

Environmental Protection Act
Pollution Prevention & Control

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

on

**COATING PLANT
BAG FILTER EXHAUST**

for

**MIDLAND QUARRY PRODUCTS
ST. IVES WORKS
MEADOW LANE
ST. IVES
CAMBRIDGESHIRE PE27 4LG**

Tested By:



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EXECUTIVE SUMMARY

EMISSIONS SUMMARY				
Determined	Units	Results	Uncertainty* +/-	Limit
Particulate Concentration (STP)	mg/Nm ³	19.46	0.44	50
Mass Emission (STP)	kg/hr	1.27	0.0291	-
Stack Temperature	°C	82	-	-
Gas Velocity	m/s	16.93	-	-
Stack Volume Flow Rate (Actual)	m ³ /hr	88545	-	-
Stack Volume Flow Rate (STP)	m ³ /hr	67362	-	-

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

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

EXECUTIVE SUMMARY

MONITORING TIMES			
Determined	Sampling Date	Sampling Times	Sampling Duration
Total Particulate Matter Run 1	22.10.19	13.40 - 14.12	32 minutes
Total Particulate Matter Run 2	22.10.19	14.18 - 14.50	32 minutes
Preliminary Stack Traverse	22.10.19	13.35	-

EXECUTIVE SUMMARY

PROCESS DETAILS	
Determined	Process Details
Process description	COATING PLANT
Continuous or Batch	Continuous feed @ 100tph.
Particulate type	Aggregate
Abatement	Bag Filter
Appearance of plume	Steam

EXECUTIVE SUMMARY

MONITORING METHODS				
Determined	Method	Technical Procedure	Limit of Detection	Calculated MU +/- %
TPM	BS EN 13284-1	EL18	0.07	7.2%
Velocity	BS EN ISO 16911-1	EL20	-	-
Volumetric Flow	BS EN ISO 16911-1	EL20	-	-

1. BACKGROUND INFORMATION

Particulate emission testing was undertaken by Yelland Environmental Services, on the roadstone coating plant bag filter exhaust at Midland Quarry Products, St Ives 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 its 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 damage 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°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. In this case no washing is required upstream of the filter as an in stack filter was used as per BS EN 13284-1 requirements.

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 rinsing's 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	130	Pa	$\geq 5\text{Pa}$	Yes	BS EN 15259
Highest differential pressure	152	Pa	-	-	-
Ratio of gas pressures	1.17	Pa	$<9:1$	Yes	BS EN 15259
Mean gas velocity	16.9	m/s	-	-	-
Temperature deviation	3	K	$<10\%$	Yes	BS EN 13284
Max angle of flow	<15	$^{\circ}$	$<15^{\circ}$	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259

Duct Details		
	Value	Units
Depth	1.36	m
Width		m
Area	1.45	m^2
Port	0.09	m

Duct Details	
	Isokinetic
Sample port size	4" BSP
Number of lines used	2
Number of points/line	4
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	Apr-23	Apr-23	Jul-24	

4. ON-SITE SUMMARY/MEASUREMENTS

TOTAL PARTICULATE MATTER SUMMARY				
Determined	Sampling Times	Concentration mg/m ³	Uncertainty mg/m ³	Limit mg/m ³
Run 1	13.40 - 14.12	21.20	0.44	50
Run 2	14.18 - 14.50	17.71	0.37	50
Blank	-	0.07	-	-

FILTER SUMMARY					
Determined	Filter No	Filter Start Weight g	Filter Start Weight g	Acetone Rinse Weight g	Combined Mass Gained g
Run 1	19	0.05617	0.07082		0.01465
Run 2	20	0.05649	0.06873		0.01224
Blank	21	0.05629	0.05634		0.00005

STANDARD UNCERTAINTY SUMMARY				
Measured Quantities	Value	Standard uncertainty	Uncertainty %	Requirement of std
Sampled Volume - V _m	0.7798	uV _m 0.001 m ³	0.13	<=2% Pass
Sampled gas Temp - T _m	282	uT _m 2 K	0.71	<=1% Pass
Sampled gas Pressure - p _m	100.3	up _m 0.5 kPa	0.50	<=1% Pass
Sampled gas Humidity - H _m	2.93	uH _m 0.5 % by vol	0.17	<=1% Pass
Oxygen content - O _{2,m}	16.5	uO _{2,m} 0.1 % by vol	0.61	<=5% Pass
Mass particulate - m	14.65	um 0.01 mg	0.07	0.03 <5% of limit val
Note - Sampled gas humidity, temperature and pressure are values at the gas meter				
Leak - L	0.24	%	0.24	<=2% Pass
Uncollected Mass - UCM (In stack filter - no rinse)	0.05	mg	0.34	<=10% Pass

MOISTURE SUMMARY					
RUN	Trap Start Weight g	Trap End Weight g	Difference g	Volume sampled m ³	Bwo %
Run 1	541.6	558.4	16.8	0.6911	2.93
Run 2	539.1	555.6	16.5	0.6910	2.88

4.1 Preliminary stack survey

On Site Velocity and Flow Data

Company	MIDLAND QUARRY PRODUCTS	Stack Diameter	1.36	m
Site	ST. IVES WORKS	Area	1.45	m ²
Location	COATING PLANT	Sample points required	8	
Job No	3150	Barometric Pressure	100.3	kPa
Operators	AJY	Stack Pressure	0.01	kPa
		Pitot Tube Coefficient	0.997	

Preliminary readings taken before sampling				
	Pitot Traverse A		Pitot Traverse B	
Pitot Settings	ΔP pa	Temp °C	ΔP pa	Temp °C
.026D	142	81	136	82
.082D	148	81	148	82
.147D	150	82	152	82
.227D	147	82	151	82
.342D	144	82	147	82
.658D	145	82	144	83
.774D	143	83	140	83
.854D	140	83	138	83
.918D	136	83	134	84
.975D	130	82	132	83
Mean	143	82	142	83

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	40	40	Pass
Run 2	40	40	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	28.61	0.07	0.07	0.57	Yes
Run 2	28.81	0.08	0.08	0.58	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	0.07	50	5	Yes

5. SAMPLING RECORDS

5.1 Process Conditions

Arrestment Plant:	Bag Filter
Particulate Type:	Aggregate
Plant Loading:	Continuous feed @ 100tph.
Appearance of plume:	Steam

5.2 Sampling Results

	Test Run No. 1.	Test Run No. 2.	Average
Time of Test:	13.40 - 14.12	14.18 - 14.50	
Sampling Duration: (mins)	32	32	
Gas Temperature (°C)	82	83	83
Mean Velocity at Sampling Points: (m/s)	16.86	16.98	16.92
Gas Flow Rate at STP (1): (m ³ /min)	1085.7	1091.7	1088.7
Particulate Loading at STP (1): (mg/m ³)	21.20	17.71	19.46
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% O₂, etc).

5.3 - Calculations Sample Run No. 1

On-site measurements

$$\begin{array}{llll} \text{O}_2 = & 16.5 \% & \text{CO}_2 = & 2.4 \% & \text{N}_2 = & 81.1 \% \\ \text{Bws} = & 0.03 & \text{Ps} = & 100.3 \text{ kPa} & \text{Ts} = & 355.3 \text{ K} \end{array}$$

$$\begin{aligned} \text{Md} &= \text{Molecular weight of gas at DGM (g/g mole)} \\ \text{Md} &= (0.44 \times \% \text{CO}_2) + (0.32 \times \% \text{O}_2) + (0.28 \times \% \text{N}_2) \\ &= 29.04 \text{ g/g mole} \end{aligned}$$

$$\begin{aligned} \text{Ms} &= \text{Molecular weight of gas wet (g/g mole)} \\ &= 28.71 \text{ g/g mole} \end{aligned}$$

Stack gas velocity at sample points

$$\begin{aligned} V &= K_p \times C_p \times \sqrt{(T_s \cdot \Delta P / P_s \cdot M_s)} \\ &= 16.86 \text{ m/s} \end{aligned}$$
$$\begin{array}{ll} K_p = & 4.07 \\ \Delta P = & 140.0 \text{ av. } \Delta p \text{ at sample plane} \\ C_p = & 1.00 \text{ pitot tube coefficient} \end{array}$$

Stack gas volume at sample points

$$\begin{aligned} Q &= V \times A \times 60 \\ &= 1469.7 \text{ m}^3/\text{min} \end{aligned}$$
$$A = 1.45 \text{ area of stack m}^2$$

Volume of water vapour collected, standard conditions (m³)

$$\begin{aligned} V_{wstd} &= 0.00124 \times V_{lc} \\ &= 0.0208 \text{ m}^3 \end{aligned}$$
$$V_{lc} = 17 \text{ ml}$$

Volume of gas metered, standard conditions (m³)

$$\begin{aligned} V_{mstd} &= \frac{2.695 \times V_m \times (P_a + (\Delta H / 102)) \times Y_d}{(T + T_m)} \\ &= 0.6911 \text{ m}^3 \end{aligned}$$
$$\begin{array}{ll} T_m = & 9 \text{ }^\circ\text{C} \\ V_m = & 0.7798 \text{ m}^3 \\ P_a = & 100.3 \text{ kPa} \\ \Delta H = & 50.3 \text{ mm H}_2\text{O} \\ Y_d = & 0.920 \end{array}$$

Moisture content

$$\begin{aligned} B_{wo} &= V_{wstd} / (V_{wstd} + V_{mstd}) \\ &= 0.0293 \end{aligned}$$

5.3 - Calculations Sample Run No. 1 Cont.

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

$$Q_{std} = \frac{Q \times P_s(2.695)(1 - B_{wo})}{T_s + 273}$$
$$= 1086 \text{ m}^3/\text{min}$$

$$T_s = 82.3 \text{ }^\circ\text{C}$$
$$P_s = 100.3 \text{ kPa}$$

Percent isokinetic

$$\%I = \frac{(6.184 \times 10^5)(T_s + 273) \times V_{mstd}}{P_s \times V \times A_a \times t \times (1 - B_{wo})}$$
$$= 102.2 \%$$

$$A_a = 28.3 \text{ area of nozzle mm}^2$$

Filter & rinsing weights sample no. 1

$$\begin{aligned} \text{weight gain on filters} &= 14.65 \text{ mg} \\ \text{weight of acetone wash} &= \text{mg} \\ \text{total weight gain (M)} &= 14.65 \text{ mg} \end{aligned}$$

Particulate concentration (mg/m³)

$$C = M/V_{mstd}$$
$$= 21.20 \text{ mg/m}^3$$

$$M = 14.65 \text{ mg}$$

Particulate emission rate (kg/hr)

$$E = (C \times Q_{std} \times 60)/1000000$$
$$= 1.38 \text{ kg/hr}$$

5.3 - Calculations Sample Run No. 2

On-site measurements

$$\begin{array}{llll} \text{O}_2 = & 16.5 \% & \text{CO}_2 = & 2.4 \% & \text{N}_2 = & 81.1 \% \\ \text{Bws} = & 0.03 & \text{Ps} = & 100.3 \text{ kPa} & \text{Ts} = & 356.0 \text{ K} \end{array}$$

$$\begin{aligned} \text{Md} &= \text{Molecular weight of gas at DGM (g/g mole)} \\ \text{Md} &= (0.44 \times \% \text{CO}_2) + (0.32 \times \% \text{O}_2) + (0.28 \times \% \text{N}_2) \\ &= 29.04 \text{ g/g mole} \end{aligned}$$

$$\begin{aligned} \text{Ms} &= \text{Molecular weight of gas wet (g/g mole)} \\ &= 28.72 \text{ g/g mole} \end{aligned}$$

Stack gas velocity at sample points

$$\begin{aligned} V &= K_p \times C_p \times \sqrt{(T_s \cdot \Delta P / P_s \cdot M_s)} \\ &= 16.98 \text{ m/s} \end{aligned} \quad \begin{array}{ll} K_p = & 4.07 \\ \Delta P = & 141.8 \text{ av. } \Delta p \text{ at sample plane} \\ C_p = & 1.00 \text{ pitot tube coefficient} \end{array}$$

Stack gas volume at sample points

$$\begin{aligned} Q &= V \times A \times 60 \\ &= 1480.2 \text{ m}^3/\text{min} \end{aligned} \quad A = 1.45 \text{ area of stack m}^2$$

Volume of water vapour collected, standard conditions (m³)

$$\begin{aligned} V_{wstd} &= 0.00124 \times V_{lc} \\ &= 0.0205 \text{ m}^3 \end{aligned} \quad V_{lc} = 17 \text{ ml}$$

Volume of gas metered, standard conditions (m³)

$$\begin{aligned} V_{mstd} &= \frac{2.695 \times V_m \times (P_a + (\Delta H / 102)) \times Y_d}{(T + T_m)} \\ &= 0.691 \text{ m}^3 \end{aligned} \quad \begin{array}{ll} T_m = & 10 \text{ }^\circ\text{C} \\ V_m = & 0.7824 \text{ m}^3 \\ P_a = & 100.3 \text{ kPa} \\ \Delta H = & 51 \text{ mm H}_2\text{O} \\ Y_d = & 0.920 \end{array}$$

Moisture content

$$\begin{aligned} B_{wo} &= V_{wstd} / (V_{wstd} + V_{mstd}) \\ &= 0.0288 \end{aligned}$$

5.3 - Calculations Sample Run No. 2 Cont.

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

$$Q_{std} = \frac{Q \times P_s(2.695)(1 - B_{wo})}{T_s + 273}$$
$$= 1091.7 \text{ m}^3/\text{min}$$

$$T_s = 83.0 \text{ }^\circ\text{C}$$
$$P_s = 100.3 \text{ kPa}$$

Percent isokinetic

$$\%I = \frac{(6.184 \times 10^5)(T_s + 273) \times V_{mstd}}{P_s \times V \times A_a \times t \times (1 - B_{wo})}$$
$$= 101.6 \%$$

$$A_a = 28.3 \text{ area of nozzle mm}^2$$

Filter & rinsing weights sample no. 2

$$\begin{aligned} \text{weight gain on filters} &= 12.24 \text{ mg} \\ \text{weight of acetone wash} &= \text{mg} \\ \text{total weight gain (M)} &= 12.24 \text{ mg} \end{aligned}$$

Particulate concentration (mg/m³)

$$C = M/V_{mstd}$$
$$= 17.71 \text{ mg/m}^3$$

$$M = 12.24 \text{ mg}$$

Particulate emission rate (kg/hr)

$$E = (C \times Q_{std} \times 60)/1000000$$
$$= 1.16 \text{ kg/hr}$$

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 180° from the direction of flow. This leads to an estimation of the dispersion of results related to the whole procedure.

weight gain on filters = 0.00005 mg

weight of acetone wash = mg

total weight gain (M) = 0.00005 mg

Particulate concentration (mg/m³)

$$C = M/V_{mstd}$$

$$M = 0.05 \text{ mg}$$

$$= 0.07 \text{ mg/m}^3$$

5.5 - Sampling Conditions

	Sample Run No. 1			Sample Run No. 2		
Sample Position	Stack Temp °C	Velocity Pressure ΔP (Pa)	Nozzle Area mm ²	Stack Temp °C	Velocity Pressure ΔP (Pa)	Nozzle Area mm ²
0.065D	81	142	28.3	82	145	28.3
0.25D	82	150	28.3	83	152	28.3
0.75D	83	140	28.3	84	142	28.3
0.935D	82	130	28.3	83	128	28.3
0.065D	82	136	28.3	84	139	28.3
0.25D	82	152	28.3	83	155	28.3
0.935D	83	138	28.3	83	140	28.3
0.935D	83	132	28.3	82	133	28.3

5.6 - Weighing Results

The below filters and acetone rinsing's 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 weighing's.

Sample Run No.1.	Ref No.	Weight gms			Sample time at each point (mins)	% weight gain
		Before	After	Collected		
Filter Acetone	19	0.05617	0.07082	0.01465	4.0	26.1%
Total weight = 0.01465						
Sample Run No.2.	Ref No.	Weight gms			Sample time at each point (mins)	
		Before	After	Collected		
Filter Acetone	20	0.05649	0.06873	0.01224	4.0	21.7%
Total weight = 0.01224						
Sample Blank	Ref No.	Weight gms			Sample time at each point (mins)	
		Before	After	Collected		
Filter Acetone	21	0.05629	0.05634	0.00005	n/a	0.1%
Total weight = 0.00005						

6. Uncertainty calculation for EN 13284-1:2017

Sample Run No. 1

Measurement Equation

Limit value	50	mg.m ⁻³	O2 Ref	21	%
Measured conc.	21.20	mg.m ⁻³			

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

Measured Quantities	Symbol	Value	Standard uncertain	Units	Uncertainty %	Requirement of std
Sampled Volume	V _m	0.7798	uV _m	0.001 m ³	0.13	<=2%
Sampled gas Tem	T _m	282.0	uT _m	2 k	0.71	<=1%
Sampled gas Pressure	p _m	100.3	up _m	0.5 kPa	0.50	<=1%
Sampled gas Humidity	H _m	2.93	uH _m	0.5 % by vol	0.17	<=1%
Oxygen content	O _{2,m}	16.5	uO _{2,m}	0.1 % by vol	0.61	<=5%
Mass particulate	m	14.65	um	0.01 mg	0	0.03 <5% of limit val
Note - Sampled gas humidity, temperature and pressure are values at the gas meter						
Leak	L	0.24		%	0.24	<=2%
Uncollected Mass (In stack filter - no rinse)	UCM	0.05		mg	0.34	<=10%

Intermediate calculations

Factor for std conds	fs	0.89				
uncertainty components	symbol	sensitivity coeff	u (in units of fs)			
	p _m	0.009	0.004			
	H _m	0.009	0.005			
	T _m	0.003	0.006			
	ufs		0.009			1.01
Corrected volume	V	0.69	uV	0.007 m ³	V = V _m f _s	1.02
Factor for O2 correction	fc	1.00				
uncertainty components	symbol	sensitivity coeff	u			
	O _{2,m}	0.22	0.022			
Factor for O2 Corr	ufc	1.00	0.022			1.00

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

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

Parameter	Uncertainty	Value	Units	sens coeff	Uncertainty in Result	Uncertainty as %
Volume(stp)	V	0.69	m ³	30.68	0.22 mg.m ⁻³	1.02 %
Mass	m	14.65	mg	1.45	0.01 mg.m ⁻³	0.07
Factor for O2 Correction	fc	1.00		0.00	0.00 mg.m ⁻³	0.00 %
Leak	L	0.030	mg.m ⁻³	1.00	0.03 mg.m ⁻³	
Uncollected mass	UCM	0.03	mg	1.45	0.04 mg.m ⁻³	
Combined uncertainty					0.22 mg.m ⁻³	

Expanded uncertainty expressed with a level of confidence of 95%

2.10 %

Expanded uncertainty expressed with a level of confidence of 95%

0.44 mg.m⁻³

6. Uncertainty calculation for EN 13284-1:2017

Sample Run No. 2

Measurement Equation

Limit value	50	mg.m ⁻³	O2 Ref	21	%
Measured conc.	17.71	mg.m ⁻³			

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

Measured Quantities	Symbol	Value	Standard uncertain	Units	Uncertainty %	Requirement of std
Sampled Volume	V _m	0.7824	uV _m	0.001 m ³	0.13	<=2%
Sampled gas Tem	T _m	283.0	uT _m	2 K	0.71	<=1%
Sampled gas Pressure	p _m	100.3	up _m	0.5 kPa	0.50	<=1%
Sampled gas Humidity	H _m	2.88	uH _m	0.5 % by vol	0.17	<=1%
Oxygen content	O _{2,m}	16.5	uO _{2,m}	0.1 % by vol	0.61	<=5%
Mass particulate	m	12.24	um	0.01 mg	0	0.03 <5% of limit val
Note - Sampled gas humidity, temperature and pressure are values at the gas meter						
Leak	L	0.28		%	0.28	<=2%
Uncollected Mass (In stack filter - no rinse)	UCM	0.05		mg	0.41	<=10%

Intermediate calculations

Factor for std conds	fs	0.88				
uncertainty components	symbol	sensitivity coeff	u (in units of fs)			
	p _m	0.009	0.004			
	H _m	0.009	0.005			
	T _m	0.003	0.006			
	ufs		0.009			1.01
Corrected volume	V	0.69	uV	0.007 m ³	V = V _m f _s	1.02
Factor for O2 correction	fc	1.00				
uncertainty components	symbol	sensitivity coeff	u			
	O _{2,m}	0.22	0.022			
Factor for O2 Corr	ufc	1.00	0.022			1.00

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

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

Parameter	Uncertainty	Value	Units	Sens coeff	Uncertainty in Result	Uncertainty as %
Volume(stp)	V	0.69	m ³	25.64	0.18 mg.m ⁻³	1.02 %
Mass	m	12.24	mg	1.45	0.01 mg.m ⁻³	0.08
Factor for O2 Correction	fc	1.00		0.00	0.00 mg.m ⁻³	0.00 %
Leak	L	0.028	mg.m ⁻³	1.00	0.03 mg.m ⁻³	
Uncollected mass	UCM	0.00	mg	1.45	0.00 mg.m ⁻³	
Combined uncertainty					0.18 mg.m ⁻³	

Expanded uncertainty expressed with a level of confidence of 95%

2.07 %

Expanded uncertainty expressed with a level of confidence of 95%

0.37 mg.m⁻³