

STACK EMISSIONS MONITORING REPORT



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Operator & Address:

Novidon
Coed Aben Road
Wrexham Ind Est
Wrexham
LL13 9UH

Permit Reference:

N/A - Investigative Test

Release Point:

Starch Refinery Heat Exchanger

Sampling Date(s):

3rd August 2023

SOCOTEC Job Number:	LNO 17896
Report Date:	8th September 2023
Version:	1
Report By:	Mark Derbyshire
MCERTS Number:	MM 07 824
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Jonathon Orley
MCERTS Number:	MM 08 983
Business Title:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Signature:	



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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Novidon operates a starch processing process at Wrexham

SOCOTEC LTD were commissioned by Crestwood Environmental to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under normal operating conditions.

Plant

Starch Refinery Heat Exchanger

Operator

Novidon
Coed Aben Road
Wrexham Ind Est
Wrexham
LL13 9UH

Stack Emissions Monitoring Test House

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

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.
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 ³	2.1	0.29	-	MCERTS
Particulate Emission Rate	g/hr	40	5.5	-	
Total Volatile Organic Compounds	mg/m ³	3.2	1.3	-	MCERTS
Total Volatile Organic Compounds Emission Rate	g/hr	58	24	-	
Oxides of Nitrogen (as NO ₂)	mg/m ³	0.29	1.9	-	MCERTS
Oxides of Nitrogen (as NO ₂) Emission Rate	g/hr	5.3	34	-	
Sulphur Dioxide	mg/m ³	1.5	2.3	-	MCERTS
Sulphur Dioxide Emission Rate	g/hr	28	43	-	
Carbon Monoxide	mg/m ³	0.33	1.2	-	MCERTS
Carbon Monoxide Emission Rate	g/hr	6.0	22	-	
Carbon Dioxide	% v/v	0.01	0.0001	-	MCERTS
Oxygen	% v/v	20.95	0.259	-	MCERTS
Moisture	%	0.28	0.02	-	MCERTS
Stack Gas Temperature	°C	40	-	-	MCERTS
Stack Gas Velocity	m/s	11.5	0.28	-	
Gas Volumetric Flow Rate (Actual)	m ³ /hr	20753	1067	-	
Gas Volumetric Flow Rate (STP, Wet)	m ³ /hr	18288	940	-	
Gas Volumetric Flow Rate (STP, Dry)	m ³ /hr	18237	937	-	
Gas Volumetric Flow Rate at Reference Conditions	m ³ /hr	18288	940	-	

ND = None Detected,

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

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

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

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	Sampling Date(s)	Sampling Times	Sampling Duration
Total Particulate Matter Run 1	03 August 2023	10:10 - 11:10	60 minutes
Total Volatile Organic Compounds Run 1	03 August 2023	10:10 - 11:10	60 minutes
Combustion Gases	03 August 2023	10:10 - 11:10	60 minutes
Preliminary Stack Traverse	03 August 2023	09:50	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Starch Processing
Continuous or batch	Continuous
Product Details	Heat
Part of batch to be monitored (if applicable)	Whilst operational
Normal load, throughput or continuous rating	-
Fuel used during monitoring	N/A
Abatement	N/A
Plume Appearance	None 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	0.14 mg/m ³	14%	N/A - No ELV
Total Volatile Organic Compounds	SRM - BS EN 12619:2013	AE 102	1015	MCERTS	0 mg/m ³	41%	N/A - No ELV
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	MCERTS	0.2 mg/m ³	641%	N/A - No ELV
Sulphur Dioxide	AM - PD CEN/TS 17021:2017	AE 102	1015	MCERTS	0.8 mg/m ³	152%	N/A - No ELV
Carbon Monoxide	SRM - BS EN 15058:2017	AE 102	1015	MCERTS	0.27 mg/m ³	369%	N/A - No ELV
Carbon Dioxide	SRM - CEN/TS 17405	AE 102	1015	MCERTS	0.1 %	0.54%	N/A - No ELV
Oxygen	SRM - BS EN 14789:2017	AE 102	1015	MCERTS	0.01%	1.2%	N/A - No ELV
Moisture	BS EN 14790	AE 105	1015	MCERTS	0.01%	7.5%	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

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

EXECUTIVE SUMMARY

Analytical Methods

The following tables list the analytical methods employed together with the custody 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 (Stockport)	N/A	8 Weeks

ON-SITE TESTING							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	Accreditation	Laboratory	Data Archive Location	Archive Period
Total Volatile Organic Compounds	Flame Ionisation Detection	AE 102	1015	MCERTS	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Oxides of Nitrogen	Chemiluminescence	AE 102	1015	MCERTS	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Sulphur Dioxide	Non Dispersive Infra Red	AE 102	1015	MCERTS	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Carbon Monoxide	Non Dispersive Infra Red	AE 102	1015	MCERTS	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Carbon Dioxide	Non Dispersive Infra Red	AE 102	1015	MCERTS	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Oxygen	Paramagnetic	AE 102	1015	MCERTS	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Moisture	Gravimetric	AE 105	1015	MCERTS	SOCOTEC (Stockport)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	Value	Units	Requirement	Compliant	Method
Lowest Differential Pressure	100	Pa	≥ 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	11.3	m/s	-	-	-
Highest Gas Velocity	11.8	m/s	-	-	-
Ratio of Gas Velocities	1.0	:1	$< 3 : 1$	Yes	BS EN 15259
Mean Velocity	11.5	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	0.80	m
Width	-	m
Area	0.50	m ²
Port Depth	0	mm

SAMPLING LINES & POINTS		
	Isokinetic	Non-Iso & Gases
Sample port size	4 Inch Hole	4 Inch Hole
Number of lines used	1	1
Number of points / line	4	1
Duct orientation	Horizontal	Horizontal
Filtration	In Stack	Out Stack
Filtration for TPM	In Stack	-

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

Single Line Sampling

There was only one sampling line available. The sampling points on the available line were doubled in line with the standard

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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
Total Volatile Organic Compounds	SRM - BS EN 12619:2013	AE 102	1015	MCERTS	1
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	MCERTS	1
Sulphur Dioxide	AM - PD CEN/TS 17021:2017	AE 102	1015	MCERTS	1
Carbon Monoxide	SRM - BS EN 15058:2017	AE 102	1015	MCERTS	1
Carbon Dioxide	SRM - CEN/TS 17405	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	LNO 13-19	Horiba PG - 350 Analyser	LNO 21-58	Laboratory Balance	LNO 00-12/13
Box Thermocouples	LNO 03-19	FT-IR	-	Tape Measure	LNO 24-MD
Meter In Thermocouple	LNO 03-19	FT-IR Oven Box	-	Stopwatch	LNO 17-MD
Meter Out Thermocouple	LNO 03-19	Bernath 3006 FID	LNO 2107	Protractor	-
Control Box Timer	LNO 17-19	Signal 3030 FID	-	Barometer	LNO 08-MD
Oven Box	LNO 09-14	Servomex	-	Digital Micromanometer	LNO 01-MD
Probe	LNO 11-21	JCT Heated Head Filter	-	Digital Temperature Meter	LNO 03-MD
Probe Thermocouple	LNO 10-21	Thermo FID	-	Stack Thermocouple	LNO 10-MD
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	LNO 06-MD	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	LNO 14-MD	Chiller (JCT/MAK 10)	LNO 21-105	1m Heated Line (3)	-
Last Impinger Arm	-	Heated Line Controller (1)	LNO 03-131	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	-	10m Heated Line (1)	-
Callipers	LNO 31-MD	Site temperature Logger	-	10m Heated Line (2)	-
Small DGM	-			15m Heated Line (1)	-
Heater Controller	-			20m Heated Line (1)	LNO 18-87
Inclinometer (Swirl Device)	LNO 25-MD			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 +/- %
Oxygen	HPC 2307	BOC	-	9.88	2.0
Propane	HPC 2178	BOC	80.7	-	2.0
Nitric Oxide	HPC 2253	BOC	40.1	-	2.0
Sulphur Dioxide	HPC 2153	BOC	34.2	-	2.0
Carbon Monoxide	HPC 2153	BOC	80.3	-	2.0
Carbon Dioxide	HPC 2243	BOC	-	8.01	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
Mark Derbyshire	MM 07 824	MCERTS Level 2	Nov-26	Nov-26	Apr-27	May-28	Jul-27	Feb-27
Oliver Denty	MM22 1747	MCERTS Trainee	Sep-27	-	-	-	-	Sep-27

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER SUMMARY					
Parameter	Sampling Times	Concentration mg/m ³	Uncertainty mg/m ³	ELV mg/m ³	Emission Rate g/hr
Run 1	10:10 - 11:10 03 August 2023	2.06	0.28	-	40
Blank	-	0.62	-	-	-

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

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	G4988	0.10432	0.10604	0.00172	61.74600	61.74730	0.00130	0.00302

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	G4987	0.10403	0.10404	0.00001	63.76470	63.76560	0.00090	0.00091

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 1			TPM	
Absolute pressure of stack gas, P_s			Molecular weight of dry gas, M_d	
Barometric pressure, P _b	Kpa	101.9	CO ₂	% 0.01
Stack static pressure, P _{static}	pa	50.0	O ₂	% 20.90
P _s = P _b + P _{static}	Kpa	102.0	Total	% 20.91
			N ₂ (100 -Total)	% 79.09
Vol. of water vapour collected, V_{wstd}			Molecular weight of wet gas, M_s	
Moisture trap weight increase, Vlc	g	3.3	M _d = 0.44(%CO ₂)+0.32(%O ₂)+0.28(%N ₂)	
V _{wstd} = (0.001246)(V _{lc})	m ³	0.0041118	M _s = M _d (1 - B _{wo}) + 18(B _{wo})	g/gmol 28.81
Volume of gas metered dry, V_{mstd}			Actual flow of stack gas, Q_a	
Volume of gas sample through gas meter, V _m		1.617	Area of stack, A _s	m ² 0.50
Gas meter correction factor, Y _d		0.964	Q _a = (60)(A _s)(V _s)	m ³ /min 366.0
Mean dry gas meter temperature, T _m		294	Total flow of stack gas, Q	
Mean pressure drop across orifice, DH mmH ₂ O		70.431	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	1.465	Q _{std} = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	Dry 320.2
Volume of gas metered wet, V_{mstw}			Q _{stdO2} = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	@O ₂ ref No O2 Ref
V _{mstw} = V _{mstd} + V _{wstd}	m ³	1.4688	Q _{stw} = $\frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet 321.15
Vol. of gas metered at O₂ Ref. Cond., V_{mstd@X%O2}			Percent isokinetic, %I	
Is the process burning hazardous waste? (If yes, no favourable oxygen correction)		No	Nozzle diameter, D _n	mm 6.89
% oxygen measured in gas stream, act%O ₂		20.9	Nozzle area, A _n	mm ² 37.29
% oxygen reference condition		21	Total sampling time, q	min 60
O ₂ Reference O ₂ Ref = 21.0 - act%O ₂		No O2 Ref	%I = $\frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	% 102.8
Factor 21.0 - ref%O ₂		No O2 Ref	Acceptable isokinetic range 95% to 115%	Yes
V _{mstd@X%oxygen} = (V _{mstd}) (O ₂ Ref)	m ³	No O2 Ref	Particulate Concentration, C	
Moisture content, B_{wo}			Mass collected on filter, M _f	g 0.00172
B _{wo} = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.28	Mass collected in probe, M _p	g 0.00130
Moisture by FTIR			Total mass collected, M _n	g 0.00302
	%	-	C _{wet} = $\frac{M_n}{V_{mstw}}$	mg/m ³ 2.056
Velocity of stack gas, V_s			C _{dry} = $\frac{M_n}{V_{mstd}}$	mg/m ³ 2.062
Velocity pressure coefficient, C _p		0.84	C _{dry@X%O2} = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³ No O2 Ref
Mean of velocity heads, DP _{avg}	Pa	117.36	Particulate Emission Rates, E	
Mean stack gas temperature, T _s	K	313	E = [(C _{wet})(Q _{stw})(60)] / 1000	39.62
Gas density (wet, ambient), ρ	kg/m ³	1.129		
ρ = (M _s *P _s)/(8.314*T _s)				
Stack Velocity, V _s	$V_s = \frac{\sum_{i=1}^n V_i}{n}$	m/s		
		12.13		

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	25.98	0.11	-	9753.6	0.52	Yes

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

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	102.77	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m ³	5% ELV mg/m ³	LOD < 5% ELV
Run 1	0.14	No ELV	N/A - No ELV

The above is based on both the Filter and rinse uncertainty

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	0.62	-	-	-

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	40	180	160

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL VOLATILE ORGANIC COMPOUNDS SUMMARY

Test	Sampling Times	Concentration mg/m ³	LOD mg/m ³	ELV mg/m ³	Emission Rate g/hr
Run 1	10:10 - 11:10 03 August 2023	3.2	0.40	-	57.63

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

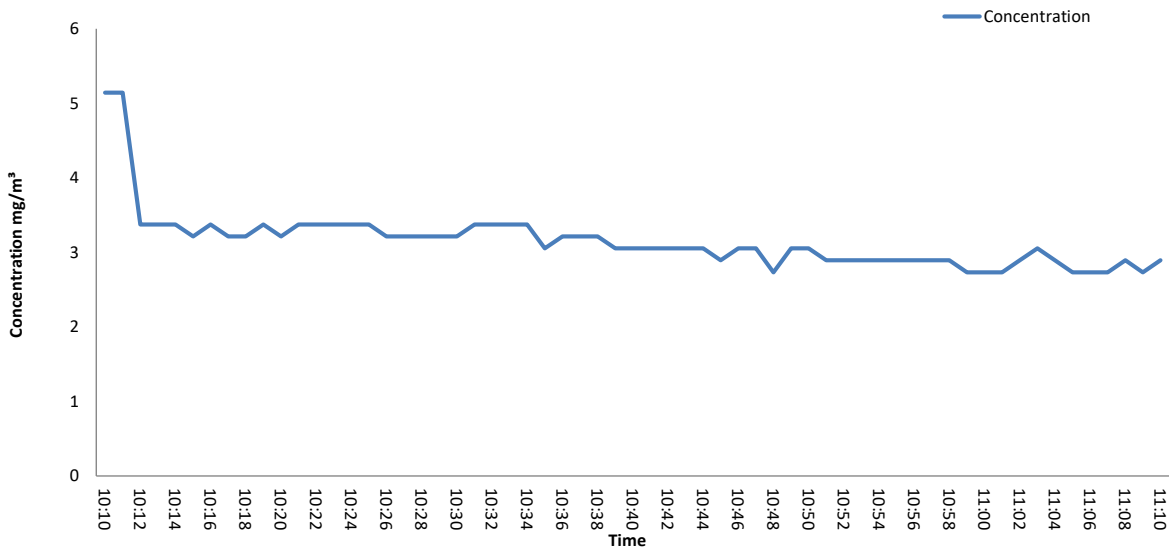
INSTRUMENTAL SPAN & ZERO CHECKS

PRE-SAMPLING CALIBRATION CHECKS								
Date	03 August 2023							
Start Time	09:45							
End Time	09:55							
Gas	Gas Conc (ppm)	Range	Instrument Zero Reading	Instrument Span Reading	Instrument Zero Reading	Zero Down line reading	Span down line reading	Leak Rate (%)
Propane	80.7	100	0.00	80.7	0.01	0.05	80.6	0.12

Zero and Span gas contained 20% Oxygen

POST-SAMPLING CALIBRATION CHECKS								
Date	03 August 2023							
Start Time	12:37							
End Time	12:45							
Gas	Mean Raw Value ppm	Zero down line reading	Span down line reading	Zero Drift (%)	Span Drift (%)	Corrected for Zero Drift	Corrected for Span Drift	Corrected Values ppm / %
Propane	1.96	0.11	80.4	0.07	-0.32	x	x	N/A - not corrected

TOTAL VOLATILE ORGANIC COMPOUNDS EMISSIONS CHART



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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

COMBUSTION GASES SUMMARY

Test	Sampling Time and Date	Concentration mg/m ³	LOD mg/m ³	ELV mg/m ³	Emission Rate g/hr
Oxides of Nitrogen	10:10 - 11:10 03 August 2023	0.29	0.20	-	5.3
Sulphur Dioxide	10:10 - 11:10 03 August 2023	1.5	0.80	-	28
Carbon Monoxide	10:10 - 11:10 03 August 2023	0.33	0.27	-	6.0

Test	Sampling Time and Date	Concentration %	LOD %
Carbon Dioxide	10:10 - 11:10 03 August 2023	0.10	0.100
Oxygen	10:10 - 11:10 03 August 2023	20.95	0.01

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

PRE-SAMPLING CALIBRATION DATA

Date	03 August 2023
Start Time	09:43
End Time	10:05

Chiller Temperature (°C)	2.1
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	100	0.00	40.1	0.02	0.05	40.2	15	-0.12
Sulphur Dioxide	200	0.00	34.2	0.03	0.06	34.1	15	0.29
Carbon Monoxide	200	0.00	80.3	0.06	0.05	80.0	15	0.37
Carbon Dioxide	10	0.00	8.01	0.02	0.08	8.00	15	0.12
Oxygen	25	0.00	9.88	0.01	0.02	9.87	15	0.10

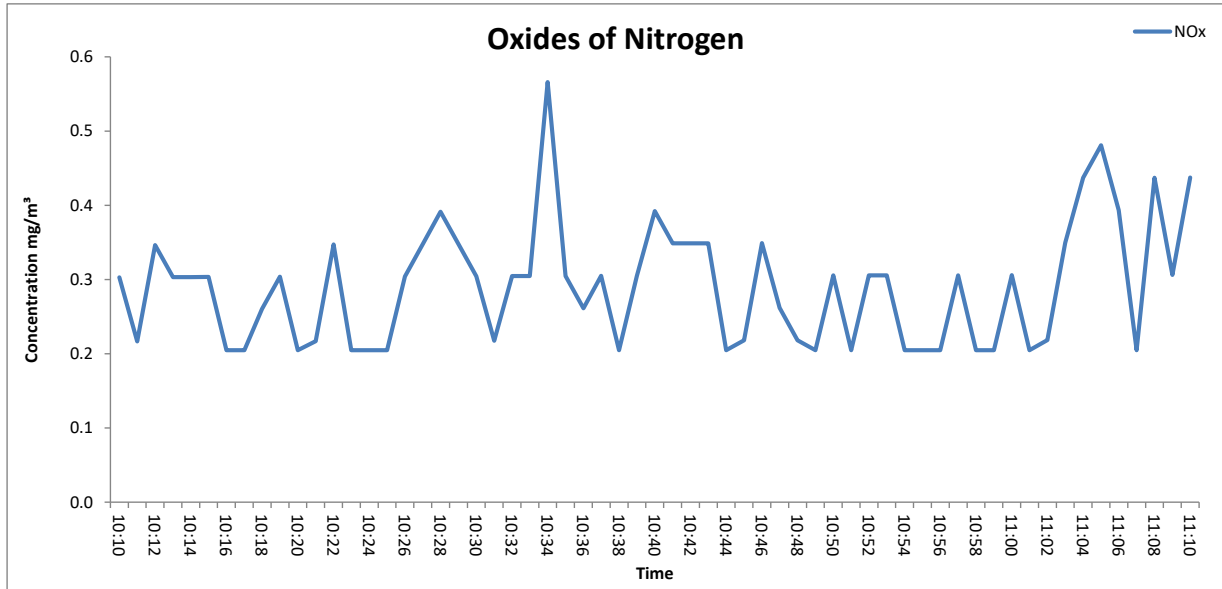
POST-SAMPLING CALIBRATION DATA

Date	03 August 2023
Start Time	12:36
End Time	12:48

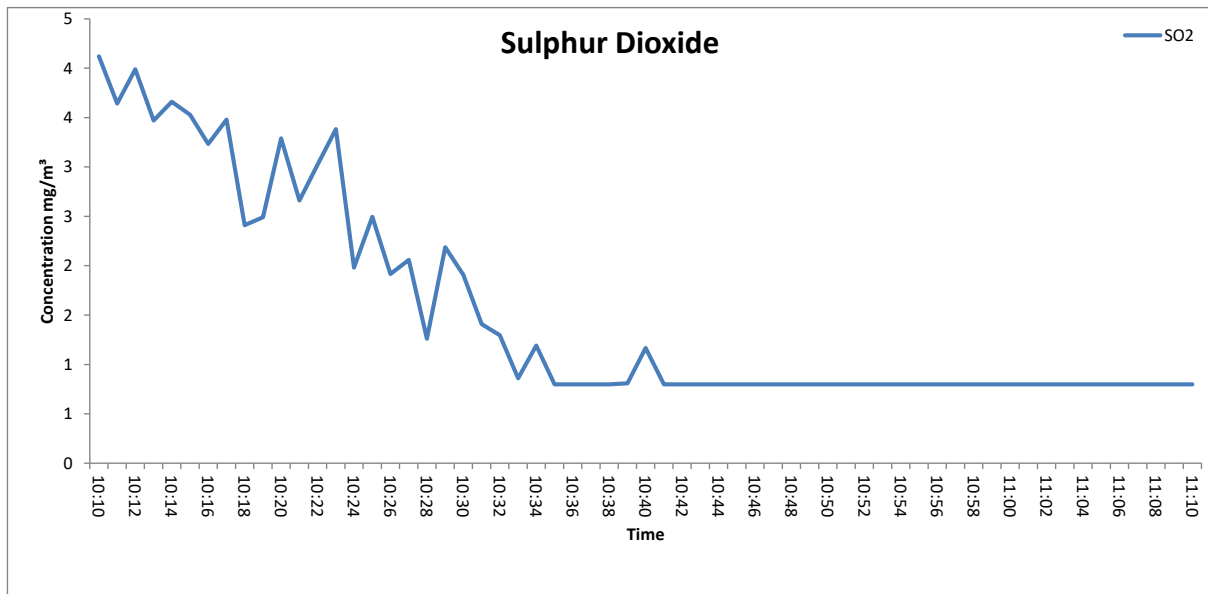
Chiller Temperature (°C)	2.2
Requirement	< 4°C
Compliant	Yes

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	0.11	40.1	0.23	-0.17	x	x	N/A - not corrected
Sulphur Dioxide	0.12	33.9	0.27	-1.14	x	x	N/A - not corrected
Carbon Monoxide	0.14	79.8	0.10	-0.72	x	x	N/A - not corrected
Carbon Dioxide	0.12	8.00	1.27	-1.37	x	x	N/A - not corrected
Oxygen	0.08	9.87	0.72	-0.81	x	x	N/A - not corrected

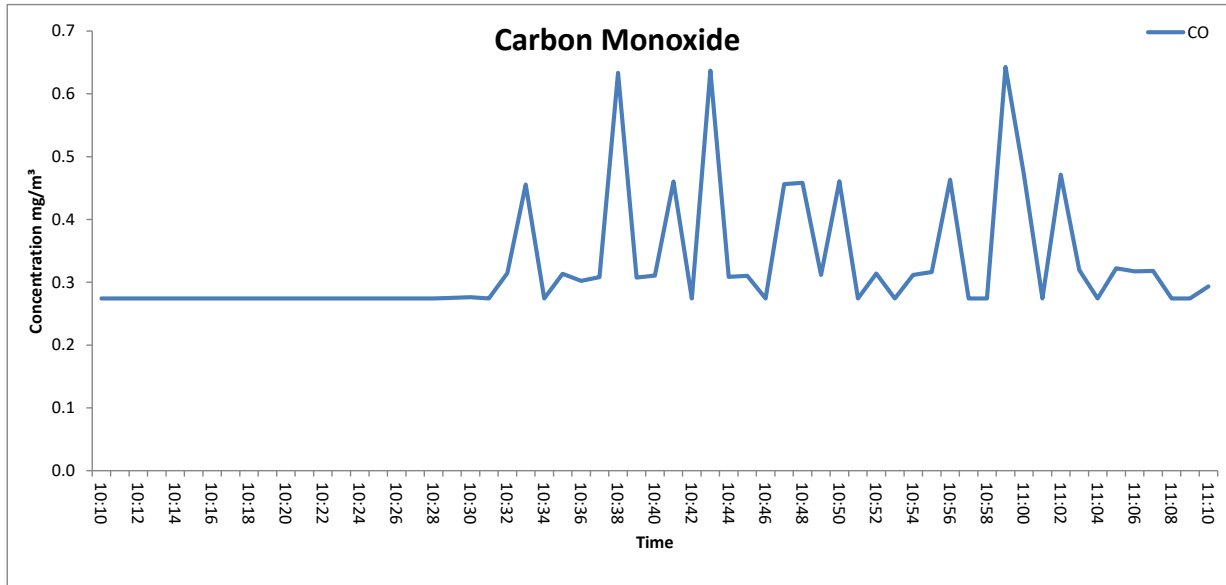
APPENDIX 2 - Summaries, Calculations, Raw Data and Charts
OXIDES OF NITROGEN (as NO₂) EMISSIONS CHART



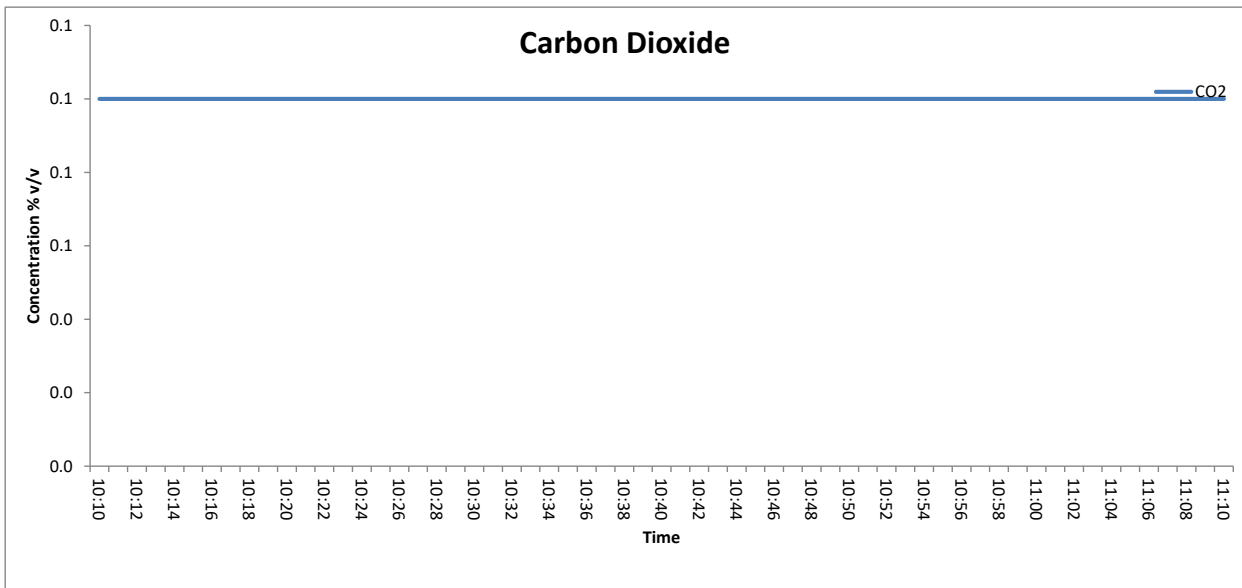
SULPHUR DIOXIDE EMISSIONS CHART



CARBON MONOXIDE EMISSIONS CHART

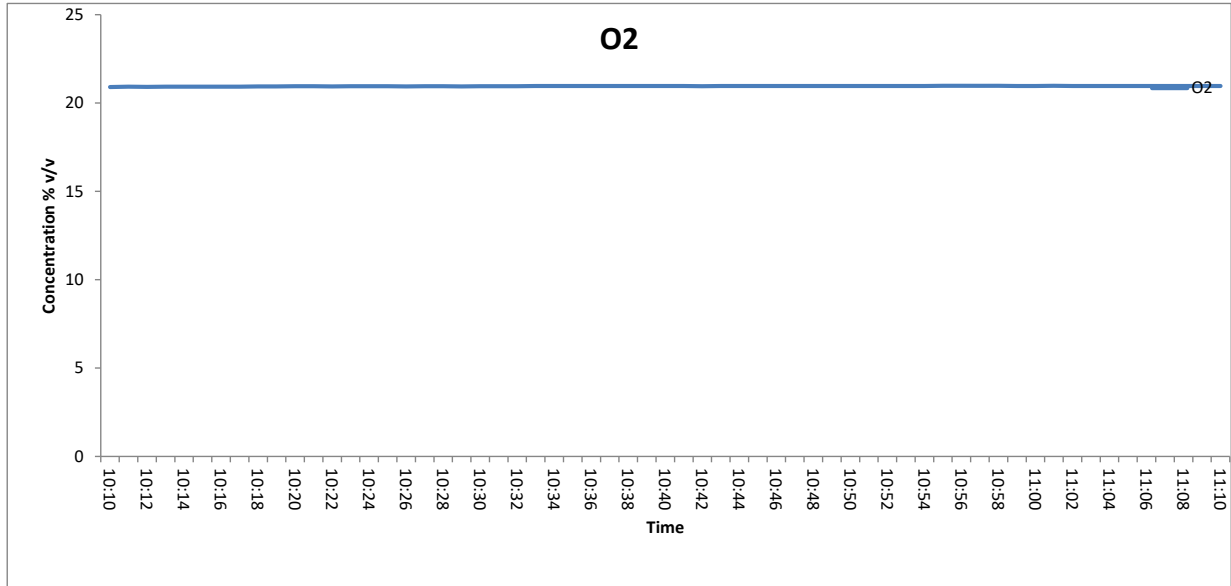


CARBON DIOXIDE EMISSIONS CHART



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

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	10:10 - 11:10 03 August 2023	3.1686	3.1719	0.0033	0.3	0.01	7.5

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	1469	26.0	0.11	-	0.52	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.80	m
Stack Width, W	-	m
Stack Area, A	0.50	m ²
Average stack gas temperature	40	°C
Stack static pressure	0.05	kPa
Barometric Pressure	102.3	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	0.011429	0.000114	0.000224	0.011397	0.000114	0.000224
O ₂	32	1.427679	20.954725	0.209547	0.299166	20.896066	0.208961	0.298329
N ₂	28	1.249219	79.033846	0.790338	0.987306	78.812602	0.788126	0.984542
H ₂ O	18	0.803070	-	-	-	0.279935	0.002799	0.002248

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

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2867	kg/m ³
Wet Density (STP), P_{STW}	1.2853	kg/m ³
Dry Density (Actual), P_{Actual}	1.1339	kg/m ³
Average Wet Density (Actual), $P_{ActualW}$	1.133	kg/m ³

Where:

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

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

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

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	03 August 2023
Time of Survey	09:50
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 ₂ O (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	104.2	10.6	40	11.4	5.7	-	-
2	0.20	102.2	10.4	40	11.3	5.7	-	-
3	0.60	110.7	11.3	40	11.8	5.9	-	-
4	0.75	103.2	10.5	40	11.4	5.7	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	105.1	10.7	40	11.5	5.8	-	-

Sampling Line B								
Traverse Point	Distance into duct (m)	DP pt Pa (average of 3 readings)	DP pt mmH ₂ O (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 mmH ₂ O	End Value mmH ₂ O	Difference %	Outcome	Start Value mmH ₂ O	End Value mmH ₂ O	Difference %	Outcome
Run 1	137	135	1.5	Pass	149	147	1.3	Pass

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

S-Type Pitot Stagnation Check				
Run	Stagnation (Pa)	Reference (Pa)	Difference (Pa)	Outcome (Permitted +/- 10 Pa)
Run 1	50	50	0.0	Pass

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY (CONTINUED)

Sampling Plane Validation Criteria				
EA Technical Guidance Note (Monitoring) M1	Result	Units	Requirement	Compliant
Lowest Average Differential Pressure	102	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	11.3	m/s	-	-
Highest Gas Velocity	11.8	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, $V = K_{pt} \times (1-e) \times \sqrt{2 * DP_{pt} / \rho_{Actual}}$		
Where:		
K_{pt} = Pitot tube calibration coefficient		
(1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, V_a	11.5	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	40	0	°C
Total Pressure	102.35	101.3	kPa
Oxygen	20.9	21	%
Moisture	0.28	0.28	%
Pitot tube calibration coefficient, K_{pt}	0.84		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (V_a)	11.47	m/s
Stack Area (A)	0.50	m ²
Gas Volumetric Flowrate (Actual), Q_{Actual}	20752.86	m ³ /hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	18288.36	m ³ /hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	18237.16	m ³ /hr
Gas Volumetric Flowrate (REF), Q_{Ref}	18288.36	m ³ /hr

Where:

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

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

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

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

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 ³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %	Uncollected Mass mg
MU required	≤ 2%	≤ 2%	≤ 1%	≤ 1%	≤ 10%	≤ 5% of ELV	≤ 2%	≤ 10% of ELV
Run 1	0.003	2.0	0.50	1.0	N/A	0.2000	-	-
as a %	0.20	0.64	0.49	1.0	N/A	N/A	0.42	N/A
compliant?	Yes	Yes	Yes	Yes	N/A	N/A	Yes	N/A

Run	Volume (STP) m ³	Mass of particulate mg	O ₂ Correction -	Leak mg/m ³	Uncollected Mass mg	Combined uncertainty
Run 1	1.29	3.0200	1.0	0.0050	0.0005	-
MU as mg/m ³	0.03	0.1362	-	0.0050	0.0004	0.14
MU as %	1.30	6.6225	-	0.244	0.0174	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.28	mg/m³	14	% Result	N/A	% ELV
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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 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	0.003	2.0	0.50	1.0	N/A	-
as a %	0.20	0.64	0.49	1.0	N/A	0.42
compliant?	Yes	Yes	Yes	Yes	N/A	Yes

Run	Volume (STP) m ³	Mass Gained mg	O ₂ Correction -	Leak mg/m ³	Uncollected Mass mg	Combined uncertainty
Run 1	1.29	3300	1.0	5.51	58	-
MU as % v/v	0.00	0.01	-	0.00	0.005	0.01
MU as %	1.30	3.03	-	0.24	1.75	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.02	% v/v	7.5	%
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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VOLATILE ORGANIC COMPOUNDS RUN 1

Measured Concentration	3.2	mg/m ³
Limit	-	mg/m ³
Calibration Gas Concentration	129.12	mg/m ³
Range	160	mg/m ³

Performance characteristics	Value	Units	specification	MU Met?
Response time	10	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	0.70	% of value	<2 % range	Yes
Zero drift	0.07	% full scale	<5% range / 24hr	Yes
Span drift	-0.32	% full scale	<5% range / 24hr	Yes
volume or pressure flow dependence	0.02	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.80	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	0.01	% full scale/10K	<3% range / 10 K	Yes
dependence on voltage	0.10	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	0.12	% of value	< 2% of span gas value	Yes
Uncertainty of calibration gas	1.0	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	0.02
Standard deviation of repeatability at span level	urs	0.02
Lack of fit	ufit	0.65
Drift	u0dr	0.04
volume or pressure flow dependence	uspres	0.00
atmospheric pressure dependence	uapres	0.04
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	0.14
losses in the line (leak)	uleak	0.00
Uncertainty of calibration gas	ucalib	0.02
Uncertainty in factor	uf	0.00

Measurement uncertainty Measured Concentration	3.15	mg/m ³
Combined uncertainty	0.66	mg/m ³
Expanded uncertainty	1.30	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	-	% ELV
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Expanded uncertainty expressed with a level of confidence of 95%	1.3	mg/m ³
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Expanded uncertainty expressed with a level of confidence of 95%	41	% value
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Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXIDES OF NITROGEN

Limit value	-	mg/m ³
Concentration @ Ref conditions	0.3	mg/m ³
Cal gas conc	82	mg/m ³
Analyser Full Scale	205	mg/m ³

	Value	Units	specification	MU Met?
Response time	15	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	0.23	% full scale	<5% range / 24hr	Yes
Span drift	-0.17	% full scale	<5% range / 24hr	Yes
volume or pressure flow dependence	0.1	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.10	% 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	0.00	% 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)	0.00	% 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_{dz}	0.1299
short term span drift	U_{ds}	-0.1008
influence of Ambient Temp at Zero	U_{tz}	0.0000
influence of Ambient Temp at Span	U_{ts}	0.8100
influence of sample gas pressure	U_p	0.0000
influence of sample gas flow	U_{fit}	0.0693
influence of supply voltage	U_v	0.0001
Combined Interference	U_i	-0.0018
Uncertainty of Cal gas	U_{adj}	0.4010

Measurement uncertainty (Concentration Measured)	0.29	mg/m ³
Combined uncertainty	0.95	mg/m ³
Expanded at a 95% confidence interval	1.86	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	-	% ELV
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Expanded uncertainty expressed with a level of confidence of 95%	1.9	mg/m ³
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Expanded uncertainty expressed with a level of confidence of 95%	641	% value
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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - SULPHUR DIOXIDE

Limit value	-	mg/m ³
Concentration @ Ref conditions	1.5	mg/m ³
Cal gas conc	97.128	mg/m ³
Analyser Full Scale	572	mg/m ³

Performance characteristics	Value	Units	specification	MU Met?
Response time	15	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	0.70	% of value	<2 % range	Yes
Zero drift	0.53	% full scale	<5% range / 24hr	Yes
Span drift	-2.28	% full scale	<5% range / 24hr	Yes
volume or pressure flow dependence	0.6	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.00	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	0.0021	% full scale/10K	<3% range / 10 K	Yes
Cross-sensitivity	0.00	% range	<4% of Range	Yes
dependence on voltage	-0.05	% full scale/10V	< 0.1%vol /10 volt	Yes
Influence of vibration	N/A	% of upper limit of Cal range	<2%	-

Uncertainty of calibration gas	% of value	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.008
lack of fit	U_{lof}	0.404
short term zero drift	$U_{d,z}$	0.144
short term span drift	$U_{d,s}$	0.087
influence of Ambient Temp at Zero	$U_{t,z}$	-1.026
influence of Ambient Temp at Span	$U_{t,s}$	0.001
influence of sample gas pressure	U_p	0.000
influence of sample gas flow	U_{fit}	0.416
influence of supply voltage	U_v	-0.156
Combined Interference	U_i	0.000
Uncertainty of Cal gas	U_{adj}	0.008

Measurement uncertainty (Concentration Measured)	1.5	mg/m ³
Combined uncertainty	1.2	mg/m ³
Expanded uncertainty	2.4	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	-	% ELV
Expanded uncertainty expressed with a level of confidence of 95%	2.4	mg/m ³
Expanded uncertainty expressed with a level of confidence of 95%	152	% value

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - CARBON MONOXIDE

Limit value	-	mg/m ³
Concentration @ Ref conditions	0.3	mg/m ³
Cal gas conc	100.4	mg/m ³
Analyser Full Scale	250	mg/m ³

Performance characteristics	Value	Units	specification	MU Met?
Response time	15	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	60	minutes	-	-
Number of readings in measurement	60	-	-	-
Repeatability at zero	0.1	% full scale	<1 % range	Yes
Repeatability at span level	0.2	% full scale	<2 % range	Yes
Deviation from linearity	0.61	% of value	<2 % range	Yes
Zero drift	0.10	% full scale	<5% range / 24hr	Yes
Span drift	-0.72	% full scale	<5% range / 24hr	Yes
volume or pressure flow dependence	0.2	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.44	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	-0.8	% full scale/10K	<3% range / 10 K	Yes
Combined interference	-0.01	% of 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%	N/A
losses in the line (leak)	0.00	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1.00	% of value	< 2% of value	Yes

N/A - Horiba's are not effected by Vibration

Performance characteristic	Uncertainty	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.003
lack of fit	U_{lof}	0.12
short term zero drift	U_{dz}	0.35
short term span drift	U_{ds}	0.06
influence of Ambient Temp zero	U_{tz}	-0.05
influence of Ambient Temp span	U_{ts}	0.16
influence of sample gas pressure	U_p	0.00
influence of sample gas flow	U_{fit}	0.14
influence of supply voltage	U_v	-0.09
Combined Interference	U_i	-0.15
Uncertainty of Cal gas	U_{adj}	0.40

Measurement uncertainty (Concentration Measured)	0.3	mg/m ³
Combined uncertainty	0.6	mg/m ³
Expanded uncertainty	1.2	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	-	% ELV
Expanded uncertainty expressed with a level of confidence of 95%	1.2	mg/m ³
Expanded uncertainty expressed with a level of confidence of 95%	369	% value

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - CARBON DIOXIDE

Limit value	-
Measured concentration	0.10
Calibration gas	8.01
Analyser Full Scale	10

Performance characteristics	Value	Units	specification	MU Met?
Response time	15	seconds	< 200 s	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	60	minutes	-	-
Number of readings in measurement	60	-	-	-
Repeatability at zero	0.015	% by volume	<0.2 % range	Yes
Repeatability at span level	0.014	% by volume	<0.4 % range	Yes
Deviation from linearity	0.13	% vol	<0.3 % volume	Yes
Zero drift (during measurement period)	0.12	% vol at zero level	<5% range / 24hr	Yes
Span drift (during measurement period)	-0.13	% vol at span level	<5% range / 24hr	Yes
volume or pressure flow dependence	0.02	% of fs / 10l/h	<1% range	Yes
atmospheric pressure dependence	0.8	% of fs/kPa	< 1.5 % range	Yes
ambient temperature dependence	0.01	% by volume /10K	<0.3% volume 10 K	Yes
Combined interference	0.56	% range	<2% range	Yes
Dependence on voltage	0.1	% by volume /10V	< 0.1%vol /10 volt	Yes
Losses in the line (leak)	0.124843945	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	-
Standard deviation of repeatability at span level	urs	0.002
Lack of fit	ufit	0.0751
Drift	u0dr	0.07
volume or pressure flow dependence	uspres	0.00001
atmospheric pressure dependence	uapres	0.005
ambient temperature dependence	utemp	0.0005
Combined interference (from mcerts)	-	0.03
dependence on voltage	uvolt	0.086
losses in the line (leak)	uleak	7E-05
Uncertainty of calibration gas	ucalib	0.0006

Measurement uncertainty	0.10	%vol
Combined uncertainty	0.14	%vol
Expanded uncertainty	0.27	%

Expanded uncertainty expressed with a level of confidence of 95%	0.54	% of value
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Expanded uncertainty expressed with a level of confidence of 95%	537.64	% vol
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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	N/A	%vol
Reported Concentration	20.95	%vol
Calibration gas	9.88	%vol
Analyser Full Scale	25	%vol

	Value	Units	specification	MU Met?
Response time	15	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	0.72	% full scale	<5% range / 24hr	Yes
Span drift	-0.81	% 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_{dz}	0.4133
short term span drift	U_{ds}	-0.4675
influence of Ambient Temp at Zero	U_{tz}	0.0014
influence of Ambient Temp at Span	U_{ts}	0.0000
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}	0.0494

Measurement uncertainty (Concentration Measured)	20.95	%
Combined uncertainty	0.63	%
Expanded uncertainty	1.24	%

Expanded uncertainty expressed with a level of confidence of 95%	1.2	%
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Expanded uncertainty expressed with a level of confidence of 95%	5.9	% vol
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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	11.5	m/s
Measured Volumetric Flow rate at Actual Conditions	20753	m ³ /hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination	-	0.010		
Uncertainty of pitot tube coefficient	-	0.93		
Uncertainty of mean local dynamic pressures	-	0.591	minimum 3	Yes
Factor loading, function of the number of measurements.	3 readings	1000		
Range of measurement device	pa	1.00		
Resolution	pa	17.10		
Calibration uncertainty	pa	0.10	<1% of Value or 20 Pa whichever is greater	Yes
Drift	% range	0.06		
Linearity	% range	0.06	<2% of value	Yes
Uncertainty of gas density determination	kg/mol	0.00003		
Uncertainty of molar mass determination	K	1.60	<1% of value	Yes
Uncertainty of temperature measurement	pa	522		
Uncertainty of absolute pressure in the duct	kg/m3	0.007		
Uncertainty associated with the calculation of density	-	0.0001		
Uncertainty associated with the measurement of local velocity	-	0.0002		
Uncertainty associated with the measurement of mean velocity	-			

Measurement Uncertainty - Velocity	m/s
Combined uncertainty	0.14
Expanded uncertainty at a 95% Confidence Interval	0.28

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 ³ /hr
Combined uncertainty	544
Expanded uncertainty at a 95% Confidence Interval	1067

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