

STACK EMISSIONS MONITORING REPORT



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Operator & Address:

Midland Quarry Products
St Ives Asphalt Plant
Meadow Lane
St Ives
Cambridgeshire
PE27 4LG

Permit:

PPC Permit: B02/97.Var PPC 08/08, PPC 26/05 & EPA 28/08

Release Point:

Asphalt Plant

Sampling Date(s):

16th April 2015

ESG Job Number:	LNO 12365
Report Date:	30th April 2015
Version:	1
Report By:	Lindsay Adams
MCERTS Number:	MM 14 1275
MCERTS Level:	MCERTS Level 1 - Technician
Technical Endorsements:	-
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MCERTS Number:	MM 03 164
Business Title:	MCERTS Level 2 - Business Manager
Technical Endorsements:	1, 2, 3 & 4
Signature:	



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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Midland Quarry Products operates a roadstone coating process at St Ives which is subject to PPC Permit B02/97.Var PPC 08/08, PPC 26/05 & EPA 28/08, under the Pollution Prevention & Control Regulations 2000.

Environmental Scientifics Group Limited were commissioned by Midland Quarry Products to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under normal operating conditions.

The results of these tests shall be used to demonstrate compliance with a set of emission limit values for prescribed pollutants as specified in the Plant's PPC Permit, B02/97.Var PPC 08/08, PPC 26/05 & EPA 28/08.

Plant

Asphalt Plant

Operator

Midland Quarry Products
St Ives Asphalt Plant
Meadow Lane
St Ives
Cambridgeshire
PE27 4LG

PPC Permit: B02/97.Var PPC 08/08, PPC 26/05 & EPA 28/08

Stack Emissions Monitoring Test House

Environmental Scientifics Group Limited - Stockport Laboratory
Unit 5 Crown Industrial Estate
Kenwood Road
Stockport
SK5 6PH
UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

MCERTS accredited results will only be claimed where both the sampling and analytical stages are UKAS accredited.

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EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	Units	Result	Calculated Uncertainty +/-	Limit	MCERTS accredited result
Total Particulate Matter	mg/m ³	13	0.59	50	✓
Particulate Emission Rate	g/hr	639	29	-	
Moisture	%	3.3	0.09	-	✓
Stack Gas Temperature	°C	94	-	-	✓
Stack Gas Velocity	m/s	12.4	0.31	-	
Gas Volumetric Flow Rate (Actual)	m ³ /hr	66026	2971	-	
Gas Volumetric Flow Rate (STP, Wet)	m ³ /hr	48678	2191	-	
Gas Volumetric Flow Rate (STP, Dry)	m ³ /hr	47094	2119	-	
Gas Volumetric Flow Rate at Reference Conditions	m ³ /hr	48678	2191	-	

ND = None Detected,

Results at or below the limit of detection are highlighted by bold italic text.

The above volumetric flow rate is calculated using data from the preliminary survey. Mass emissions for non isokinetic tests are calculated using these values. For all isokinetic testing the mass emission is calculated using test specific flow data and not the above values.

Reference conditions are 273K, 101.3kPa without correction for water vapour

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	Sampling Date(s)	Sampling Times	Sampling Duration
Total Particulate Matter Run 1	16 April 2015	08:30 - 09:42	64 minutes
Stack Gas Flow Rate & Temperature Run 1	16 April 2015	08:00	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Roadstone Coating
Continuous or batch	Batch
Product Details	32mm Granite & Sharp Sand
Part of batch to be monitored (if applicable)	N/A
Normal load, throughput or continuous rating	70 t/hr
Fuel used during monitoring	Waste Oil
Abatement	Bag Filter
Plume Appearance	None Visible

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard reference / alternative methods employed by Environmental Scientifics Group Limited is determined, wherever possible by the hierarchy of method selection outlined in Environment Agency Technical Guidance Note (Monitoring) M2. i.e. CEN, ISO, BS, US EPA etc.

MONITORING METHODS						
Species	Method Standard Reference Method / Alternative Method	ESG Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Limit of Detection (LOD)	Calculated MU +/- %
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	0.23 mg/m ³	4.6 %
H ₂ O	SRM - BS EN 14790	AE 105	1015	Yes	0.01%	2.8%
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	5 Pa	2.5 %
Volumetric Flow Rate	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	-	4.5 %

BS EN 14790 has been validated over a range of 4 - 40%. It is however the preferred method of the Environment Agency for concentrations below 4%

EXECUTIVE SUMMARY

Analytical Methods

The following tables list the analytical methods employed together with the custody and archiving details:

SAMPLING METHODS WITH SUBSEQUENT ANALYSIS							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	UKAS Accredited Lab Analysis	Analysis Lab (ESG or Subcontract)	Sample Archive Location	Archive Period
TPM	Gravimetric	AE 106	1015	Yes	ESG Stockport	ESG Stockport	3 months

ON-SITE TESTING							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	MCERTS Accredited Analysis	Laboratory	Data Archive Location	Archive Period
H ₂ O	Gravimetric	AE 105	1015	Yes	ESG Stockport	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	Value	Units	Requirement	Compliant	Method
Lowest Differential Pressure	98	Pa	≥ 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	11.9	m/s	-	-	-
Highest Gas Velocity	12.9	m/s	-	-	-
Ratio of Gas Velocities	1.1	: 1	$< 3 : 1$	Yes	BS EN 15259
Mean Velocity	12.4	m/s	-	-	-
Maximum angle of flow with regard to duct axis	< 15	$^{\circ}$	$< 15^{\circ}$	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259
Highly homogeneous flow stream / gas velocity	Yes	-	-	Yes	BS EN 15259

DUCT CHARACTERISTICS		
	Value	Units
Shape	Circular	-
Depth	1.37	m
Width	-	m
Area	1.47	m ²
Port Depth	90	mm

SAMPLING LINES & POINTS			
	Isokinetic (CEN Methods)	Isokinetic (ISO Methods)	Non-Iso & Gases
Sample port size	4 inch BSP	-	-
Number of lines used	2	-	-
Number of points / line	4	-	-
Duct orientation	Vertical	-	-
Filtration for TPM	In Stack	-	-

SAMPLING PLATFORM	
General Platform Information	
Permanent / Temporary Platform / Ground level / Floor Level / Roof	Permanent
Inside / Outside	Outside

M1 Platform requirements	
Is there a sufficient working area so work can be performed in a compliant manner	Yes
Platform has 2 levels of handrails (approximately 0.5 m & 1.0 m high)	Yes
Platform has vertical base boards (approximately 0.25 m high)	Yes
Platform has removable chains / self closing gates at the top of ladders	N/A
Handrail / obstructions do not hamper insertion of sampling equipment	Yes
Depth of Platform = $\geq$ Stack depth / diameter + wall and port thickness + 1.5m	Yes

Sampling Platform Improvement Recommendations (if applicable)

The sampling location meets all the requirements as specified in EA Guidance Note M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

In this instance there were no deviations from the sampling and analytical methods employed.

APPENDICES

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APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

APPENDIX 3 - Measurement Uncertainty Budget Calculations

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

MONITORING SCHEDULE					
Species	Method Standard Reference Method / Alternative Method	ESG Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Number of Samples
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	1
H ₂ O	SRM - BS EN 14790	AE 105	1015	Yes	1
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	1

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

CALIBRATEABLE EQUIPMENT CHECKLIST					
Extractive Sampling		Instrumental Analyser/s		Miscellaneous	
Equipment	Equipment I.D.	Equipment	Equipment I.D.	Equipment	Equipment I.D.
Control Box DGM	LNO 13-03	Horiba PG-250 Analyser	-	Laboratory Balance	LNO 00-13, 00-12
Box Thermocouples	LNO 03-03	FT-IR	-	Tape Measure	LNO 24-LM
Meter In Thermocouple	LNO 03-03	FT-IR Oven Box	-	Stopwatch	-
Meter Out Thermocouple	LNO 03-03	Bernath 3006 FID	-	Protractor	-
Control Box Timer	LNO 17-03	Signal 3030 FID	-	Barometer	LNO 08-LM
Oven Box	-	Servomex	-	Digital Micromanometer	-
Probe	LNO 11-46	JCT Heated Head Filter	-	Digital Temperature Meter	-
Probe Thermocouple	LNO 10-46	Thermo FID	-	Stack Thermocouple	-
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	LNO 06-LM	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	LNO 14-LM	Chiller (JCT/MAK 10)	-	1m Heated Line (3)	-
Last Impinger Arm	-	Heated Line Controller (1)	-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	-	10m Heated Line (1)	-
Callipers	LNO 31-LM	Site temperature Logger	-	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	-		-	20m Heated Line (1)	-
Inclinometer (Swirl Device)	LNO 23-LM		-	20m Heated Line (2)	-

NOTE: If the equipment I.D. is represented by a dash (-), then this piece of equipment has not been used for this test.

STACK EMISSIONS MONITORING TEAM

MONITORING TEAM							
Personnel	MCERTS Number	MCERTS Qualification	TE / H&S Qualifications and Expiry Date				
			TE1	TE2	TE3	TE4	H&S
Lawrence Mason	MM 07 849	MCERTS Level 2 - Team Leader	Jun-18	Dec-15	Sep-16	Sep-15	Jul-17
Andre Houghton	MM 10 1077	MCERTS Level 1 - Technician	-	-	-	-	Apr-17

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER SUMMARY					
Parameter	Sampling Times	Concentration mg/m ³	Uncertainty mg/m ³	Limit mg/m ³	Emission Rate g/hr
Run 1	08:30 - 09:42 16 April 2015	12.8	0.58	50	639
Blank	-	0.31	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

Acetone Blank Value mg/l	Acceptable Value mg/l
2.0	10

FILTER INFORMATION

SAMPLES								
Test	Filter & Probe Rinse Number	Filter Start Weight g	Filter End Weight g	Mass Gained on Filter g	Probe Rinse Start Weight g	Probe Rinse End Weight g	Mass Gained on Probe g	Combined Total Mass Gained g
Run 1	G3130	0.10796	0.12174	0.01378	185.47490	185.47910	0.00420	0.01798

If total mass gained is less than the LOD then the LOD is reported

BLANKS								
Test	Filter & Probe Number	Filter Start Weight g	Filter End Weight g	Mass Gained Filter g	Probe Start Weight g	Probe End Weight g	Mass Gained Probe g	Combined Total Mass Gained g
Run 1	G3129	0.10798	0.10801	0.00003	165.16220	165.16260	0.00040	0.00043

If total mass gained is less than the LOD then the LOD is reported

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 1				TPM
Absolute pressure of stack gas, P_s			Molecular weight of dry gas, M_d	
Barometric pressure, P _b	mm Hg	752.26	CO ₂	% 0.03
Stack static pressure, P _{static}	mm H ₂ O	10.20	O ₂	% 20.95
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	753.01	Total	% 20.98
			N ₂ (100 - Total)	% 79.02
Vol. of water vapour collected, V_{wstd}			$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2)$	28.84
Moisture trap weight increase, Vlc	g	36.7	Molecular weight of wet gas, M_s	
$V_{wstd} = (0.001246)(V_{lc})$	m ³	0.0457282	$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol 28.49
Volume of gas metered dry, V_{mstd}			Actual flow of stack gas, Q_a	
Volume of gas sample through gas meter, V _m		1.445	Area of stack, A _s	m ² 1.47
Gas meter correction factor, Y _d		1.003458	$Q_a = (60)(A_s)(V_s)$	m ³ /min 1126.7
Mean dry gas meter temperature, T _m		16.625	Total flow of stack gas, Q	
Mean pressure drop across orifice, ΔH mmH ₂ O		49.990	Conversion factor (K/mm.Hg)	0.3592
$V_{mstd} = \frac{(0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)}{T_m + 273}$		1.359	$Q_{std} = \frac{(Q_a)P_s(0.3592)(1 - B_{wo})}{(T_s) + 273}$	Dry 805.2
Volume of gas metered wet, V_{mstw}			$Q_{stdO_2} = \frac{(Q_a)P_s(0.3592)(1 - B_{wo})(O_2REF)}{(T_s) + 273}$	@O ₂ ref No O2 Ref
$V_{mstw} = V_{mstd} + V_{wstd}$	m ³	1.4051	$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) + 273}$	Wet 832.24
Vol. of gas metered at O₂ Ref. Cond., V_{mstd@X%O₂}			Percent isokinetic, %I	
Is the process burning hazardous waste? (If yes, no favourable oxygen correction)	No		Nozzle diameter, D _n	mm 6.87
% oxygen measured in gas stream, act%O ₂	21.0		Nozzle area, A _n	mm ² 37.07
% oxygen reference condition	21		Total sampling time, θ	min 64
O ₂ Reference O ₂ Ref = 21.0 - act%O ₂	No O2 Ref		$\%I = \frac{(4.6398E6)(T_s + 273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1 - B_{wo})}$	% 104.9
Factor 21.0 - ref%O ₂	No O2 Ref		Acceptable isokinetic range 95% to 115%	Yes
$V_{mstd@X\%oxygen} = (V_{mstd}) (O_2 Ref)$	m ³	No O2 Ref	Particulate Concentration, C	
Moisture content, B_{wo}			Mass collected on filter, M _f	g 0.01378
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0325	Mass collected in probe, M _p	g 0.00420
		3.25	Total mass collected, M _n	g 0.01798
Moisture by FTIR	%	-	$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m ³ 12.796
Velocity of stack gas, V_s			$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m ³ 13.226
Pitot tube velocity constant, K _p		34.97	$C_{dry@X\%O_2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³ No O2 Ref
Velocity pressure coefficient, C _p		0.823	Particulate Emission Rates, E	
Mean of velocity heads, ΔP _{avg} mm H ₂ O		11.48	$E = [(C_{wet})(Q_{stw})(60)] / 1000$	638.96
Mean square root of velocity heads, √ΔP		3.39		
Mean stack gas temperature, T _s °C		93		
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	12.74		

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER QUALITY ASSURANCE CHECKLIST

LEAK RATE						
Run	Mean Sampling Rate litre/min	Pre-sampling Leak Rate litre/min	Post-sampling Leak Rate litre/min	Maximum Vacuum mm Hg	Acceptable Leak Rate litre/min	Leak Tests Acceptable?
Run 1	22.7	0.10	0.11	-381	0.45	Yes

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	104.9	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m ³	5% ELV mg/m ³	LOD < 5% ELV
Run 1	0.23	2.5	Yes

The above is based on both the Filter and rinse uncertainty

BLANK VALUE				
Run	Overall Blank Value mg/m ³	Daily Emission Limit Value mg/m ³	Acceptable Blank Value mg/m ³	Overall Blank Acceptable
Blank 1	0.31	50	5.0	Yes

FILTERS					
Run	Filter Material	Filter Size mm	Max Filtration Temperature °C	Pre-use Filter Conditioning Temperature °C	Post-use Filter Conditioning Temperature °C
Run 1	GF	47	111	180	160

GF = Glass Fibre

QF = Quartz Fibre

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MOISTURE CALCULATIONS

Moisture Determination - Isokinetic							
Test Number	Sampling Time and Date	Start Weight kg	End Weight kg	Total gain kg	Concentration %	LOD %	Uncertainty %
Run 1	08:30 - 09:42 16 April 2015	3.5355	3.5722	0.0367	3.3	0.009	2.8

Moisture Quality Assurance							
Test Number	Sampling Duration mins	Total Volume Sampled l	Sampling Rate l/min	Start Leak Rate l/min	End Leak Rate l/min	Acceptable Leak Rate l/min	Leak Tests Acceptable?
Run 1	64	1405	22.7	0.10	0.11	0.45	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	1.37	m
Stack Width, W	-	m
Stack Area, A	1.47	m ²
Average stack gas temperature	94	°C
Stack static pressure	0.1	kPa
Barometric Pressure	100.3	kPa
Pitot tube calibration coefficient, K _{pt}	0.82	-

Stack Gas Composition & Molecular Weights								
Component	Molar Mass M	Density kg/m ³ p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m ³ pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m ³ pi
CO ₂	44	1.963059	0.030000	0.000300	0.000589	0.029024	0.000290	0.000570
O ₂	32	1.427679	20.950000	0.209500	0.299099	20.268213	0.202682	0.289365
N ₂	28	1.249219	79.020000	0.790200	0.987133	76.448410	0.764484	0.955008
H ₂ O	18	0.803070	-	-	-	3.254354	0.032544	0.026135

Where: $p = M / 22.41$ $pi = r \times p$

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2868	kg/m ³
Wet Density (STP), P_{STW}	1.2711	kg/m ³
Dry Density (Actual), P_{Actual}	0.9487	kg/m ³
Average Wet Density (Actual), $P_{ActualW}$	0.937	kg/m ³

Where:

P_{STD} = sum of component concentrations, kg/m³ (not including water vapour)

$P_{STW} = (P_{STD} + pi \text{ of H}_2\text{O}) / (1 + (pi \text{ of H}_2\text{O} / 0.8036))$

$P_{Actual} = P_{STD} \times (Ts / Ps) \times (Pa / Ta)$

$P_{ActualW} = P_{STW} \times (Ts / Ps) \times (Pa / Ta)$

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	16 April 2015
Time of Survey	08:00
Velocity Measurement Device:	S-Type Pitot

Sampling Line A								
Traverse Point	Distance into duct (m)	ΔP pt mmH ₂ O (average of 3)	ΔP pt Pa (average of 3)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m ³ /s	O ₂ % Vol	Angle of Swirl °
1	0.09	11.9	117	94	12.9	19.1	-	<15
2	0.34	11.5	113	94	12.7	18.7	-	<15
3	1.03	11.1	109	94	12.5	18.4	-	<15
4	1.28	10.5	103	94	12.1	17.9	-	<15
Mean	-	11.3	110	94	12.6	18.5	-	

Sampling Line B								
Traverse Point	Distance into duct (m)	ΔP pt mmH ₂ O (average of 3)	ΔP pt Pa (average of 3)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m ³ /s	O ₂ % Vol	Angle of Swirl °
1	0.09	11.5	113	94	12.7	18.7	-	<15
2	0.34	11.1	108	94	12.4	18.3	-	<15
3	1.03	10.8	106	94	12.3	18.1	-	<15
4	1.28	10.1	99	94	11.9	17.5	-	<15
Mean	-	10.9	106	94	12.3	18.2	-	

PRELIMINARY STACK SURVEY QUALITY ASSURANCE CHECKLIST

PITOT LEAK CHECK								
Run	Pre Traverse Leak Rate				Post Traverse Leak Rate			
	Start Value mmH ₂ O	End Value mmH ₂ O	Difference %	Outcome	Start Value mmH ₂ O	End Value mmH ₂ O	Difference %	Outcome
Run 1	197	193	2.0	Pass	190	184	3.2	Pass

To complete a compliant pitot leak check a pressure of over 80 mmH₂O (or 800 Pa) is applied and the pressure drop monitored over 5 mins. A drop of less than 5% must be observed.

S-Type Pitot Stagnation Check				
Run	Stagnation (Pa)	Reference (Pa)	Difference (Pa)	Outcome (Permitted +/- 10 Pa)
Run 1	100	100	0.0	Pass

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY (CONTINUED)

Sampling Plane Validation Criteria				
EA Technical Guidance Note (Monitoring) M1	Result	Units	Requirement	Compliant
Lowest Differential Pressure	98.7	Pa	≥ 5 Pa	Yes
Lowest Gas Velocity	11.9	m/s	-	-
Highest Gas Velocity	12.9	m/s	-	-
Ratio of Gas Velocities	1.1	-	$< 3 : 1$	Yes
Maximum angle of flow with regard to duct axis	< 15	$^{\circ}$	$< 15^{\circ}$	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, $V = K_{pt} \times (1-\epsilon) \times \sqrt{2 \times \Delta P_{pt} / \rho_{ActualW}}$		
Where: K_{pt} = Pitot tube calibration coefficient $(1-\epsilon)$ = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, V_a	12.4	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	94	0	$^{\circ}\text{C}$
Total Pressure	100.4	101.3	kPa
Oxygen	21.0	21	%
Moisture	3.25	3.25	%

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (V_a)	12.4	m/s
Stack Area (A)	1.47	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	66026	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	48678	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	47094	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	48678	m^3/hr

Where:

$$Q_{Actual} = V_a \times A \times 3600$$

$$Q_{STP} = Q_{Actual} \times (T_s / T_a) \times (P_a / P_s) \times 3600$$

$$Q_{STP,Dry} = Q_{STP} / (100 - (100 / Ma)) \times 3600$$

$$Q_{Ref} = Q_{STP} \times ((100 - Ma) / (100 - Ms)) \times ((20.9 - O_{2a}) / (20.9 - O_{2s}))$$

Nomenclature:

T_s = Absolute Temperature, Standard Conditions, 273 K

P_s = Absolute Pressure, Standard Conditions, 101.3 kPa

T_a = Absolute Temperature, Actual Conditions, K

P_a = Absolute Pressure, Actual Conditions, kPa

Ma = Water vapour, Actual Conditions, % Vol

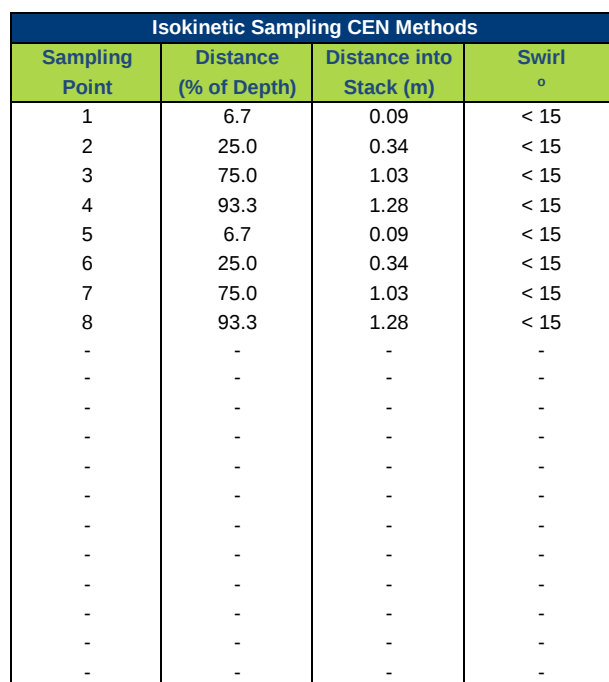
Ms = Water vapour, Reference Conditions, % Vol

O_{2a} = Oxygen, Actual Conditions, % Vol

O_{2s} = Oxygen, Reference Conditions, % Vol

STACK DIAGRAM

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
-	-	-	-



- ## SAMPLING LOCATION



APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume m ³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %	Uncollected Mass mg
MU required	≤ 2%	≤ 2%	≤ 1%	≤ 1%	≤ 10%	≤ 5% of ELV	≤ 2%	≤ 10% of ELV
Run 1	0.001	2.0	0.50	1.0	N/A	0.33	-	-
as a %	0.07	0.69	0.50	1.0	N/A	0.47	0.49	0.001
compliant?	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes

Run	Volume (STP) m ³	Mass of particulate mg	O ₂ Correction -	Leak mg/m ³	Uncollected Mass mg	Combined uncertainty
Run 1	1.31	17.9800	1.00	0.036	0.0002	-
MU as mg/m ³	0.17	0.2349	-	0.036	0.0002	0.29
MU as %	1.32	1.8354	-	0.280	0.0014	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.58	mg/m³	4.6	%
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(k is a coverage factor which gives a 95% confidence in the quoted figures)

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - MOISTURE

Run	Sampled Volume m ³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Leak %
MU required	≤ 2%	≤ 2%	≤ 1%	≤ 1%	≤ 10%	≤ 2%
Run 1	0.001	2.0	0.50	1.0	N/A	-
as a %	0.07	0.69	0.50	1.0	N/A	0.49
compliant?	Yes	Yes	Yes	Yes	N/A	Yes
Run	Volume (STP) m ³	Mass Gained mg	O ₂ Correction -	Leak mg/m ³	Uncollected Mass mg	Combined uncertainty
Run 1	1.31	36700.00	1.00	73.21	57.74	-
MU as % v/v	0.04	0.01	-	0.01	0.005	0.05
MU as %	1.32	0.27	-	0.28	0.16	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.09	% v/v	2.8	%
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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	12.4	m/s
Measured Volumetric Flow rate at Actual Conditions	66026	m ³ /hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination				
Uncertainty of pitot tube coefficient	-	0.010		
Uncertainty of mean local dynamic pressures	-	0.36		
Factor loading, function of the number of measurements.	3 readings	0.591	minimum 3	Yes
Range of measurment device	pa	1000		
Resolution	pa	1.00		
Calibration uncertainty	pa	3.55	<1% of Value or 20 Pa whichever is greater	Yes
Drift	% range	0.10		
Linearity	% range	0.06	<2% of value	Yes
Uncertainty of gas density determination				
Uncertainty of molar mass determination	kg/mol	0.00003		
Uncertainty of temperature measurement	K	1.87	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	512		
Uncertainty associated with the estimate of density	-	0.007		
Uncertainty associated with the measurement of local velocity	-	0.0001		
Uncertainty associated with the measurement of mean velocity	-	0.0002		

Measurement Uncertainty - Velocity	m/s
Combined uncertainty	0.16
Expanded uncertainty at a 95% Confidence Interval	0.31

Note - The expanded uncertainty uses a coverage factor of $k = 2$.

Expanded Measurement Uncertainty of Velocity at a 95% Confidence Interval	%
Expressed as a % of the Measured Concentration	1.3
Expanded uncertainty at a 95% Confidence Interval	2.5

Measurement Uncertainty Volumetric Flow Rate	m ³ /hr
Combined uncertainty	1525
Expanded uncertainty at a 95% Confidence Interval	2989

Note - The expanded uncertainty uses a coverage factor of $k = 2$.

Expanded Measurement Uncertainty of Volumetric Flow Rate at a 95% Confidence Interval	%
Expressed as a % of the Measured Concentration	2.3
Expanded uncertainty at a 95% Confidence Interval	4.5

END OF REPORT