STACK EMISSIONS MONITORING REPORT

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Operator & Address:
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Permit Reference:
DEFRA Process Guidance Note: PG 3/15 (12)

Release Point:
Coating Plant

Sampling Date(s):
7th November 2019

SOCOTEC Job Number:	LNO 15335
Report Date:	17th April 2019
Version:	Site
Report By:	Waheed Rasul
MCERTS Number:	MM 07 851
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Mark Woodruff
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

CEMEX UK Materials Limited operates a roadstone coating process at Grimsby which is subject to DEFRA Process Guidance Note PG 3/15 (12), under the Environmental Permitting Regulations 2010.

SOCOTEC LTD were commissioned by CEMEX UK Materials Limited 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 DEFRA Process Guidance Note, PG 3/15 (12).

Plant

Coating Plant

Operator

CEMEX UK Materials Limited
Grimsby Coated Stone
Gilbey Road
Pyewipe
Grimsby
Lincolnshire
DN31 2SJ

DEFRA Process Guidance Note: PG 3/15 (12)

Stack Emissions Monitoring Test House

SOCOTEC - 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.

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	**Units**	**Result**	**Calculated Uncertainty +/-**	**Emission Limit Value (ELV)**	**MCERTS accredited result**
Total Particulate Matter	mg/m³	5.4	1.70	50	✓
Particulate Emission Rate	g/hr	57	17.9	-	
Moisture	%	3.28	0.10	-	✓
Stack Gas Temperature	°C	31	-	-	✓
Stack Gas Velocity	m/s	13.3	0.32	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	13540	696	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	11938	614	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	11546	594	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	11938	614	-	

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	07 November 2019	07:58 - 08:30	32 minutes
Total Particulate Matter Run 2	07 November 2019	08:55 - 09:27	32 minutes
Preliminary Stack Traverse	07 November 2019	07:20	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Roadstone Coating
Continuous or batch	Continuous
Product Details	20mm
Part of batch to be monitored (if applicable)	When mixing
Normal load, throughput or continuous rating	26 t/hr
Fuel used during monitoring	Kerosene
Abatement	Bag Filter
Plume Appearance	Slight Plume Visible

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard reference / alternative methods employed by SOCOTEC is determined, wherever possible by the hierarchy of method selection outlined in Environmental Protection Agency Technical Guidance Note (Monitoring) AG2.

MONITORING METHODS							
Species	**Method** Standard Reference Method / Alternative Method	**SOCOTEC Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Limit of Detection (LOD)**	**Calculated MU +/- % Result**	**Calculated MU +/- % ELV**
Total Particulate Matter	SRM - EN 13284-1	AE 104	1015	Yes	0.35 mg/m³	31.4%	1.5%
Moisture	SRM - BS EN 14790	AE 063	1015	Yes	0.02%	3.11%	N/A - No ELV
Velocity	SRM - EN ISO 16911-1	AE 154	1015	Yes	5 Pa	2.4%	N/A - No ELV
Volumetric Flow Rate	SRM - EN ISO 16911-1	AE 154	1015	Yes	-	5.1%	N/A - No ELV

EXECUTIVE SUMMARY

Analytical Methods

The following tables list the analytical methods employed together with the custody details. Unless otherwise stated the samples are archived at the analysis lab location.

SAMPLING METHODS WITH SUBSEQUENT ANALYSIS							
Species	**Analytical Technique**	**Analytical Procedure**	**UKAS Lab Number**	**UKAS Accredited Lab Analysis**	**Analysis Lab**	**Analysis Report number**	**Archive Period**
Total Particulate Matter	Gravimetric	AE 106	1015	Yes	SOCOTEC (Stockport)	N/A	8 Weeks

ON-SITE TESTING							
Species	**Analytical Technique**	**Analytical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Analysis**	**Laboratory**	**Data Archive Location**	**Archive Period**
Moisture	Gravimetric	AE 105	1015	Yes	SOCOTEC (Stockport)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	138	Pa	>= 5 Pa	Yes	EN 15259
Lowest Gas Velocity	13.2	m/s	-	-	-
Highest Gas Velocity	13.4	m/s	-	-	-
Ratio of Gas Velocities	1.0	: 1	< 3 : 1	Yes	EN 15259
Mean Velocity	13.3	m/s	-	-	-
Maximum angle of flow with regard to duct axis	<15	°	< 15°	Yes	EN 15259
No local negative flow	Yes	-	-	Yes	EN 15259

DUCT CHARACTERISTICS		
	Value	**Units**
Shape	Circular	-
Depth	0.60	m
Width	-	m
Area	0.28	m^2
Port Depth	90	mm

SAMPLING LINES & POINTS		
	Isokinetic	**Non-Iso & Gases**
Sample port size	3.75 inch port	-
Number of lines used	1	-
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

AG1 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	Yes
Handrail / obstructions do not hamper insertion of sampling equipment	Yes
Depth of Platform = >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

Sample Runs

Due to limited production on the day of the emissions monitoring, sampling was only possible over 2 sampling periods as opposed to the 3 sampling runs the process guidance note outlines as an ideal. BS EN 13284-1 stipulates a minimum sampling duration of 30mins, in order to obtain a compliant result this minimum duration for sampling has been met, the overall effect of not obtaining a third sample (or second, change as appropriate) is seen as negligible and the result fully compliant.","Due to limited production on the day of the emissions monitoring

Sample Points

The sampling point requirements of EN 13284-1 could not be met as one of the sample ports is siezed. As required in MID 13284-1 for such situations the number of sampling points has been doubled.

APPENDICES

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APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

MONITORING SCHEDULE					
Species	**Method** Standard Reference Method / Alternative Method	**SOCOTEC Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Number of Samples**
Total Particulate Matter	SRM - EN 13284-1	AE 104	1015	Yes	2
Moisture	SRM - BS EN 14790	AE 063	1015	Yes	1
Velocity	SRM - 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 13-23	Horiba PG-250 Analyser	-	Laboratory Balance	LNO 0013/0014
Box Thermocouples	LNO 03-23	FT-IR Gasmet	-	Tape Measure	LNO 18-WR
Meter In Thermocouple	LNO 03-23	FT-IR Oven Box	-	Stopwatch	LNO 17-WR
Meter Out Thermocouple	LNO 03-23	Bernath 3006 FID	-	Protractor	-
Control Box Timer	LNO 17-23	Signal 3030 FID	-	Barometer	LNO 08-WR
Oven Box	-	Servomex	-	Digital Micromanometer	-
Probe	LNO 11-05	JCT Heated Head Filter	-	Digital Temperature Meter	-
Probe Thermocouple	LNO 10-05	Thermo FID	-	Stack Thermocouple	-
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	LNO 06-JO	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	LNO 14-JO	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 JO	Site temperature Logger	-	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	-		-	20m Heated Line (1)	-
Inclinometer (Swirl Device)	LNO 23-JO		-	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.

CALIBRATION / CHECK GASES

Gas (traceable to ISO 17025)	Cylinder I.D Number	Supplier	ppm	%	Analytical Tolerance +/- %
-	-	-	-	-	-

STACK EMISSIONS MONITORING TEAM

MONITORING TEAM								
Personnel	**MCERTS Number**	**MCERTS**		**TE / H&S Qualifications and Expiry Date**				
		Level	**Expiry**	**TE1**	**TE2**	**TE3**	**TE4**	**H&S**
Waheed Rasul	MM 07 851	MCERTS Level 2	Mar-20	Dec-23	Jun-20	Dec-20	Mar-20	Mar-22
Pete Watson	MM 08 953	MCERTS Level 1	Jun-21	-	-	-	-	Jun-21

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER SUMMARY					
Parameter	Sampling Times	Concentration mg/m³	Uncertainty mg/m³	ELV mg/m³	Emission Rate g/hr
Run 1	07:58 - 08:30 07 November 2019	1.3	0.71	50	14
Run 2	08:55 - 09:27 07 November 2019	9.5	0.77	50	100
Blank	-	0.35	-	-	-

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	G9839	0.11079	0.11126	0.00047	202.95780	202.95810	0.00030	0.00077
Run 2	G9840	0.10716	0.10737	0.00021	208.09020	208.09550	0.00530	0.00551

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	G9737	0.10751	0.10742	-0.00009	182.94170	182.93900	-0.00270	0.00021

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		
Barometric pressure, P_b	Kpa	99.3
Stack static pressure, P_{static}	pa	150
$P_s = P_b + P_{static}$	Kpa	99.5
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	15.7
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.0195622
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.626
Gas meter correction factor, Y_d		0.990
Mean dry gas meter temperature, T_m		289
Mean pressure drop across orifice, DH	mmH_2O	37.097
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m}$	m^3	0.577
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.5962
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No
% oxygen measured in gas stream, act%O_2		20.9
% oxygen reference condition		21
O_2 Reference Factor O_2 Ref $= \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0328
	%	3.28
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Velocity pressure coefficient, C_p		0.84
Mean of velocity heads, DP_{avg}	Pa	124.22
Mean stack gas temperature, T_s	K	323
Gas density (wet, ambient), p		
p=(Ms*Ps)/(8.314*Ts)	kg/m^3	1.055
Stack Velocity, Vs $V_s = Cp\sqrt{\frac{\Delta DPavg}{p}}$	m/s	12.89

Molecular weight of dry gas, M_d		
CO_2	%	0.08
O_2	%	20.90
Total	%	20.98
N_2 (100 -Total)	%	79.02
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.85
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.49
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.28
$Q_a = (60)(A_s)(V_s)$	m^3/min	218.7
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	Dry	175.4
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	@O_2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet	181.40
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	5.88
Nozzle area, A_n	mm^2	27.19
Total sampling time, q	min	32
$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	106.8
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00047
Mass collected in probe, M_p	g	0.00030
Total mass collected, M_n	g	0.00077
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	1.292
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	1.335
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		14.06

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 2 — TPM

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	Kpa	99.3
Stack static pressure, P_{static}	pa	150
$P_s = P_b + P_{static}$	Kpa	99.5
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	-
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.614
Gas meter correction factor, Y_d		0.990
Mean dry gas meter temperature, T_m		291
Mean pressure drop across orifice, DH	mmH_2O	33.137
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m}$	m^3	0.560
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.5787
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No
% oxygen measured in gas stream, act%O_2		20.9
% oxygen reference condition		21
O_2 Reference Factor O_2 Ref $= \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0328
	%	3.28
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Velocity pressure coefficient, C_p		0.84
Mean of velocity heads, DP_{avg}	Pa	120.17
Mean stack gas temperature, T_s	K	336
Gas density $_{(wet, ambient)}$, p		
p=(Ms*Ps)/(8.314*Ts)	kg/m^3	1.014
Stack Velocity, Vs $V_s = Cp\sqrt{\frac{\Delta DPavg}{p}}$	m/s	12.93

Molecular weight of dry gas, M_d		
CO_2	%	0.08
O_2	%	20.90
Total	%	20.98
N_2 (100 -Total)	%	79.02
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.85
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.49
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.28
$Q_a = (60)(A_s)(V_s)$	m^3/min	219.4
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	Dry	169.2
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	@O_2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet	174.93
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	5.88
Nozzle area, A_n	mm^2	27.19
Total sampling time, q	min	32
$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	107.5
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00021
Mass collected in probe, M_p	g	0.00530
Total mass collected, M_n	g	0.00551
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	9.521
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	9.844
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		99.93

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	19.36	0.15	-	-381	0.39	Yes
Run 2	18.99	0.15	-	3.81	0.38	Yes

In BS EN 13284-1:2017 a post sampling leak check is not require.

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	106.81	Yes
Run 2	107.52	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.35	2.5	Yes
Run 2	0.36	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 mg/m^3
Blank 1	0.35	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	Glass Fibre	47	53	180	160
Run 2	Glass Fibre	47	63	180	160

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	07:58 - 08:30 07 November 2019	3.5231	3.5388	0.0157	3.3	0.02	3.1

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	32	596	19.4	0.15	-	0.39	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.60	m
Stack Width, W	-	m
Stack Area, A	0.28	m^2
Average stack gas temperature	31	^oC
Stack static pressure	0.15	kPa
Barometric Pressure	99.3	kPa

Stack Gas Composition & Molecular Weights								
Component	Molar Mass M	Density kg/m³ p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m³ pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m³ pi
CO_2	44	1.963059	0.075238	0.000752	0.001477	0.072769	0.000728	0.001429
O_2	32	1.427679	20.900000	0.209000	0.298385	20.214191	0.202142	0.288594
N_2	28	1.249219	79.024762	0.790248	0.987193	76.431658	0.764317	0.954799
H_2O	18	0.803070	-	-	-	3.281382	0.032814	0.026352

Where: p = M / 22.41 pi = r x p

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2871	kg/m^3
Wet Density (STP), P_{STW}	1.2712	kg/m^3
Dry Density (Actual), P_{Actual}	1.1347	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.121	kg/m^3

Where:

P_{STD} = sum of component concentrations, kg/m^3 (not including water vapour)

$P_{STW} = (P_{STD} + pi \text{ of } H_2O) / (1 + (pi \text{ of } H_2O / 0.8036))$

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

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	07 November 2019
Time of Survey	07:20
Velocity Measurement Device:	S-Type Pitot

Sampling Line A								
Traverse Point	Distance into duct (m)	DP pt Pa (average of 3 readings)	DP pt mmH_2O (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	0.05	138.5	14.1	31	13.2	3.7	-	<15
2	0.15	140.5	14.3	31	13.3	3.8	-	<15
3	0.45	141.1	14.4	31	13.3	3.8	-	<15
4	0.55	142.1	14.5	31	13.4	3.8	-	<15
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	140.5	14.3	31	13.3	3.8	-	-

Sampling Line B								
Traverse Point	Distance into duct (m)	DP pt Pa (average of 3 readings)	DP pt mmH_2O (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-

PRELIMINARY STACK SURVEY QUALITY ASSURANCE CHECKLIST

PITOT LEAK CHECK								
Run	Pre Traverse Leak Rate				Post Traverse Leak Rate			
	Start Value mmH2O	End Value mmH2O	Difference %	Outcome	Start Value mmH2O	End Value mmH2O	Difference %	Outcome
Run 1	140	138	1.4	Pass	165	161	2.4	Pass

To complete a compliant pitot leak check a pressure of over 80 mmH_2O (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	150	150	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	139	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	13.2	m/s	-	-
Highest Gas Velocity	13.4	m/s	-	-
Ratio of Gas Velocities	1.0	-	< 3 : 1	Yes
Maximum angle of flow with regard to duct axis	<15	°	< 15°	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, V = K_{pt} x (1-e) * O(2 * DP_{pt} / $P_{ActualW}$)		
Where:		
K_{pt} = Pitot tube calibration coefficient		
(1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**13.3**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	31	0	°C
Total Pressure	99.45	101.3	kPa
Oxygen	20.9	21	%
Moisture	3.28	3.28	%
Pitot tube calibration coefficient, K_{pt}	0.84		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	13.30	m/s
Stack Area (A)	0.28	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	13540	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	11938	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	11546	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	11938	m^3/hr

Where:

Q_{Actual} = Va x A x 3600

Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600

$Q_{STP,Dry}$ = Q (STP) / (100 - (100 / Ma)) x 3600

Q_{Ref} = Q (STP) x ((100 - Ma) / (100 - Ms)) x ((21 - O_2a) / (21 - O_2s))

Nomenclature:

Ts = Absolute Temperature, Standard Conditions, 273 K
Ps = Absolute Pressure, Standard Conditions, 101.3 kPa
Ta = Absolute Temperature, Actual Conditions, K
Pa = 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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK DIAGRAM

	Value	Units
Stack Depth	0.60	m
Stack Width	-	m
Area	0.28	m^2

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

Isokinetic Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	8.3	0.05	< 15
2	25.0	0.15	< 15
3	75.0	0.45	< 15
4	91.7	0.55	< 15
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

○ Isokinetic sampling point
● Isokinetic sampling points not used
◎ Non Isokinetic/Gases sampling point

SAMPLING LOCATION

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak	Uncollected Mass
	m^3	K	kPa	% by volume	% by volume	% by 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	0.2100	-	-
as a %	0.17	0.62	0.50	1.0	N/A	0.70451	0.77	0.000
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**
Run 2	0.001157469	2.0	0.50	1.0	N/A	0.210	-	-
as a %	0.20	0.69	0.50	1.0	N/A	0.726	0.79	0.000
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP)	Mass of particulate	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.48	0.7700	1.0	0.006	0.0001	-
MU as mg/m^3	0.02	0.3523	-	0.006	0.0002	**0.35**
MU as %	1.30	27.2727	-	0.447	0.0157	-
Run 2	0.53	5.5100	1.0	0.043	0.0001	-
MU as mg/m^3	0.13	0.3629	-	0.043	0.0002	**0.39**
MU as %	1.3	3.8113	-	0.456	0.0022	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.71**	**mg/m^3**	**54.61**	**% Result**	**1.41**	**% ELV**

R2 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.77**	**mg/m^3**	**8.13**	**% Result**	**1.55**	**% ELV**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

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 %	0.17	0.62	0.50	1.0	N/A	0.77
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	0.48	15700	1.0	121.80	58	-
MU as % v/v	0.04	0.02	-	0.02	0.013	**0.05**
MU as %	1.30	0.64	-	0.45	0.37	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.11**	**% v/v**	**3.11**	**%**

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	13.3	m/s
Measured Volumetric Flow rate at Actual Conditions	13540	m³/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	-	1.18		
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	22.21	<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	1.55	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	507		
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	0.17
Expanded uncertainty at a 95% Confidence Interval	0.32

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 Velocity	1.2
Expanded uncertainty at a 95% Confidence Interval	2.4

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	355
Expanded uncertainty at a 95% Confidence Interval	696

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 Volumetric Flow Rate	2.6
Expanded uncertainty at a 95% Confidence Interval	5.1

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

END OF REPORT

Thank you for choosing SOCOTEC for your environmental monitoring needs. We hope our services have met your requirements and that you are fully satisfied with your experience of working with us, we really do value your custom and would welcome your feedback. We would appreciate it if you could take a moment to complete a short online questionnaire so that we can improve our operations and address any areas that have not met with your expectations, by clicking on the following

https://www.surveymonkey.co.uk/r/CAE_customer_feedback_weblink