STACK EMISSIONS MONITORING REPORT

Units C & D
Bankside Trade Park
Cirencester
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Operator & Address:
Hillgreen Energy Limited Hillgreen Energy Limited Wellington Farm Stewkley Road Leighton Buzzard LU7 0LD

Permit Reference:
EPR Permit: EPR/XP3437MW

Release Point:
A1 - Biomass Boiler

Sampling Date(s):
10th June 2024

SOCOTEC Job Number:	LSW 240432
Report Date:	25th June 2024
Version:	1
Report By:	Owen May
MCERTS Number:	MM 10 1072
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Jose Navarro
MCERTS Number:	MM 19 1542
Business Title:	MCERTS Level 2 - Project Manager
Technical Endorsements:	1, 2, 3 & 4
Signature:	

UKAS TESTING 1015

mCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Hillgreen Energy Limited operates a boiler process at Wellington Farm which is subject to EPR Permit EPR/XP3437MW, under the Environmental Permitting Regulations 2016.

SOCOTEC LTD were commissioned by Laura Steyn 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 EPR Permit, EPR/XP3437MW.

Plant

A1 - Biomass Boiler

Operator

Hillgreen Energy Limited
Hillgreen Energy Limited
Wellington Farm
Stewkley Road
Leighton Buzzard
LU7 0LD

EPR Permit: EPR/XP3437MW

Stack Emissions Monitoring Test House

SOCOTEC - Cirencester Laboratory
Units C & D
Bankside Trade Park
Cirencester
GL7 1YT
UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.
The results of this testing relate only to the emission release point(s) listed in the report.
MCERTS accredited results will only be claimed where both the sampling and analytical stages are MCERTS accredited.

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	**Units**	**Result**	**Calculated Uncertainty +/-**	**Emission Limit Value (ELV)**	**Accreditation**
Total Particulate Matter Particulate Emission Rate	mg/m³ g/hr	4.5 41	1.06 9.8	10 -	MCERTS
Sulphur Dioxide Sulphur Dioxide Emission Rate	mg/m³ g/hr	0.27 2.5	0.08 0.75	50 -	MCERTS
Oxides of Nitrogen (as NO_2) Oxides of Nitrogen (as NO_2) Emission Rate	mg/m³ g/hr	188 1739	4.0 37	200 -	MCERTS
Oxygen	% v/v	11.1	1.569	-	MCERTS
Moisture	%	9.50	0.32	-	MCERTS
Stack Gas Temperature	°C	169	-	-	MCERTS
Stack Gas Velocity	m/s	17.3	0.42	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	17647	907	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	10659	548	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	9646	496	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	9517	489	-	

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, dry gas 11% Oxygen.

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	**Sampling Date(s)**	**Sampling Times**	**Sampling Duration**
Total Particulate Matter Run 1	10 June 2024	12:24 - 13:24	60 minutes
Sulphur Dioxide Run 1	10 June 2024	12:24 - 13:24	60 minutes
Combustion Gases	10 June 2024	12:24 - 13:24	60 minutes
Preliminary Stack Traverse	10 June 2024	10:06	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Boiler
Continuous or batch	Continuous
Product Details	Energy & Heat
Part of batch to be monitored (if applicable)	N/A
Normal load, throughput or continuous rating	Normal Load
Fuel used during monitoring	Mixed wood
Abatement	Bag Filter & Lime Injection
Plume Appearance	White 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 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**	**Method Accreditation**	**Limit of Detection (LOD)**	**Calculated MU +/- % Result**	**Calculated MU +/- % ELV**
Total Particulate Matter	SRM - BS EN 13284-1	AE 104	1015	MCERTS	0.53 mg/m³	23.8%	10.63%
Sulphur Dioxide	SRM - BS EN 14791	AE 112	1015	MCERTS	0.013 mg/m³	30.4%	0.16%
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	MCERTS	0.54 mg/m³	2.2%	2.02%
Oxygen	SRM - BS EN 14789:2017	AE 102	1015	MCERTS	0.01%	14.1%	N/A - No ELV
Moisture	BS EN 14790	AE 105	1015	MCERTS	0.01%	3.4%	N/A - No ELV
Velocity	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	5 Pa	2.4%	N/A - No ELV
Volumetric Flow Rate	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	-	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	Analysis Accreditation	Analysis Lab	Analysis Report No. Date of Analyis	Archive Period
Total Particulate Matter	Gravimetric	AE 106	1015	MCERTS	SOCOTEC (Cirencester)	N/A	8 Weeks
Sulphur Dioxide	Ion Chromatography	ASC/SOP/110	1252	MCERTS	SOCOTEC (Bretby)	ASC/63129	8 Weeks

ON-SITE TESTING							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	Accreditation	Laboratory	Data Archive Location	Archive Period
Oxides of Nitrogen	Chemiluminescence	AE 102	1015	MCERTS	SOCOTEC (Cirencester)	SOCOTEC (Cirencester)	5 years
Oxygen	Paramagnetism	AE 102	1015	MCERTS	SOCOTEC (Cirencester)	SOCOTEC (Cirencester)	5 years
Moisture	Gravimetric	AE 105	1015	MCERTS	SOCOTEC (Cirencester)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	137	Pa	>= 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	15.9	m/s	-	-	-
Highest Gas Velocity	18.3	m/s	-	-	-
Ratio of Gas Velocities	1.2	: 1	< 3 : 1	Yes	BS EN 15259
Mean Velocity	17.3	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	0.60	m
Width	-	m
Area	0.28	m^2
Port Depth	80	mm

SAMPLING LINES & POINTS		
	Isokinetic	**Non-Iso & Gases**
Sample port size	4" BSP	4" BSP
Number of lines used	1	1
Number of points / line	4	1
Duct orientation	Vertical	Vertical
Filtration	In Stack	Out stack
Filtration for TPM	In Stack	Barrel filter

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

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	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

Sampling Lines

Only one port accessable, therefore isokinetic sampling could only be conducted on one sampling line.

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 - BS EN 13284-1	AE 104	1015	MCERTS	1
Sulphur Dioxide	SRM - BS EN 14791	AE 112	1015	MCERTS	1
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	MCERTS	1
Oxygen	SRM - BS EN 14789:2017	AE 102	1015	MCERTS	1
Moisture	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	P3337	Horiba PG-350 Analyser	P2875	Laboratory Balance	P3225
Box Thermocouples	P3337	FT-IR	-	Tape Measure	P2024
Meter In Thermocouple	P3337	FT-IR Oven Box	-	Stopwatch	P2370
Meter Out Thermocouple	P3337	Bernath 3006 FID	-	Protractor	-
Control Box Timer	P3337	Signal 3030 FID	-	Barometer	P1916
Oven Box	-	Servomex	-	Digital Micromanometer	P1599
Probe	P2777	JCT Heated Head Filter	-	Digital Temperature Meter	P1475
Probe Thermocouple	P3000	Thermo FID	-	Stack Thermocouple	P2997
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	P2105	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P1952	Chiller (JCT/MAK 10)	P2903	1m Heated Line (3)	-
Last Impinger Arm	-	Heated Line Controller (1)	-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	P2582	10m Heated Line (1)	-
Callipers	-	Site temperature Logger	P2208	10m Heated Line (2)	-
Small DGM	-			15m Heated Line (1)	-
Heater Controller	-			20m Heated Line (1)	-
Inclinometer (Swirl Device)	P3079			20m Heated Line (2)	P2404

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 +/- %
Oxygen	CG 58	BOC	-	9.9	2.0
Nitric Oxide	SM 23	BOC	202	-	2.0

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**
Owen May	MM 10 1072	MCERTS Level 2	Jun-25	Sep-26	Jul-26	Feb-28	Mar-27	Jun-25
Alecs Perez	MM 19 1560	MCERTS Level 2	May-28	May-28	-	-	Mar-29	May-29

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	12:24 - 13:24 10 June 2024	4.46	1.06	10	41
Blank	-	0.52	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

Acetone Blank Value mg/l	Acceptable Value mg/l
0.3	1.0

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	329459	0.14997	0.15411	0.00414	72.73950	72.73960	0.00010	0.00424

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	320790	0.15214	0.15216	0.00002	72.06230	72.06250	0.00020	0.00050

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	101.1
Stack static pressure, P_{static}	pa	-2100.0
$P_s = P_b + P_{static}$	Kpa	99.0
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	81.2
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.1011752
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		1.045
Gas meter correction factor, Y_d		0.998
Mean dry gas meter temperature, T_m		296
Mean pressure drop across orifice, DH	mmH_2O	32.803
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m}$	m^3	0.964
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.0649
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		11.1
% oxygen reference condition		11
O_2 Reference Factor O_2 Ref = $\frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		0.99
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\,Ref})$	m^3	0.9508
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0950
	%	9.50
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Velocity pressure coefficient, C_p		0.84
Mean of velocity heads, DP_{avg}	Pa	154.35
Mean stack gas temperature, T_s	K	435
Gas density $_{(wet,\ ambient)}$, ρ p=(Ms*Ps)/(8.314*Ts)	kg/m^3	0.796
Stack Velocity, Vs $V_s = \frac{\sum_{i=1}^{n} V_i}{n}$	m/s	16.51

Molecular weight of dry gas, M_d		
CO_2	%	11.26
O_2	%	11.13
Total	%	22.39
N_2 (100 -Total)	%	77.61
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		30.25
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	29.08
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	280.0
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	155.3
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	@O_2ref	153.22
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet	171.60
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	6.01
Nozzle area, A_n	mm^2	28.37
Total sampling time, q	min	60
$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	103.1
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00414
Mass collected in probe, M_p	g	0.00010
Total mass collected, M_n	g	0.00424
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	3.982
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	4.400
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	4.459
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		41.00

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	17.38	0.16	-	-406.4	0.35	Yes

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

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	103.08	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.53	0.5	No

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	0.52	10	1.0	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	Quartz Fibre	47	166	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	12:24 - 13:24 10 June 2024	0.27	0.013	50	2.5
Field Blank	-	0.031	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

SULPHUR DIOXIDE QUALITY ASSURANCE CHECKLIST

	Barometric Pressure Kpa	Average Oxygen Value for Referencing %	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	101.1	11.1	0.951	17.4	0.16	-	0.35	Yes

	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Temperature during storage / transit <25°C	Type of Absorbers	Absorption Solutions
Run 1	Quartz Fibre	47	0	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	254.7	12.3	95	95	Yes

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		0.84
Stack static pressure, P_{static}	Pa	-2100	Mean of velocity heads, DP_{avg}	Pa	154.35
$P_s = P_b + (P_{static})$	kPa	99.00	Mean stack gas temperature, T_s	K	435.25
			Gas density $_{(wet, ambient)}$, p		
Vol. of water vapour collected, V_{wstd}			p=(Ms*Ps)/(8.314*Ts)	kg/m^3	0.796
Moisture trap weight increase,Vlc	g	-	Stack Velocity, Vs		
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-	$V_s = \frac{\sum_{i=1}^{n} V_i}{n}$	m/s	16.51
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	1.0450	Area of stack, A_s	m^2	0.28
Gas meter correction factor, Y_d		0.9979	$Q_a = (60)(A_s)(V_s)$	m³/min	280
Mean dry gas meter temperature, T_m	K	295.67	**Dry total flow of stack gas, Q_{std}**		
Mean pressure drop across orifice, DH	mmH_2O	32.80	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	0.96	$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	m³/min	155
Volume of gas metered wet, V_{mstw}			**Wet total flow of stack gas, Q_{stw}**		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.0649	$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	m³/min	172
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	$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	m³/min	153
% oxygen measured in gas stream, act%O_2		11.13			
% oxygen reference condition		11	**Percent isokinetic, %I**		
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		0.99	Nozzle diameter, D_n	mm	6.01
			Nozzle area, A_n	mm^2	28.37
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	0.9508	Total sampling time, q	min	60
Moisture content, B_{wo}			$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	103
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0950			
	%	9.50	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	255
CO_2		11.26	$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	0.239
O_2		11.13			
Total		22.39	$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	0.264
N_2 (100 -Total)		77.61			
			$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	0.268
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		30.25			
Molecular weight of wet gas, M_s			**Sulphur Dioxide Emission Rates, E**		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	29.1	$E = [(C_{wet})(Q_{stw})(60)] / 1000$	g/hr	2.46

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
Oxides of Nitrogen	12:24 - 13:24 10 June 2024	187.7	0.54	200	1739

Test	Sampling Time and Date	Concentration %	LOD %
Oxygen	12:24 - 13:24 10 June 2024	11.13	0.01

Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

PRE-SAMPLING CALIBRATION DATA

Date	10 June 2024
Start Time	09:45
End Time	10:15

Chiller Temperature (°C)	1.6
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 %
Nitric Oxide	250	0.00	202.0	-0.10	0.40	202.3	76	-0.15
Oxygen	25	0.00	9.90	-0.01	0.11	9.96	75	-0.61

POST-SAMPLING CALIBRATION DATA

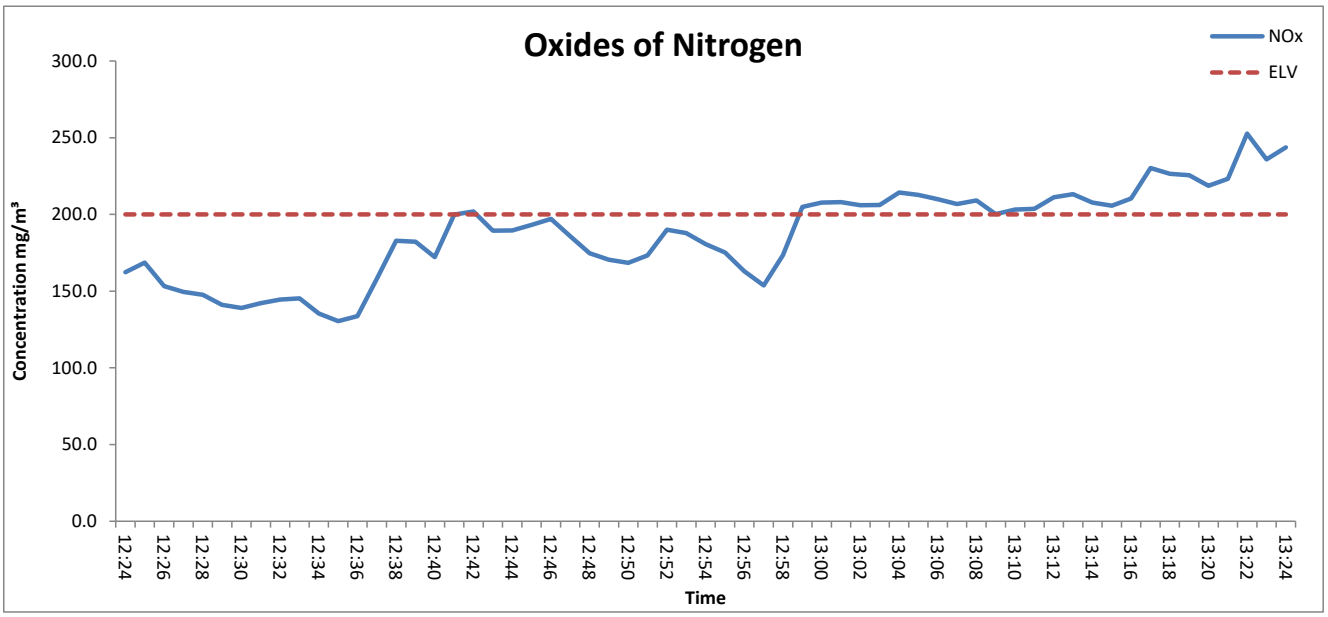
Date	10 June 2024
Start Time	13:30
End Time	13:40

Chiller Temperature (°C)	2.2
Requirement	< 4°C
Compliant	Yes

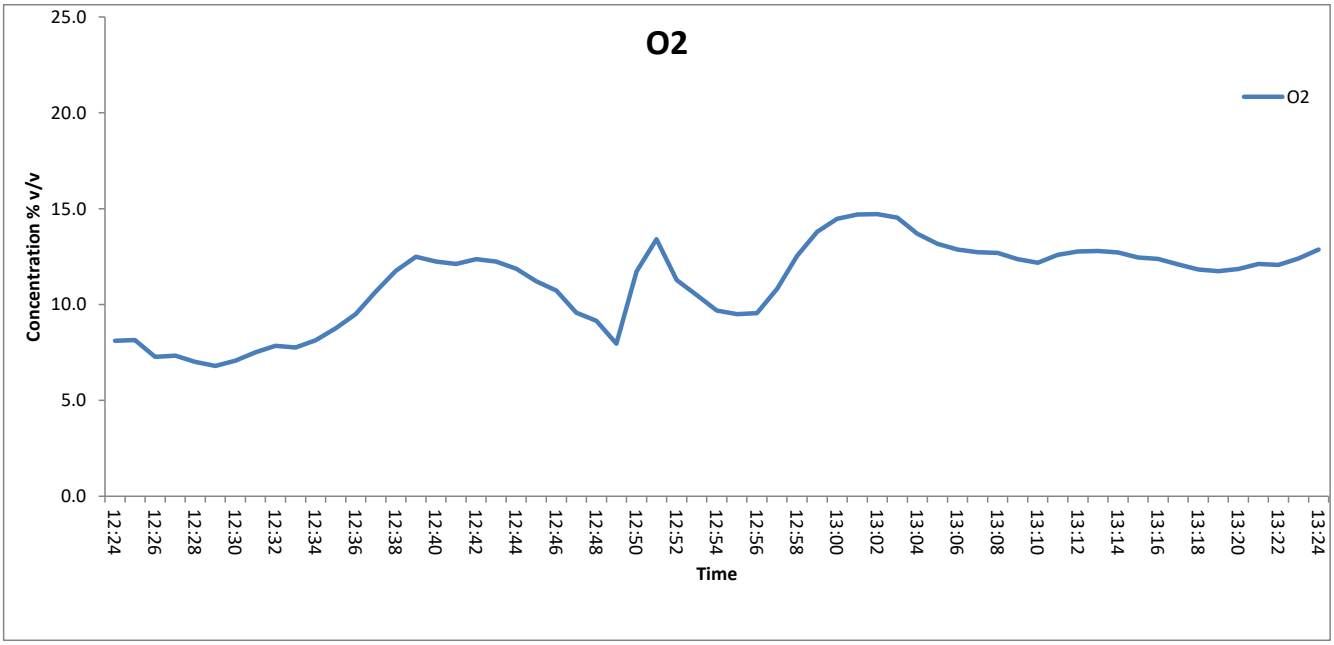
Gas	Zero Check at Analyser	Span Check at Analyser	Zero Drift (%)	Span Drift (%)	Corrected for Zero Drift	Corrected for Span Drift	Corrected Values ppm / %
Nitric Oxide	0.50	202.5	0.30	-0.05	×	×	N/A - not corrected
Oxygen	0.12	9.99	1.32	-0.40	×	×	N/A - not corrected

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

OXIDES OF NITROGEN (as NO_2) EMISSIONS CHART



OXYGEN EMISSIONS CHART



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	12:24 - 13:24 10 June 2024	3.3655	3.4467	0.0812	9.5	0.01	3.4

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	60	1065	17.4	0.16	-	0.35	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	169	°C
Stack static pressure	-2.095	kPa
Barometric Pressure	101.1	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	11.257143	0.112571	0.220984	10.187568	0.101876	0.199988
O_2	32	1.427679	11.133715	0.111337	0.158954	10.075867	0.100759	0.143851
N_2	28	1.249219	77.609143	0.776091	0.969508	70.235264	0.702353	0.877392
H_2O	18	0.803070	-	-	-	9.501301	0.095013	0.076302

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

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.3494	kg/m^3
Wet Density (STP), P_{STW}	1.2975	kg/m^3
Dry Density (Actual), P_{Actual}	0.8151	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	0.784	kg/m^3

Where:

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

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

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

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	10 June 2024
Time of Survey	10:06
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	140.5	14.3	168	15.9	4.5	-	<15
2	0.15	163.3	16.7	169	17.1	4.8	-	<15
3	0.45	186.2	19.0	169	18.3	5.2	-	<15
4	0.55	179.7	18.3	169	18.0	5.1	-	<15
Mean	-	167.4	17.1	169	17.3	4.9	-	-

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	130	128	1.5	Pass	134	133	0.7	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	-2095	-2090	-5.0	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 Average Differential Pressure	140	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	15.9	m/s	-	-
Highest Gas Velocity	18.3	m/s	-	-
Ratio of Gas Velocities	1.2	-	< 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, $V = K_{pt} \times (1\text{-}e) * Ô(2 * DP_{pt} / P_{ActualW})$		
Where: K_{pt} = Pitot tube calibration coefficient (1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**17.3**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	169	0	°C
Total Pressure	99.005	101.3	kPa
Oxygen	11.1	11	%
Moisture	9.50	0.00	%
Pitot tube calibration coefficient, K_{pt}	0.84		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	17.33	m/s
Stack Area (A)	0.28	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	17646.83	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	10658.61	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	9645.90	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	9516.92	m^3/hr

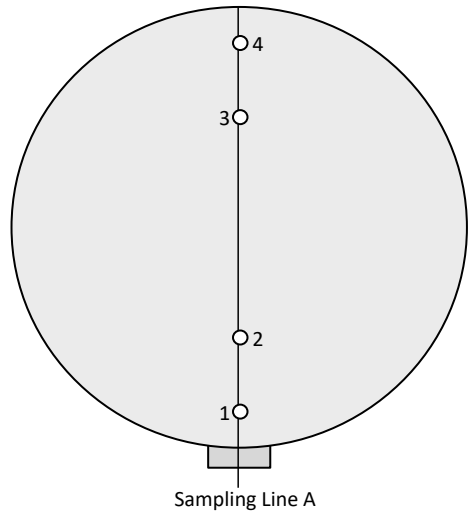
Where:
Q_{Actual} = Va x A x 3600
Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600
$Q_{STP,Dry}$ = Q (STP) / (100 - (100 / Ma)) x 3600
Q_{Ref} = Q (STP) x ((100 - Ma) / (100 - Ms)) x ((21 - O_2a) / (21 - O_2s))

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



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

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	40	0.24	m

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
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
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-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

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	0.002	2.0	0.50	1.0	0.1	0.5000	-	-
as a %	0.20	0.46	0.49	1.0	0.90	5.25876	0.92	0.005
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**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	0.60	4.2400	1.0	0.0237	0.0003	-
MU as mg/m^3	0.06	0.5259	0.05	0.0237	0.0003	**0.53**
MU as %	1.25	11.7925	-	0.532	0.0068	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**1.06**	**mg/m^3**	**23.83**	**% Result**	**10.63**	**% 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 m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=10%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.951	296	80.1	1.0	11.13371451	0.4	-
as a %	0.11	0.68	0.62	1.0	0.90	0.08	0.92
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Run	Volume (STP) m³	Mass of Sulphur Dioxide mg	O2 Correction -	Leak mg/m³	Lab Uncertainty mg	Combined uncertainty
Run 1	0.6942	0.3689	1.0136	0.0014	-	-
MU as mg/m^3	0.0037	0.0383	0.0027	0.0014	0.0129	**0.0407**
MU as %	1.3667	14.2870	1.0136	0.5315	4.8	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.08**	**mg/m³**	**30.35**	**% Result**	**0.16**	**% 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	0.002	2.0	0.50	1.0	0.1	-
as a %	0.20	0.46	0.49	1.0	0.90	0.92
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Run	Volume (STP) m^3	Mass Gained mg	O_2 Correction -	Leak mg/m^3	Uncollected Mass mg	Combined uncertainty
Run 1	0.60	81200	1.0	447.85	58	-
MU as % v/v	0.13	0.01	0.11	0.06	0.008	**0.18**
MU as %	1.25	0.12	1.01	0.53	0.07	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.36**	**% v/v**	**3.40**	**%**

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXIDES OF NITROGEN

Limit value	200	mg/m^3
Concentration @ Ref conditions	187.7	mg/m^3
Cal gas conc	414	mg/m^3
Analyser Full Scale	513	mg/m^3

	Value	Units	specification	MU Met?
Response time	76	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	60	minutes	-	-
Number of readings in measurement	60	-	-	-
Repeatability at zero	0.11	% full scale	<1 % range	Yes
Repeatability at span level	0.1	% full scale	<2 % range	Yes
Deviation from linearity	-0.40	% of value	<2 % range	Yes
Zero drift	0.30	% full scale	<5% range / 24hr	Yes
Span drift	-0.05	% full scale	<5% range / 24hr	Yes
volume or pressure flow dependence	0.25	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.25	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	0.00	% full scale/10K	<3% range / 10 K	Yes
Combined interference	-0.01	% range	<4% of Range	Yes
dependence on voltage	0.07	% full scale/10V	< 0.1%vol /10 volt	Yes
Influence of Vibration	N/A	% of upper limit of Cal range	<2%	-
losses in the line (leak)	0.07	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.0037
lack of fit	U_{lof}	-0.2309
short term zero drift	$U_{d,z}$	0.1715
short term span drift	$U_{d,s}$	-0.0286
influence of Ambient Temp at Zero	$U_{t,z}$	0.0000
influence of Ambient Temp at Span	$U_{t,s}$	0.1299
influence of sample gas pressure	U_p	0.0000
influence of sample gas flow	U_{fit}	0.1732
influence of supply voltage	U_v	0.1939
Combined Interfence	U_i	-0.0018
Uncertainty of Cal gas	U_{adj}	2.0200

Measurement uncertainty (Concentration Measured)	187.73	mg/m^3
Combined uncertainty	2.06	mg/m^3
Expanded at a 95% confidence interval	4.04	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**2.02**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**4.0**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**2.2**	**% value**

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXYGEN

Reference	11	%vol
Reported Concentration	11.13	%vol
Calibration gas	9.9	%vol
Analyser Full Scale	25	%vol

	Value	Units	specification	MU Met?
Response time	75	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	60	minutes	-	-
Number of readings in measurement	60	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.13	% of value	<2 % range	Yes
Zero drift	1.32	% full scale	<5% range / 24hr	Yes
Span drift	-0.40	% full scale	<5% range / 24hr	Yes
volume or pressure flow dependence	0.03	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.05	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	-0.05	% full scale/10K	<3% range / 10 K	Yes
Combined interference	0.01	% range	<4% of Range	Yes
dependence on voltage	0.00	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	0.01	% of value	< 2% of value	Yes
Uncertainty of calibration gas	0.0	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.0083
lack of fit	U_{lof}	0.0751
short term zero drift	$U_{d,z}$	0.7602
short term span drift	$U_{d,s}$	-0.2333
influence of Ambient Temp at Zero	$U_{t,z}$	0.0000
influence of Ambient Temp at Span	$U_{t,s}$	-0.0004
influence of sample gas pressure	U_p	0.0000
influence of sample gas flow	U_{fit}	0.0173
influence of supply voltage	U_v	0.0001
Combined Interfence	U_i	0.0017
Uncertainty of Cal gas	U_{adj}	0.0495

Measurement uncertainty (Concentration Measured)	11.13	% vol
Combined uncertainty	0.80	% vol
Expanded uncertainty	1.57	% vol

Expanded uncertainty expressed with a level of confidence of 95%	**1.57**	**% vol**
Expanded uncertainty expressed with a level of confidence of 95%	**14.09**	**% value**

Maximum permissible uncertainty is 6% of value or 0.3% by volume.
Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	17.3	m/s
Measured Volumetric Flow rate at Actual Conditions	17647	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	-	1.37		
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	26.08	<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	0.00005		
Uncertainty of temperature measurement	K	2.25	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	505		
Uncertainty associated with the calculation of density	kg/m3	0.008		
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	0.22
Expanded uncertainty at a 95% Confidence Interval	0.42

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	463
Expanded uncertainty at a 95% Confidence Interval	907

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