (in units of fs)	
	ρ_m	0.009	0.004	
	H_m	0.009	0.009	$f_s = \frac{(100 - H_m)}{100} \frac{273}{T_m} \frac{\rho_m}{101.3}$
	T_m	0.003	0.006	
	ufs		0.012	1.35
Corrected volume	V	0.51 uV	0.007 m^3	$V = V_m f_s$ 1.36
Factor for O2 correction	fc	1.00		
uncertainty components	symbol	sensitivity coeff	u	$f_c = \frac{21 - O_{2,ref}}{21 - O_{2,m}}$
	$O_{2,m}$	0.42	0.042	
Factor for O2 Corr	ufc	1.00	0.042	1.00

Parameter	Uncertainty	Value	Units	Sens coeff	Uncertainty in Result		Uncertainty as %	
Volume(stp)	V	0.51	m^3	10.39	0.07	mg.m^{-3}	1.36	%
Mass	m	2.67	mg	1.97	0.02	mg.m^{-3}	0.37	
Factor for O2 Correction	fc	1.00		0.00	0.00	mg.m^{-3}	0.00	%
Leak	L	0.01	mg.m^{-3}	1.00	0.01	mg.m^{-3}		
Uncollected mass	UCM	0.02	mg	1.97	0.03	mg.m^{-3}		
Combined uncertainty					**0.08**	mg.m^{-3}		

Expanded uncertainty expressed with a level of confidence of 95%   3.16 %

Expanded uncertainty expressed with a level of confidence of 95%   0.17 mg.m^{-3}

6. Uncertainty calculation for EN 13284-1:2002

Sample Run No. 2

Measurement Equation

$$c = \frac{m}{V} f_c$$

Limit value	50 mg.m^{-3}	O2 Ref	21	%
Measured conc.	6.89 mg.m^{-3}			

Measured Quantities	Symbol	Value	Standard uncertaint		Units	Uncertainty %		Requirement of std
Sampled Volume	V_m	0.5914	uV_m	0.001	m^3	0.17		<=2%
Sampled gas Tem	T_m	291.0	uTm	2	k	0.69		<=1%
Sampled gas Pressure	ρ_m	100.1	$u\rho_m$	0.5	kPa	0.50		<=1%
Sampled gas Humidity	H_m	4.38	uH_m	1	% by vol	0.23		<=1%
Oxygen content	$O_{2,m}$	18.6	$uO_{2,m}$	0.1	% by vol	0.54		<=5%
Mass particulate	m	3.56	um	0.01	mg	0	0.04	<5% of limit val
Note - Sampled gas humidity, temperature and pressure are values at the gas meter								
Leak	L	0.39			%	0.39		<=2%
Uncollected Mass	UCM	0.03			mg	0.84		<=10%
(Instack filter - no rinse)								

Intermediate calculations

Factor for std conds	fs		0.87			
uncertainty components	symbol	sensitivity coeff		u (in units of fs)		
	ρ_m	0.009		0.004		
	H_m	0.009		0.009		
	T_m	0.003		0.006		
	ufs			0.012		1.35
Corrected volume	V	0.52	uV	0.007	m^3	1.36

$$f_s = \frac{(100 - H_m)}{100} \frac{273}{T_m} \frac{\rho_m}{101.3}$$

$$V = V_m f_s$$

Factor for O2 correction	fc		1.00	
uncertainty components	symbol	sensitivity coeff		u
	$O_{2,m}$	0.42		0.042
Factor for O2 Corr	ufc	1.00		0.042

$$f_c = \frac{21 - O_{2,ref}}{21 - O_{2,m}}$$

Parameter	Uncertainty	Value	Units	Sens coeff	Uncertainty in Result		Uncertainty as %
Volume(stp)	V	0.52	m^3	13.33	0.09	mg.m^{-3}	1.36 %
Mass	m	3.56	mg	1.94	0.02	mg.m^{-3}	0.28
Factor for O2 Correction	fc	1.00		0.00	0.00	mg.m^{-3}	0.00 %
Leak	L	0.02	mg.m^{-3}	1.00	0.02	mg.m^{-3}	
Uncollected mass	UCM	0.00	mg	1.94	0.00	mg.m^{-3}	
Combined uncertainty					**0.10**	mg.m^{-3}	

Expanded uncertainty expressed with a level of confidence of 95%   **2.82 %**

Expanded uncertainty expressed with a level of confidence of 95%   **0.19 mg.m^{-3}**