

# STACK EMISSIONS MONITORING REPORT



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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
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Technical Endorsements:	1, 2, 3 & 4
Signature:	



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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.  
This test report shall not be reproduced, except in full, without written approval of SOCOTEC LTD.

## EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	Units	Result	Calculated Uncertainty +/-	Emission Limit Value (ELV)	Accreditation
Total Particulate Matter	mg/m <sup>3</sup>	3.6	0.89	10	MCERTS
Particulate Emission Rate	g/hr	40	10.0	-	
Sulphur Dioxide	mg/m <sup>3</sup>	0.53	0.09	50	MCERTS
Sulphur Dioxide Emission Rate	g/hr	5.9	1.00	-	
Oxides of Nitrogen (as NO <sub>2</sub> )	mg/m <sup>3</sup>	141	4.0	200	MCERTS
Oxides of Nitrogen (as NO <sub>2</sub> ) Emission Rate	g/hr	1603	46	-	
Oxygen	% v/v	9.2	1.569	-	MCERTS
Moisture	%	9.21	0.31	-	MCERTS
Stack Gas Temperature	°C	169	-	-	MCERTS
Stack Gas Velocity	m/s	17.3	0.42	-	
Gas Volumetric Flow Rate (Actual)	m <sup>3</sup> /hr	17657	908	-	
Gas Volumetric Flow Rate (STP, Wet)	m <sup>3</sup> /hr	10665	548	-	
Gas Volumetric Flow Rate (STP, Dry)	m <sup>3</sup> /hr	9682	498	-	
Gas Volumetric Flow Rate at Reference Conditions	m <sup>3</sup> /hr	11406	586	-	

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	10:26 - 11:26	60 minutes
Sulphur Dioxide Run 1	10 June 2024	10:26 - 11:26	60 minutes
Combustion Gases	10 June 2024	10:26 - 11:26	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	Roundwood only
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	0.44 mg/m <sup>3</sup>	24.8%	8.91%
Sulphur Dioxide	SRM - BS EN 14791	AE 112	1015	MCERTS	0.013 mg/m <sup>3</sup>	16.8%	0.18%
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	MCERTS	0.44 mg/m <sup>3</sup>	2.9%	2.02%
Oxygen	SRM - BS EN 14789:2017	AE 102	1015	MCERTS	0.01%	17.0%	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 Analysis	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	$\geq 5 \text{ Pa}$	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	$< 15$	$^{\circ}$	$< 15^{\circ}$	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 <sup>2</sup>
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 accessible, therefore isokinetic sampling could only be conducted on one sampling line.

APPENDICES

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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

APPENDIX 3 - Measurement Uncertainty Budget Calculations

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

MONITORING SCHEDULE					
Species	Method Standard Reference Method / Alternative Method	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/m <sup>3</sup>	Uncertainty mg/m <sup>3</sup>	ELV mg/m <sup>3</sup>	Emission Rate g/hr
Run 1	10:26 - 11:26 10 June 2024	3.59	0.89	10	40
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	320119	0.14035	0.14332	0.00297	67.16980	67.17090	0.00110	0.00407

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	320120	0.14418	0.14418	0.00000	66.71280	66.71300	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
<b>Absolute pressure of stack gas, P<sub>s</sub></b>			<b>Molecular weight of dry gas, M<sub>d</sub></b>	
Barometric pressure, P <sub>b</sub>	Kpa	101.1	CO <sub>2</sub>	% 11.26
Stack static pressure, P <sub>static</sub>	pa	-2100.0	O <sub>2</sub>	% 9.22
P <sub>s</sub> = P <sub>b</sub> + P <sub>static</sub>	Kpa	99.0	Total	% 20.48
<b>Vol. of water vapour collected, V<sub>wstd</sub></b>			N <sub>2</sub> (100 - Total)	% 79.52
Moisture trap weight increase, V <sub>lc</sub>	g	78.3	M <sub>d</sub> = 0.44(%CO <sub>2</sub> )+0.32(%O <sub>2</sub> )+0.28(%N <sub>2</sub> )	30.17
V <sub>wstd</sub> = (0.001246)(V <sub>lc</sub> )	m <sup>3</sup>	0.0975618	<b>Molecular weight of wet gas, M<sub>s</sub></b>	
<b>Volume of gas metered dry, V<sub>mstd</sub></b>			M <sub>s</sub> = M <sub>d</sub> (1 - B <sub>wo</sub> ) + 18(B <sub>wo</sub> )	g/gmol 29.05
Volume of gas sample through gas meter, V <sub>m</sub>		1.044	<b>Actual flow of stack gas, Q<sub>a</sub></b>	
Gas meter correction factor, Y <sub>d</sub>		0.998	Area of stack, A <sub>s</sub>	m <sup>2</sup> 0.28
Mean dry gas meter temperature, T <sub>m</sub>		296	Q <sub>a</sub> = (60)(A <sub>s</sub> )(V <sub>s</sub> )	m <sup>3</sup> /min 288.6
Mean pressure drop across orifice, DH	mmH <sub>2</sub> O	34.008	<b>Total flow of stack gas, Q</b>	
V <sub>mstd</sub> = $\frac{(0.3592)(V_m)(P_b + (DH/13.6))(Y_d)}{T_m}$	m <sup>3</sup>	0.961	Conversion factor (K/mm.Hg)	0.3592
<b>Volume of gas metered wet, V<sub>mstw</sub></b>			Q <sub>std</sub> = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	Dry 158.5
V <sub>mstw</sub> = V <sub>mstd</sub> + V <sub>wstd</sub>	m <sup>3</sup>	1.0588	Q <sub>stdO2</sub> = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	@O <sub>2</sub> ref 186.71
<b>Vol. of gas metered at O<sub>2</sub> Ref. Cond., V<sub>mstd@X%O2</sub></b>			Q <sub>stw</sub> = $\frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet 174.58
Is the process burning hazardous waste? (If yes, no favourable oxygen correction)		No	<b>Percent isokinetic, %I</b>	
% oxygen measured in gas stream, act%O <sub>2</sub>		9.2	Nozzle diameter, D <sub>n</sub>	mm 6.01
% oxygen reference condition		11	Nozzle area, A <sub>n</sub>	mm <sup>2</sup> 28.37
O <sub>2</sub> Reference O <sub>2</sub> Ref = 21.0 - act%O <sub>2</sub>		1.18	Total sampling time, q	min 60
Factor = $\frac{21.0 - ref\%O_2}{21.0 - act\%O_2}$			%I = $\frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	% 100.7
V <sub>mstd@X%oxygen</sub> = (V <sub>mstd</sub> ) (O <sub>2</sub> Ref)	m <sup>3</sup>	1.1324	Acceptable isokinetic range 95% to 115%	
<b>Moisture content, B<sub>wo</sub></b>			<b>Particulate Concentration, C</b>	
B <sub>wo</sub> = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0921	Mass collected on filter, M <sub>f</sub>	g 0.00297
		9.21	Mass collected in probe, M <sub>p</sub>	g 0.00110
<b>Moisture by FTIR</b>			Total mass collected, M <sub>n</sub>	g 0.00407
	%	-	C <sub>wet</sub> = $\frac{M_n}{V_{mstw}}$	mg/m <sup>3</sup> 3.844
<b>Velocity of stack gas, V<sub>s</sub></b>			C <sub>dry</sub> = $\frac{M_n}{V_{mstd}}$	mg/m <sup>3</sup> 4.234
Velocity pressure coefficient, C <sub>p</sub>		0.84	C <sub>dry@X%O2</sub> = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m <sup>3</sup> 3.594
Mean of velocity heads, DP <sub>avg</sub>	Pa	161.70	<b>Particulate Emission Rates, E</b>	
Mean stack gas temperature, T <sub>s</sub>	K	441	E = [(C <sub>wet</sub> )(Q <sub>stw</sub> )(60)] / 1000	
Gas density (wet, ambient), ρ	kg/m <sup>3</sup>	0.785		
ρ = (M <sub>s</sub> *P <sub>s</sub> )/(8.314*T <sub>s</sub> )				
Stack Velocity, V <sub>s</sub>	$V_s = \frac{\sum_{i=1}^n V_i}{n}$	m/s		
		17.01		

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	17.36	0.22	-	-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	100.74	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m <sup>3</sup>	5% ELV mg/m <sup>3</sup>	LOD < 5% ELV
Run 1	0.44	0.5	Yes

The above is based on both the Filter and rinse uncertainty

BLANK VALUE				
Run	Overall Blank Value mg/m <sup>3</sup>	Daily Emission Limit Value mg/m <sup>3</sup>	Acceptable Blank Value mg/m <sup>3</sup>	Overall Blank Acceptable mg/m <sup>3</sup>
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	171	180	160

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

SULPHUR DIOXIDE SUMMARY					
Test	Sampling Times	Concentration mg/m <sup>3</sup>	LOD mg/m <sup>3</sup>	ELV mg/m <sup>3</sup>	Emission Rate g/hr
Run 1	10:26 - 11:26 10 June 2024	0.53	0.013	50	5.9
Field Blank	-	0.024	-	-	-

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  m <sup>3</sup>	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	9.2	1.132	17.4	0.22	-	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	601.1	14.5	98	95	Yes

ND - None Detected

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS 1			Sulphur Dioxide	
<b>Absolute pressure of stack gas, P<sub>s</sub></b>			<b>Velocity of stack gas, V<sub>s</sub></b>	
Barometric pressure, P <sub>b</sub>	kPa	101	Velocity pressure coefficient, C <sub>p</sub>	0.84
Stack static pressure, P <sub>static</sub>	Pa	-2100	Mean of velocity heads, DP <sub>avg</sub>	Pa 161.70
P <sub>s</sub> = P <sub>b</sub> + (P <sub>static</sub> )	kPa	99.00	Mean stack gas temperature, T <sub>s</sub>	K 440.83
<b>Vol. of water vapour collected, V<sub>wstd</sub></b>			Gas density (wet, ambient), ρ	
Moisture trap weight increase, V <sub>lc</sub>	g	-	ρ = (M <sub>s</sub> *P <sub>s</sub> ) / (8.314*T <sub>s</sub> )	kg/m <sup>3</sup> 0.785
V <sub>wstd</sub> = (0.001246)(V <sub>lc</sub> )	m <sup>3</sup>	-	Stack Velocity, V <sub>s</sub>	$V_s = \frac{\sum_{i=1}^n V_i}{n}$ m/s 17.01
<b>Volume of gas metered dry, V<sub>mstd</sub></b>			<b>Actual flow of stack gas, Q<sub>a</sub></b>	
Volume of gas sample through gas meter, V <sub>m</sub>	m <sup>3</sup>	1.0440	Area of stack, A <sub>s</sub>	m <sup>2</sup> 0.28
Gas meter correction factor, Y <sub>d</sub>		0.9979	Q <sub>a</sub> = (60)(A <sub>s</sub> )(V <sub>s</sub> )	m <sup>3</sup> /min 289
Mean dry gas meter temperature, T <sub>m</sub>	K	296.17	<b>Dry total flow of stack gas, Q<sub>std</sub></b>	
Mean pressure drop across orifice, DH	mmH <sub>2</sub> O	34.01	Conversion factor (K/mm.Hg)	0.3592
V <sub>mstd</sub> = (0.3592)(V <sub>m</sub> )(P <sub>b</sub> +(DH/13.6))(Y <sub>d</sub> ) / T <sub>m</sub>	m <sup>3</sup>	0.96	Q <sub>std</sub> = (Q <sub>a</sub> )P <sub>s</sub> (0.3592)(1-B <sub>w0</sub> ) / (T <sub>s</sub> )	m <sup>3</sup> /min 158
<b>Volume of gas metered wet, V<sub>mstw</sub></b>			<b>Wet total flow of stack gas, Q<sub>stw</sub></b>	
V <sub>mstw</sub> = V <sub>mstd</sub> + V <sub>wstd</sub>	m <sup>3</sup>	1.0588	Q <sub>stw</sub> = (Q <sub>a</sub> )P <sub>s</sub> (0.3592) / (T <sub>s</sub> )	m <sup>3</sup> /min 175
<b>Vol. of gas metered at O<sub>2</sub> Ref. Cond., V<sub>mstd@X%O2</sub></b>			<b>Dry total flow of stack gas at X% O<sub>2</sub>, Q<sub>stdO2</sub></b>	
Is the process burning hazardous waste? (If yes, no favourable oxygen correction)		No	Q <sub>stdO2</sub> = (Q <sub>a</sub> )P <sub>s</sub> (0.3592)(1-B <sub>w0</sub> )(O <sub>2</sub> REF) / (T <sub>s</sub> )	m <sup>3</sup> /min 187
% oxygen measured in gas stream, act%O <sub>2</sub>		9.22	<b>Percent isokinetic, %I</b>	
% oxygen reference condition		11	Nozzle diameter, D <sub>n</sub>	mm 6.01
O <sub>2</sub> Reference O <sub>2</sub> Ref = 21.0 - act%O <sub>2</sub>		1.18	Nozzle area, A <sub>n</sub>	mm <sup>2</sup> 28.37
Factor 21.0 - ref%O <sub>2</sub>			Total sampling time, q	min 60
V <sub>mstd@X%oxygen</sub> = (V <sub>mstd</sub> ) (O <sub>2</sub> Ref) / (21.0 - act%O <sub>2</sub> )	m <sup>3</sup>	1.1324	%I = (4.6398E6)(T <sub>s</sub> )(V <sub>mstd</sub> ) / (P <sub>s</sub> )(V <sub>s</sub> )(A <sub>n</sub> )(q)(1-B <sub>w0</sub> )	% 101
<b>Moisture content, B<sub>w0</sub></b>			Acceptable isokinetic range 95% to 115%	
B <sub>w0</sub> = V <sub>wstd</sub> / (V <sub>mstd</sub> + V <sub>wstd</sub> )	%	0.0921	Yes	
<b>Moisture by FTIR</b>			<b>Sulphur Dioxide Concentration, C</b>	
<b>Molecular weight of dry gas, M<sub>d</sub></b>			Mass collected, M	
CO <sub>2</sub>		11.26	C <sub>wet</sub> = M <sub>n</sub> / V <sub>mstw</sub>	ug 601
O <sub>2</sub>		9.22	C <sub>dry</sub> = M <sub>n</sub> / V <sub>mstd</sub>	mg/m <sup>3</sup> 0.568
Total		20.48	C <sub>dry@X%O2</sub> = M <sub>n</sub> / (V <sub>mstd@X%oxygen</sub> )	mg/m <sup>3</sup> 0.625
N <sub>2</sub> (100 -Total)		79.52		mg/m <sup>3</sup> 0.531
M <sub>d</sub> = 0.44(%CO <sub>2</sub> )+0.32(%O <sub>2</sub> )+0.28(%N <sub>2</sub> )		30.17	<b>Sulphur Dioxide Emission Rates, E</b>	
<b>Molecular weight of wet gas, M<sub>s</sub></b>			E = [(C <sub>wet</sub> )(Q <sub>stw</sub> )(60)] / 1000	
M <sub>s</sub> = M <sub>d</sub> (1 - B <sub>w0</sub> ) + 18(B <sub>w0</sub> )	g/gmol	29.0	g/hr 5.95	

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**COMBUSTION GASES SUMMARY**

Test	Sampling Time and Date	Concentration mg/m <sup>3</sup>	LOD mg/m <sup>3</sup>	ELV mg/m <sup>3</sup>	Emission Rate g/hr
Oxides of Nitrogen	10:26 - 11:26 10 June 2024	141.4	0.44	200	1603

Test	Sampling Time and Date	Concentration %	LOD %
Oxygen	10:26 - 11:26 10 June 2024	9.22	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

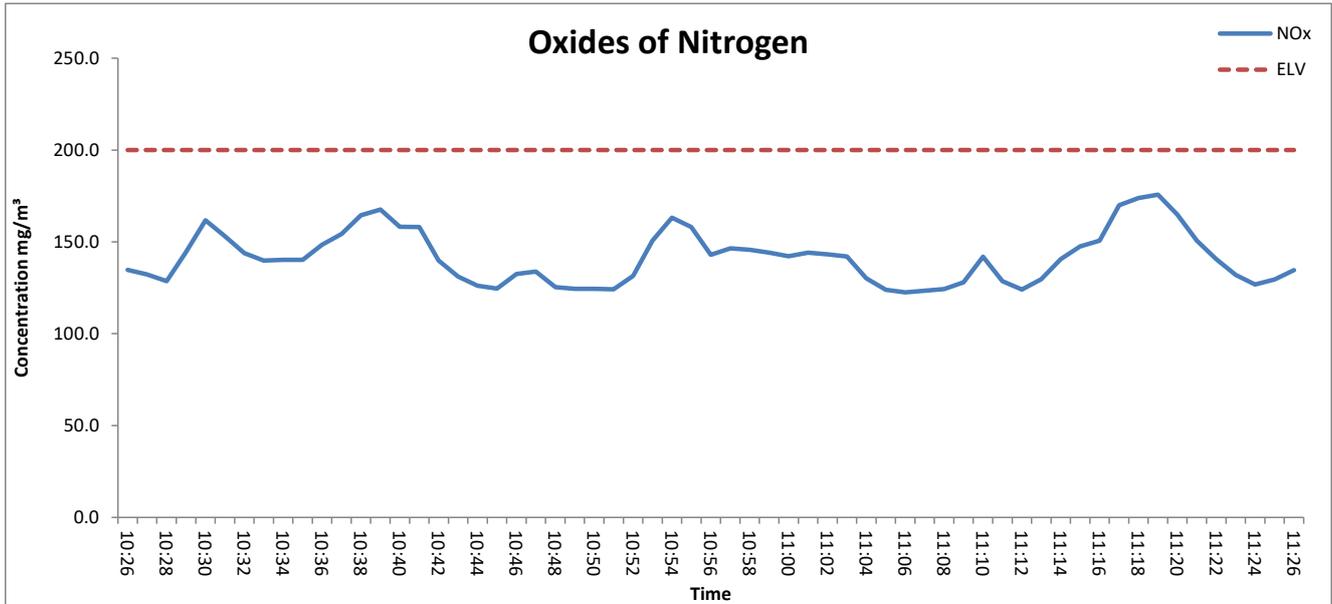
**POST-SAMPLING CALIBRATION DATA**

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

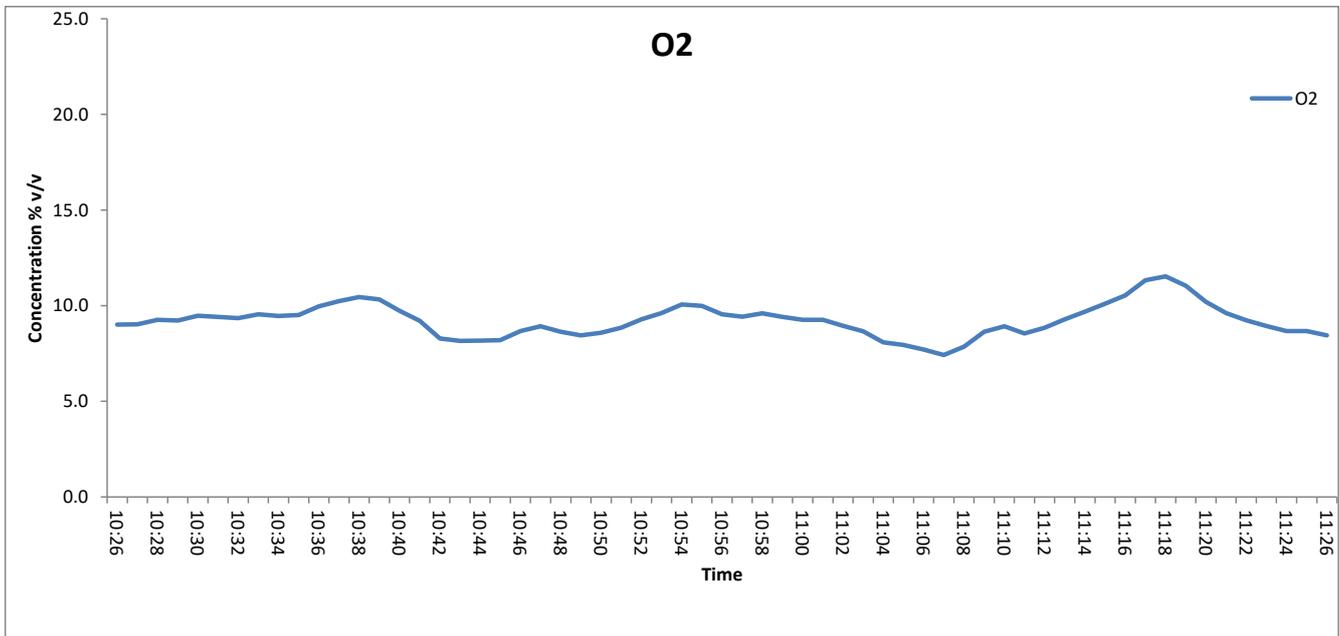
Chiller Temperature (°C)	2.2
Requirement	< 4°C
Compliant	Yes

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	x	x	N/A - not corrected
Oxygen	0.12	9.99	1.32	-0.40	x	x	N/A - not corrected

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts  
**OXIDES OF NITROGEN (as NO<sub>2</sub>) 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	End Weight	Total gain	Concentration	LOD	Uncertainty
		kg	kg	kg	%	%	%
Run 1	10:26 - 11:26 10 June 2024	3.4663	3.5446	0.0783	9.2	0.01	3.4

Moisture Quality Assurance							
Test Number	Sampling Duration	Total Volume Sampled	Sampling Rate	Start Leak Rate	End Leak Rate	Acceptable Leak Rate	Leak Tests Acceptable?
	mins	l	l/min	l/min	l/min	l/min	
Run 1	60	1059	17.4	0.22	-	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 <sup>2</sup>
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 <sup>3</sup> ρ	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m <sup>3</sup> p <sub>i</sub>	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m <sup>3</sup> p <sub>i</sub>
CO <sub>2</sub>	44	1.963059	11.257143	0.112571	0.220984	10.219875	0.102199	0.200622
O <sub>2</sub>	32	1.427679	9.219787	0.092198	0.131629	8.370247	0.083702	0.119500
N <sub>2</sub>	28	1.249219	79.523070	0.795231	0.993417	72.195567	0.721956	0.901881
H <sub>2</sub> O	18	0.803070	-	-	-	9.214311	0.092143	0.073997

Where:  $\rho = M / 22.41$      $p_i = r \times p$

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), $P_{STD}$	1.3460	kg/m <sup>3</sup>
Wet Density (STP), $P_{STW}$	1.2960	kg/m <sup>3</sup>
Dry Density (Actual), $P_{Actual}$	0.8130	kg/m <sup>3</sup>
Average Wet Density (Actual), $P_{ActualW}$	0.783	kg/m <sup>3</sup>

Where:

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

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

$$P_{Actual} = P_{STD} \times (T_s / P_s) \times (P_a / T_a)$$

$$P_{ActualW} = P_{STW} \times (T_s / P_s) \times (P_a / T_a)$$

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 <sub>2</sub> O (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m <sup>3</sup> /s	O <sub>2</sub> % 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	17.2	4.9	-	<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 mmH <sub>2</sub> O	End Value mmH <sub>2</sub> O	Difference %	Outcome	Start Value mmH <sub>2</sub> O	End Value mmH <sub>2</sub> O	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<sub>2</sub>O (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, $V = K_{pt} \times (1-e) \times \sqrt{2 \times DP_{pt} / P_{ActualW}}$		
<b>Where:</b>		
$K_{pt}$ = Pitot tube calibration coefficient		
(1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, $V_a$	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	9.2	11	%
Moisture	9.21	0.00	%
Pitot tube calibration coefficient, $K_{pt}$	0.84		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity ( $V_a$ )	17.34	m/s
Stack Area (A)	0.28	m <sup>2</sup>
Gas Volumetric Flowrate (Actual), $Q_{Actual}$	17657.26	m <sup>3</sup> /hr
Gas Volumetric Flowrate (STP, Wet), $Q_{STP}$	10664.91	m <sup>3</sup> /hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	9682.21	m <sup>3</sup> /hr
Gas Volumetric Flowrate (REF), $Q_{Ref}$	11405.85	m <sup>3</sup> /hr

**Where:**

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

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

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

$$Q_{Ref} = Q (STP) \times ((100 - Ma) / (100 - Ms)) \times ((21 - O_{2a}) / (21 - O_{2s}))$$

**Nomenclature:**

$T_s$  = Absolute Temperature, Standard Conditions, 273 K  
 $P_s$  = Absolute Pressure, Standard Conditions, 101.3 kPa  
 $T_a$  = Absolute Temperature, Actual Conditions, K  
 $P_a$  = Absolute Pressure, Actual Conditions, kPa  
 $Ma$  = Water vapour, Actual Conditions, % Vol  
 $Ms$  = Water vapour, Reference Conditions, % Vol  
 $O_{2a}$  = Oxygen, Actual Conditions, % Vol  
 $O_{2s}$  = Oxygen, Reference Conditions, % Vol



APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER**

Run	Sampled Volume m <sup>3</sup>	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %	Uncollected Mass mg
<b>MU required</b>	<b>≤ 2%</b>	<b>≤ 2%</b>	<b>≤ 1%</b>	<b>≤ 1%</b>	<b>≤ 10%</b>	<b>≤ 5% of ELV</b>	<b>≤ 2%</b>	<b>≤ 10% of ELV</b>
Run 1	0.002	2.0	0.50	1.0	0.1	0.5000	-	-
as a %	0.20	0.45	0.49	1.0	1.08	4.41553	1.27	0.005
<b>compliant?</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>

Run	Volume (STP) m <sup>3</sup>	Mass of particulate mg	O <sub>2</sub> Correction -	Leak mg/m <sup>3</sup>	Uncollected Mass mg	Combined uncertainty
Run 1	0.59	4.0700	0.8	0.0263	0.0003	-
MU as mg/m <sup>3</sup>	0.04	0.4416	0.03	0.0263	0.0003	<b>0.45</b>
MU as %	1.25	12.2850	-	0.732	0.0071	-

<b>R1 - Uncertainty expressed at a 95% confidence level (where k = 2)</b>	<b>0.89</b>	<b>mg/m<sup>3</sup></b>	<b>24.80</b>	<b>% Result</b>	<b>8.91</b>	<b>% ELV</b>
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(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 m <sup>3</sup>	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %
<b>MU required</b>	<b>&lt;=2%</b>	<b>&lt;2.5 k</b>	<b>&lt;=1%</b>	<b>&lt;=1%</b>	<b>&lt;=10%</b>	<b>≤ 5% of ELV</b>	<b>&lt;=2%</b>
Run 1	1.132	296	80.1	1.0	9.21978741	0.8	-
as a %	0.09	0.68	0.62	1.0	1.08	0.07	1.27
<b>compliant?</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>

Run	Volume (STP) m <sup>3</sup>	Mass of Sulphur Dioxide mg	O2 Correction -	Leak mg/m <sup>3</sup>	Lab Uncertainty mg	Combined uncertainty
Run 1	0.8253	0.8460	0.8489	0.0039	-	-
MU as mg/m <sup>3</sup>	0.0072	0.0354	0.0045	0.0039	0.0255	<b>0.0446</b>
MU as %	1.3639	6.6690	0.8489	0.7315	4.8	-

<b>R1 - Uncertainty expressed at a 95% confidence level (where k = 2)</b>	<b>0.09</b>	<b>mg/m<sup>3</sup></b>	<b>16.81</b>	<b>% Result</b>	<b>0.18</b>	<b>% ELV</b>
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(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 <sup>3</sup>	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Leak %
<b>MU required</b>	<b>≤ 2%</b>	<b>≤ 2%</b>	<b>≤ 1%</b>	<b>≤ 1%</b>	<b>≤ 10%</b>	<b>≤ 2%</b>
Run 1	0.002	2.0	0.50	1.0	0.1	-
as a %	0.20	0.45	0.49	1.0	1.08	1.27
<b>compliant?</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>

Run	Volume (STP) m <sup>3</sup>	Mass Gained mg	O <sub>2</sub> Correction -	Leak mg/m <sup>3</sup>	Uncollected Mass mg	Combined uncertainty
Run 1	0.59	78300	0.8	595.87	58	-
MU as % v/v	0.13	0.01	0.09	0.08	0.008	<b>0.17</b>
MU as %	1.25	0.13	0.85	0.73	0.07	-

<b>R1 - Uncertainty expressed at a 95% confidence level (where k = 2)</b>	<b>0.35</b>	<b>% v/v</b>	<b>3.37</b>	<b>%</b>
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APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - OXIDES OF NITROGEN**

Limit value	200	mg/m <sup>3</sup>
Concentration @ Ref conditions	141.4	mg/m <sup>3</sup>
Cal gas conc	414	mg/m <sup>3</sup>
Analyser Full Scale	513	mg/m <sup>3</sup>

	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	0.06	% 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)	0.06	% 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	$U_v$	0.1781
Combined Interference	$U_i$	-0.0018
Uncertainty of Cal gas	$U_{adj}$	2.0200

Measurement uncertainty (Concentration Measured)	141.39	mg/m <sup>3</sup>
Combined uncertainty	2.06	mg/m <sup>3</sup>
Expanded at a 95% confidence interval	4.04	mg/m <sup>3</sup>

<b>Expanded uncertainty expressed with a level of confidence of 95%</b>	<b>2.02</b>	<b>% ELV</b>
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<b>Expanded uncertainty expressed with a level of confidence of 95%</b>	<b>4.0</b>	<b>mg/m<sup>3</sup></b>
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<b>Expanded uncertainty expressed with a level of confidence of 95%</b>	<b>2.9</b>	<b>% value</b>
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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	9.22	%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 Interference	$U_i$	0.0017
Uncertainty of Cal gas	$U_{adj}$	0.0495

Measurement uncertainty (Concentration Measured)	9.22	% vol
Combined uncertainty	0.80	% vol
Expanded uncertainty	1.57	% vol

<b>Expanded uncertainty expressed with a level of confidence of 95%</b>	<b>1.57</b>	<b>% vol</b>
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<b>Expanded uncertainty expressed with a level of confidence of 95%</b>	<b>17.02</b>	<b>% value</b>
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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	17657	m <sup>3</sup> /hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination	-	0.010		
Uncertainty of pitot tube coefficient	-	1.37		
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 measurement 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/m <sup>3</sup>	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	m <sup>3</sup> /hr
Combined uncertainty	463
Expanded uncertainty at a 95% Confidence Interval	908

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](https://www.surveymonkey.co.uk/r/CAE_customer_feedback_weblink)