STACK EMISSIONS MONITORING REPORT

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Operator & Address:
Exxon Mobil
Fife Ethylene Plant
Mossmorran
Cowdenbeath
KY4 8EP

Permit Reference:
PPC Permit: PPC/A/1013494

Release Point:
Boiler A

Sampling Date(s):
18th January 2021

SOCOTEC Job Number:	LEK 12554
Report Date:	22nd January 2020
Version:	1
Report By:	[redacted]
MCERTS Number:	[redacted]
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	
Report Approved By:	[redacted]
MCERTS Number:	[redacted]
Business Title:	[redacted]
Technical Endorsements:	1, 2, 3 & 4
Signature:	

UKAS TESTING 1015

mCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

CONTENTS

EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Exxon Mobil operates a boiler process at Fife Ethylene Plant which is subject to PPC Permit PPC/A/1013494, under the PPC regulations 2000.

SOCOTEC LTD were commissioned by Exxon Mobil 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, PPC/A/1013494.

Plant

Boiler A

Operator

Exxon Mobil
Fife Ethylene Plant
Mossmorran
Cowdenbeath
KY4 8EP

Stack Emissions Monitoring Test House

SOCOTEC - East Kilbride Laboratory
2-4 Langlands Place
Kelvin South Business Park
East Kilbride
G75 0YF
UKAS and MCERTS Accreditation Number: 1015

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	**Units**	**Result**	**Calculated Uncertainty +/-**	**Emission Limit Value (ELV)**	**Accrediation**
Total Particulate Matter Particulate Emission Rate	mg/m³ g/hr	0.2 8	0.39 13.7	5 -	MCERTS
Sulphur Dioxide Sulphur Dioxide Emission Rate	mg/m³ g/hr	0.5 19	0.08 2.7	35 -	MCERTS
Oxides of Nitrogen (as NO_2) Oxides of Nitrogen (as NO_2) Emission Rate	mg/m³ g/hr	159 5455	5.0 171	300 -	MCERTS
Carbon Monoxide Carbon Monoxide Emission Rate	mg/m³ g/hr	3.25 111.53	2.55 87.53	- -	MCERTS
Oxygen	% v/v	4.5	0.017	-	MCERTS
Moisture	%	16.03	0.49	-	MCERTS
Stack Gas Temperature	°C	150	-	-	MCERTS
Stack Gas Velocity	m/s	10.5	0.27	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	76328	3954	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	49085	2543	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	41215	2135	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	34346	1779	-	

ND = None Detected,

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

The above volumetric flow rate is an average of the data collected during the isokinetic tests. Mass emissions for non isokinetic tests are also calculated using these values.

Reference conditions are 273K, 101.3kPa, dry gas 3% Oxygen.

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	**Sampling Date(s)**	**Sampling Times**	**Sampling Duration**
Total Particulate Matter Run 1	18 January 2021	14:11 - 15:15	64 minutes
Sulphur Dioxide Run 1	18 January 2021	14:11 - 15:15	64 minutes
Preliminary Stack Traverse	18 January 2021	13:40	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Boiler
Continuous or batch	Continuous
Product Details	N/A
Part of batch to be monitored (if applicable)	N/A
Normal load, throughput or continuous rating	1.8 T/H Fuel Gas @ 50.3% MCR
Fuel used during monitoring	Fuel Gas
Abatement	None
Plume Appearance	None

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 Environment Agency technical Guidance 'Monitoring stack emissions: techniques and standards for periodic monitoring'.

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 - BS EN 13284-1	AE 104	1015	MCERTS	0.15 mg/m³	180%	7.83%
Sulphur Dioxide	SRM - EN 14791	AE 112	1015	MCERTS	0.012 mg/m³	14.6%	0.22%
Moisture	SRM - BS EN 14790	AE 105	1015	MCERTS	0.01%	3.1%	N/A - No ELV
Velocity	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	5 Pa	2.5%	N/A - No ELV
Volumetric Flow Rate	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	-	5.2%	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	MCERTS	SOCOTEC (East Kilbride)	N/A	8 Weeks
Sulphur Dioxide	Ion Chromatography	ASC/SOP/110	1252	MCERTS	SOCOTEC (Bretby)	ASC/47796	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	MCERTS	SOCOTEC (East Kilbride)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	50	Pa	>= 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	10.3	m/s	-	-	-
Highest Gas Velocity	10.7	m/s	-	-	-
Ratio of Gas Velocities	1.0	: 1	< 3 : 1	Yes	BS EN 15259
Mean Velocity	10.5	m/s	-	-	-
Maximum angle of flow with regard to duct axis	<15	°	< 15°	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259

DUCT CHARACTERISTICS		
	Value	**Units**
Shape	Circular	-
Depth	1.60	m
Width	-	m
Area	2.01	m^2
Port Depth	250	mm

SAMPLING LINES & POINTS		
	Isokinetic	**Non-Iso & Gases**
Sample port size	6" Flange	6" Flange
Number of lines used	1	1
Number of points / line	8	1
Duct orientation	Vertical	Vertical
Filtration	-	In Stack
Filtration for TPM	In Stack	-

SAMPLING PLATFORM	
General Platform Information	
Permanent / Temporary Platform / Ground level / Floor Level / Roof	Temporary
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	Yes
Handrail / obstructions do not hamper insertion of sampling equipment	Yes
Depth of Platform = >Stack depth / diameter + wall and port thickness + 1.5m	No

Sampling Platform Improvement Recommendations (if applicable)

The Platform was suitable for testing but only one line was available due to not being able to remove the flange.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Sample Lines

Access to only Line A was available, In accordance to MID BS EN 13284 the number of sample points were doubled. Please allow access to both A & B.

APPENDICES

CONTENTS

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 - BS EN 13284-1	AE 104	1015	MCERTS	1
Sulphur Dioxide	SRM - EN 14791	AE 112	1015	MCERTS	1
Moisture	SRM - BS EN 14790	AE 105	1015	MCERTS	1
Velocity	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	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	9.35	Horiba PG-250 Analyser	12.1	Laboratory Balance	-
Box Thermocouples	9.38	FT-IR Gasmet	-	Tape Measure	20.9
Meter In Thermocouple	9.38	FT-IR Oven Box	-	Stopwatch	17.31
Meter Out Thermocouple	9.39	Bernath 3006 FID	-	Protractor	-
Control Box Timer	17.21	Signal 3030 FID	-	Barometer	-
Oven Box	-	Servomex	-	Digital Micromanometer	1.18
Probe	6.32	JCT Heated Head Filter	-	Digital Temperature Meter	2.19
Probe Thermocouple	-	Thermo FID	-	Stack Thermocouple	3.226
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	3.227	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	-	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	23.18	Chiller (JCT/MAK 10)	12.11	1m Heated Line (3)	-
Last Impinger Arm	3.213	Heated Line Controller (1)	8.34	5m Heated Line (1)	8.34
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	8.32	10m Heated Line (1)	-
Callipers	15.14	Site temperature Logger	-	10m Heated Line (2)	-
Small DGM	-			15m Heated Line (1)	-
Heater Controller	-			20m Heated Line (1)	8,32
Inclinometer (Swirl Device)	24.12			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 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**
[redacted]	[redacted]	MCERTS Level 2	May-23	Jul-23	-	Nov-23	Jan-24	May-23
[redacted]	[redacted]	MCERTS Level 1	Apr-24	-	-	-	-	Apr-24

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	14:11 - 15:15 18 January 2021	0.22	0.39	5	8
Blank	-	0.34	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas 3% Oxygen.

Acetone Blank Value mg/l	Acceptable Value mg/l
0.3	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	AC 1668	0.09812	0.09812	0.00000	185.28900	185.28920	0.00020	0.00020

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	AC 1667	0.09758	0.09749	-0.00009	202.72540	202.72590	0.00050	0.00041

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	101.0
Stack static pressure, P_{static}	pa	-62.0
$P_s = P_b + P_{static}$	Kpa	100.9
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	154.3
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.1922578
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		1.080
Gas meter correction factor, Y_d		0.971
Mean dry gas meter temperature, T_m		284
Mean pressure drop across orifice, DH	mmH_2O	35.988
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m}$	m^3	1.007
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.1991
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		4.6
% oxygen reference condition		3
O_2 Reference Factor $O_2\ Ref = \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		0.91
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	0.9201
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.1603
	%	16.03
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Velocity pressure coefficient, C_p		0.81
Mean of velocity heads, DP_{avg}	Pa	58.80
Mean stack gas temperature, T_s	K	423
Gas density $_{(wet, ambient)}$, p		
p=(Ms*Ps)/(8.314*Ts)	kg/m^3	0.802
Stack Velocity, Vs $V_s = Cp\sqrt{\frac{\Delta DPavg}{p}}$	m/s	9.82

Molecular weight of dry gas, M_d		
CO_2	%	10.49
O_2	%	4.55
Total	%	15.04
N_2 (100 -Total)	%	84.96
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.86
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	27.96
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	2.01
$Q_a = (60)(A_s)(V_s)$	m^3/min	1184.5
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	639.4
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	@O_2ref	584.34
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet	761.50
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	7.97
Nozzle area, A_n	mm^2	49.94
Total sampling time, q	min	64
$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	99.1
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00000
Mass collected in probe, M_p	g	0.00020
Total mass collected, M_n	g	0.00020
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	0.167
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	0.199
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	0.217
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		7.62

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	16.38	0.20	-	-203.2	0.33	Yes

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

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	99.07	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.15	0.3	N/A - ELV <5 mg/m³

The above is based on both the Filter and rinse uncertainty
Where installations have ELVs of 5 mg/m³ or less, it may not be practical to meet the 5% of ELV requirement. Under these circumstances, a minimum one hour sample time shall used.

BLANK VALUE				
Run	Overall Blank Value mg/m^3	Daily Emission mg/m^3	Acceptable Blank Value mg/m^3	Overall Blank Acceptable mg/m^3
Blank 1	0.34	5	1.0	Yes

*For ELVs of 5 mg/m3 and lower a blank value must be <20% of the ELV

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	150	180	160

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

SULPHUR DIOXIDE SUMMARY					
Test	**Sampling Times**	**Concentration mg/m³**	**LOD mg/m³**	**ELV mg/m³**	**Emission Rate g/hr**
Run 1	14:11 - 15:15 18 January 2021	0.54	0.012	35	19
Field Blank	-	0.031	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas 3% Oxygen.

SULPHUR DIOXIDE QUALITY ASSURANCE CHECKLIST

Leak Test Results	Total Sample Volume @ ref Conditions m³	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	-	16.4	0.20	0.20	0.33	Yes

	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Temperature during storage / transit <25°C	Type of Absorbers	Absorption Solutions
Run 1	Glass Fibre	47	160	N/A	Glass	0.3% Hydrogen Peroxide

SULPHUR DIOXIDE ABSORPTION EFFICIENCY

Parameter	**Total ug**	**IMP C ug**	**Absorption Efficiency %**	**Acceptable Absorption Efficiency %**	**Absorption Efficiency Acceptable ?**
Run 1	493.8	79.8	84	95	N/A- < 1mg/m³

ND - None Detected

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS 1 — Sulphur Dioxide

Absolute pressure of stack gas, P_s			**Velocity of stack gas, V_s**		
Barometric pressure, P_b	kPa	101	Velocity pressure coefficient, C_p		0.811
Stack static pressure, P_{static}	Pa	-62	Mean of velocity heads, DP_{avg}	Pa	58.80
$P_s = P_b + (P_{static})$	kPa	100.94	Mean stack gas temperature, T_s	K	423.00
			Gas density $_{(wet, ambient)}$, p		
Vol. of water vapour collected, V_{wstd}			p=(Ms*Ps)/(8.314*Ts)	kg/m^3	0.802
Moisture trap weight increase,Vlc	g	-	Stack Velocity, Vs $V_s = Cp\sqrt{\frac{\Delta DPavg}{p}}$	m/s	9.82
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-			
Volume of gas metered dry, V_{mstd}			**Actual flow of stack gas, Q_a**		
Volume of gas sample through gas meter, V_m	m^3	1.0800	Area of stack, A_s	m^2	2.01
Gas meter correction factor, Y_d		0.9705	$Q_a = (60)(A_s)(V_s)$	m^3/min	1185
Mean dry gas meter temperature, T_m	K	284.25	**Dry total flow of stack gas, Q_{std}**		
Mean pressure drop across orifice, DH	mmH_2O	35.99	Conversion factor (K/mm.Hg)		0.3592
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m}$	m^3	1.01	$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	m^3/min	639
Volume of gas metered wet, V_{mstw}			**Wet total flow of stack gas, Q_{stw}**		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.1991	$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	m^3/min	761
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$			**Dry total flow of stack gas at X% O_2, Q_{stdO2}**		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No	$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	m^3/min	584
% oxygen measured in gas stream, act%O_2		4.55			
% oxygen reference condition		3	**Percent isokinetic, %I**		
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		0.91	Nozzle diameter, D_n	mm	7.97
			Nozzle area, A_n	mm^2	49.94
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	0.9201	Total sampling time, q	min	64
Moisture content, B_{wo}			$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	99
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.1603			
	%	16.03	Acceptable isokinetic range 95% to 115%		Yes
Moisture by FTIR	%	-	**Sulphur Dioxide Concentration, C**		
Molecular weight of dry gas, M_d			Mass collected , M	ug	494
CO_2		10.49	$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	0.412
O_2		4.55	$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	0.490
Total		15.04			
N_2 (100 -Total)		84.96	$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	0.537
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.86			
Molecular weight of wet gas, M_s			**Sulphur Dioxide Emission Rates, E**		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.0	$E = [(C_{wet})(Q_{stw})(60)] / 1000$	g/hr	18.82

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

COMBUSTION GASES SUMMARY

Test	Sampling Time and Date	Concentration mg/m³	LOD mg/m³	ELV mg/m³	Emission Rate g/hr

Reference conditions are 273K, 101.3kPa, dry gas 3% Oxygen.

PRE-SAMPLING CALIBRATION DATA

Date	18 January 2021
Start Time	12:20
End Time	12:45

Chiller Temperature (°C)	2.8
Requirement	< 4°C
Compliant	Yes

Gas	Range (ppm / %)	Zero Reading at analyser	Span Reading at analyser	Zero Check at analyser	Zero Check down line	Span Check down line	Response Time (Secs)	Leak Rate %

POST-SAMPLING CALIBRATION DATA

Date	18 January 2021
Start Time	15:30
End Time	15:40

Chiller Temperature (°C)	20.6
Requirement	< 4°C
Compliant	Yes

Gas	Zero Check at Analyser	Span Check at Analyser	Zero Drift (%)	Span Drift (%)	Corrected for Zero Drift	Corrected for Span Drift	Corrected Values ppm / %

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	14:11 - 15:15 18 January 2021	3.0524	3.2067	0.1543	16.0	0.01	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	64	1199	16.4	0.20	-	0.33	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	1.60	m
Stack Width, W	-	m
Stack Area, A	2.01	m^2
Average stack gas temperature	150	^oC
Stack static pressure	-0.062	kPa
Barometric Pressure	101	kPa

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	10.490044	0.104900	0.205926	8.808106	0.088081	0.172908
O_2	32	1.427679	4.549171	0.045492	0.064948	3.819773	0.038198	0.054534
N_2	28	1.249219	84.960785	0.849608	1.061346	71.338464	0.713385	0.891174
H_2O	18	0.803070	-	-	-	16.033658	0.160337	0.128761

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

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.3322	kg/m^3
Wet Density (STP), P_{STW}	1.2474	kg/m^3
Dry Density (Actual), P_{Actual}	0.8567	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	0.802	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	18 January 2021
Time of Survey	13:40
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	70.3	7.2	150	10.7	21.6	-	<15
2	0.17	70.0	7.1	150	10.7	21.5	-	<15
3	0.31	68.3	7.0	150	10.6	21.3	-	<15
4	0.52	66.0	6.7	150	10.4	20.9	-	<15
5	1.08	64.3	6.6	150	10.3	20.7	-	<15
6	1.29	70.0	7.1	150	10.7	21.5	-	<15
7	1.43	67.7	6.9	150	10.5	21.2	-	<15
8	1.55	66.0	6.7	150	10.4	20.9	-	<15
-	-	-	-	150	-	-	-	-
-	-	-	-	150	-	-	-	-
Mean	-	67.8	6.9	150	10.5	21.2	-	-

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 Pa	End Value Pa	Difference %	Outcome	Start Value Pa	End Value Pa	Difference %	Outcome
Run 1	104	102	1.9	Pass	102	102	0.0	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	-62	-63	1.0	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	64	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	10.3	m/s	-	-
Highest Gas Velocity	10.7	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) * Ö(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	**10.5**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	150	0	°C
Total Pressure	100.938	101.3	kPa
Oxygen	6.0	3	%
Moisture	16.03	16.03	%
Pitot tube calibration coefficient, K_{pt}	0.81		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	10.54	m/s
Stack Area (A)	2.01	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	76328	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	49085	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	41215	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	34346	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))

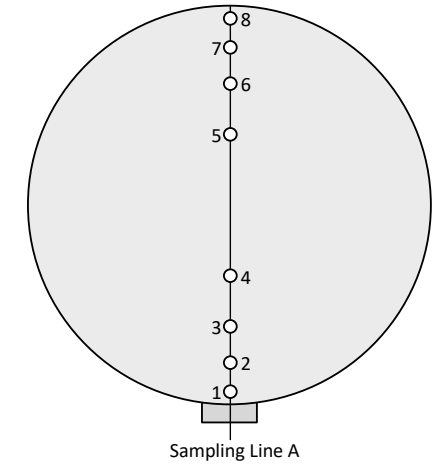
Nomenclature:
Ts = Absolute Temperature, Standard Conditions, 273 K
Ps = Absolute Pressure, Standard Conditions, 101.3 kPa
Ta = Absolute Temperature, Actual Conditions, K
Pa = Absolute Pressure, Actual Conditions, kPa
Ma = Water vapour, Actual Conditions, % Vol
Ms = Water vapour, Reference Conditions, % 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	1.60	m
Stack Width	-	m
Area	2.01	m^2

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	50	0.80	m



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

Isokinetic Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	3.2	0.05	< 15
2	10.5	0.17	< 15
3	19.4	0.31	< 15
4	32.3	0.52	< 15
5	67.7	1.08	< 15
6	80.6	1.29	< 15
7	89.5	1.43	< 15
8	96.8	1.55	< 15
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

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	0.1	0.1800	-	-
as a %	0.10	0.47	0.50	1.0	2.20	3.91248	1.22	0.008
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

*Where installations have ELVs of 5 mg/m³ or less, it may not be practical to meet the 5% of ELV requirement. Under these circumstances, a minimum one hour sample time shall used.

Run	Volume (STP)	Mass of particulate	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.65	0.2000	1.1	0.0015	0.0002	-
MU as mg/m^3	0.00	0.1956	0.00	0.0015	0.0003	**0.20**
MU as %	1.22	90.0000	-	0.705	0.1184	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.39**	**mg/m^3**	**180.03**	**% Result**	**7.83**	**% 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 - ISOKINETIC SULPHUR DIOXIDE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak
	m^3	K	kPa	% by volume	% by volume	% by mass	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.920	284	100.38	1.0	-	0.9	-
as a %	0.11	0.70	0.50	1.0	-	0.08	1.22
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**Yes**	**Yes**

Run	Volume (STP)	Mass of Sulphur Dioxide	O2 Correction	Leak	Lab Uncertainty	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.8757	0.8721	-	0.0038	-	-
MU as mg/m^3	0.0071	0.0283	-	0.0038	0.0258	**0.0391**
MU as %	1.3252	5.2677	-	0.7051	4.8	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.08**	**mg/m^3**	**14.57**	**% Result**	**0.22**	**% 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

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	10.5	m/s
Measured Volumetric Flow rate at Actual Conditions	76328	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	-	0.68		
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	11.73	<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	0.00001		
Uncertainty of temperature measurement	K	2.16	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	515		
Uncertainty associated with the estimate of density	-	0.008		
Uncertainty associated with the measurement of local velocity	-	0.0002		
Uncertainty associated with the measurement of mean velocity	-	0.0002		

Measurement Uncertainty - Velocity	m/s
Combined uncertainty	0.14
Expanded uncertainty at a 95% Confidence Interval	0.27

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	1.3
Expanded uncertainty at a 95% Confidence Interval	2.5

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	2017
Expanded uncertainty at a 95% Confidence Interval	3954

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	5.2

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