

STACK EMISSIONS MONITORING REPORT



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Operator & Address:

Finning (UK) Limited
Virtus LON14
DC6
Prologis Park
West Drayton
UB7 9FN
-
-

Permit Reference:

EPR Permit: Commissioning

Release Point:

Set 2-5 (ref 5% O2)

Sampling Date(s):

23rd January 2025

SOCOTEC Job Number:	LSE3467
Report Date:	17th February 2025
Version:	1
Report By:	Nik Agopian
MCERTS Number:	MM 08 902
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Paul Jones
MCERTS Number:	MM 02 044
Business Title:	MCERTS Level 2 - Business Manager
Technical Endorsements:	1, 2, 3 & 4
Signature:	



1015



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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Finning (UK) Limited operates a generator process at LON14 West Drayton which is subject to EPR Permit Commissioning, under the Environmental Permitting Regulations 2016.

SOCOTEC UK LTD were commissioned by Finning (UK) Limited to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under trial 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, Commissioning.

Plant

Set 2-5 (ref 5% O₂)

Operator

Finning (UK) Limited
Virtus LON14
DC6
Prologis Park
West Drayton
UB7 9FN
-

EPR Permit: Commissioning

Stack Emissions Monitoring Test House

SOCOTEC UK LTD - Romford Laboratory
Unit 20
The Falcon Business Centre
Romford
RM3 8UR
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 UK LTD.

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	Units	Result	Calculated Uncertainty +/-	Emission Limit Value (ELV)	Accreditation
Total Particulate Matter	mg/m ³	32.1	2.4	-	MCERTS
Particulate Emission Rate	g/hr	226.1	17.2	-	
PM ₁₀	mg/m ³	1.85	0.83	-	MCERTS
PM ₁₀ Emission Rate	g/hr	11.5	5.2	-	
PM _{2.5}	mg/m ³	1.55	0.59	-	MCERTS
PM _{2.5} Emission Rate	g/hr	9.68	3.69	-	
Total Volatile Organic Compounds	mg/m ³	0.61	1.31	-	MCERTS
Total Volatile Organic Compounds Emission Rate	g/hr	4.4	9.4	-	
Oxides of Nitrogen (as NO ₂)	mg/m ³	14.3	4.6	-	MCERTS
Oxides of Nitrogen (as NO ₂) Emission Rate	g/hr	102.8	32.8	-	
Carbon Monoxide	mg/m ³	230.0	9.8	-	MCERTS
Carbon Monoxide Emission Rate	g/hr	1655	71	-	
Carbon Dioxide	% v/v	7.82	0.27	-	MCERTS
Oxygen	% v/v	10.64	0.29	-	MCERTS
Moisture	%	12.46	0.47	-	MCERTS
Stack Gas Temperature	°C	336	-	-	MCERTS
Stack Gas Velocity	m/s	27.0	0.7	-	
Gas Volumetric Flow Rate (Actual)	m ³ /hr	28454	1463	-	
Gas Volumetric Flow Rate (STP, Wet)	m ³ /hr	12659	651	-	
Gas Volumetric Flow Rate (STP, Dry)	m ³ /hr	11082	570	-	
Gas Volumetric Flow Rate at Reference Conditions	m ³ /hr	7175	369	-	

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 5% Oxygen.

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	Sampling Date(s)	Sampling Times	Sampling Duration
Total Particulate Matter Run 1	23 January 2025	11:18 - 12:20	64 minutes
PM ₁₀ Run 1	23 January 2025	12:40 - 13:40	60 minutes
PM _{2.5} Run 1	23 January 2025	12:40 - 13:40	60 minutes
Total Volatile Organic Compounds Run 1	23 January 2025	12:33 - 13:33	60 minutes
Combustion Gases	23 January 2025	12:33 - 13:33	60 minutes
Preliminary Stack Traverse	23 January 2025	11:11	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Generator
Continuous or batch	Continuous when in operation
Product Details	Power
Part of batch to be monitored (if applicable)	n/a
Normal load, throughput or continuous rating	3000kVa (100 load)
Fuel used during monitoring	Diesel
Abatement	SCR
Plume Appearance	Not visible from monitoring location

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	1.06 mg/m ³	7.6%	N/A - No ELV
PM ₁₀	SRM - BS EN 23210	AE 136	1015	MCERTS	0.42 mg/m ³	45.2%	N/A - No ELV
PM _{2.5}	SRM - BS EN 23210	AE 136	1015	MCERTS	0.29 mg/m ³	38.1%	N/A - No ELV
Total Volatile Organic Compounds	SRM - BS EN 12619:2013	AE 102	1015	MCERTS	0.53 mg/m ³	215.4%	N/A - No ELV
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	MCERTS	0.79 mg/m ³	31.9%	N/A - No ELV
Carbon Monoxide	SRM - BS EN 15058:2017	AE 102	1015	MCERTS	2.12 mg/m ³	4.3%	N/A - No ELV
Carbon Dioxide	SRM - CEN/TS 17405	AE 102	1015	MCERTS	0.15 %	3.5%	N/A - No ELV
Oxygen	SRM - BS EN 14789:2017	AE 102	1015	MCERTS	0.01%	2.7%	N/A - No ELV
Moisture	BS EN 14790	AE 105	1015	MCERTS	0.01%	3.8%	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
PM ₁₀	Gravimetric	AE 106	1015	MCERTS	SOCOTEC - (Cirencester)	N/A	8 Weeks
PM _{2.5}	Gravimetric	AE 106	1015	MCERTS	SOCOTEC - (Cirencester)	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 (Romford)	SOCOTEC (Romford)	5 years
Oxides of Nitrogen	Chemiluminescence	AE 102	1015	MCERTS	SOCOTEC (Romford)	SOCOTEC (Romford)	5 years
Carbon Monoxide	Non Dispersive Infra Red	AE 102	1015	MCERTS	SOCOTEC (Romford)	SOCOTEC (Romford)	5 years
Carbon Dioxide	Non Dispersive Infra Red	AE 102	1015	MCERTS	SOCOTEC (Romford)	SOCOTEC (Romford)	5 years
Oxygen	Paramagnetism	AE 102	1015	MCERTS	SOCOTEC (Romford)	SOCOTEC (Romford)	5 years
Moisture	Gravimetric	AE 105	1015	MCERTS	SOCOTEC (Romford)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	Value	Units	Requirement	Compliant	Method
Lowest Differential Pressure	265	Pa	≥ 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	26.1	m/s	-	-	-
Highest Gas Velocity	28.2	m/s	-	-	-
Ratio of Gas Velocities	1.1	: 1	$< 3 : 1$	Yes	BS EN 15259
Mean Velocity	27.0	m/s	-	-	-
Maximum angle of flow with regard to duct axis	< 15	$^{\circ}$	$< 15^{\circ}$	Yes	BS EN 15259
No local negative flow	No	-	-	No	BS EN 15259

DUCT CHARACTERISTICS		
	Value	Units
Shape	Circular	-
Depth	0.61	m
Width	-	m
Area	0.29	m ²
Port Depth	250	mm

SAMPLING LINES & POINTS		
	Isokinetic	Non-Iso & Gases
Sample port size	5 inch Flange	5 inch Flange
Number of lines used	2	1
Number of points / line	2	1
Duct orientation	Vertical	Vertical
Filtration	Out Stack	Out Stack
Filtration for TPM	Out Stack	-

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

EA Guidance, Monitoring stack emissions: measurement locations.	
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 specified in EA Guidance, Monitoring stack emissions: measurement locations.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Particulate nozzle size

Due to the high flow and particulate loading a nozzle less than 6mm was used in order to achieve isokinetics throughout the sample run.

pm10/2.5 sample run time

The pm10/2.5 sample runtime was shortened from 3hrs to 1hr based on higher than expected particulate loading experienced during the prior total particulate run.

APPENDICES

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APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

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
PM10	SRM - BS EN 23210	AE 136	1015	MCERTS	1
PM2.5	SRM - BS EN 23210	AE 136	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
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	P3431	Horiba PG - 350E Analyser	P2939	Laboratory Balance	-
Box Thermocouples	P3431	FT-IR	-	Tape Measure	P2255
Meter In Thermocouple	P3431	FT-IR Oven Box	-	Stopwatch	P2731
Meter Out Thermocouple	P3431	Bernath 3006 FID	P1999	Protractor	-
Control Box Timer	P3431	Signal 3030 FID	-	Barometer	P2746
Oven Box	P2383	Servomex	-	Digital Micromanometer	-
Probe	-	JCT Heated Head Filter	-	Digital Temperature Meter	-
Probe Thermocouple	P2717	Thermo FID	-	Stack Thermocouple	P3184
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	P2152	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P2237	Chiller (JCT/MAK 10)	P2902	1m Heated Line (3)	-
Last Impinger Arm	P2964	Heated Line Controller (1)	P3403	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	-	10m Heated Line (1)	P2789
Callipers	-	Site temperature Logger	-	10m Heated Line (2)	-
Small DGM	-			15m Heated Line (1)	-
Heater Controller	-			20m Heated Line (1)	-
Inclinometer (Swirl Device)	P3039			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	CJ43	BOC	-	10.06	2.0
Propane	CG67	BOC	8.3	-	2.0
Nitric Oxide	TE1	BOC	200.8	-	2.0
Carbon Monoxide	CJ43	BOC	812	-	2.0
Carbon Dioxide	CJ43	BOC	-	12.51	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
Paul Jones	MM 02 044	MCERTS Level 2	Jun-25	Mar-28	Dec-29	Mar-29	Sep-29	Jun-25
Nik Agopian	MM 08 902	MCERTS Level 2	Mar-26	Mar-29	Sep-27	Mar-26	May-29	Jan-28

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	11:18 - 12:20 23 January 2025	32.1	2.43	-	226.1
Blank	-	0.68	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas 5% 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	Filter End Weight	Mass Gained on Filter	Probe Rinse Start Weight	Probe Rinse End Weight	Mass Gained on Probe	Combined Total Mass Gained
		g	g	g	g	g	g	g
Run 1	321370	0.14926	0.15455	0.00529	104.61890	104.62880	0.00990	0.01519

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

BLANKS								
Test	Filter & Probe Number	Filter Start Weight	Filter End Weight	Mass Gained Filter	Probe Start Weight	Probe End Weight	Mass Gained Probe	Combined Total Mass Gained
		g	g	g	g	g	g	g
Run 1	321369	0.15180	0.15186	0.00006	82.21690	81.29620	-0.92070	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	100.3		
Stack static pressure, P _{static}	pa	280.0		
P _s = P _b + P _{static}	Kpa	100.6		
Vol. of water vapour collected, V_{wstd}				
Moisture trap weight increase, V _{lc}	g	84.1		
V _{wstd} = (0.001246)(V _{lc})	m ³	0.1047886		
Volume of gas metered dry, V_{mstd}				
Volume of gas sample through gas meter, V _m		0.755		
Gas meter correction factor, Y _d		1.017		
Mean dry gas meter temperature, T _m		282		
Mean pressure drop across orifice, DH	mmH ₂ O	16.742		
V _{mstd} = $\frac{(0.3592)(V_m)(P_b + (DH/13.6))(Y_d)}{T_m}$	m ³	0.736		
Volume of gas metered wet, V_{mstw}				
V _{mstw} = V _{mstd} + V _{wstd}	m ³	0.8408		
Vol. of gas metered at O₂ 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		10.7		
% oxygen reference condition		5		
O ₂ Reference	O ₂ Ref = 21.0 - act%O ₂	0.64		
Factor	$\frac{21.0 - \text{ref}\%O_2}{21.0 - \text{ref}\%O_2}$			
V _{mstd@X%oxygen} = (V _{mstd}) (O ₂ Ref)	m ³	0.4738		
Moisture content, B_{wo}				
B _{wo} = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	12.46		
Moisture by FTIR				
	%	-		
Velocity of stack gas, V_s				
Velocity pressure coefficient, C _p		0.84		
Mean of velocity heads, DP _{avg}	Pa	313.60		
Mean stack gas temperature, T _s	K	672		
Gas density (wet, ambient), P				
p = (M _s *P _s)/(8.314*T _s)	kg/m ³	0.508		
Stack Velocity, V _s	$V_s = \frac{\sum_{i=1}^n V_i}{n}$	m/s	29.51	
Molecular weight of dry gas, M_d				
CO ₂	%	7.82		
O ₂	%	10.70		
Total	%	18.52		
N ₂ (100 - Total)	%	81.48		
M _d = 0.44(%CO ₂) + 0.32(%O ₂) + 0.28(%N ₂)		29.68		
Molecular weight of wet gas, M_s				
M _s = M _d (1 - B _{wo}) + 18(B _{wo})	g/gmol	28.22		
Actual flow of stack gas, Q_a				
Area of stack, A _s	m ²	0.29		
Q _a = (60)(A _s)(V _s)	m ³ /min	517.5		
Total flow of stack gas, Q				
Conversion factor (K/mm.Hg)		0.3592		
Q _{std} = (Q _a)P _s (0.3592)(1-B _{wo})	Dry	182.6		
(T _s)				
Q _{stdO2} = (Q _a)P _s (0.3592)(1-B _{wo})(O ₂ REF)	@O ₂ ref	117.54		
(T _s)				
Q _{stw} = $\frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet	208.57		
Percent isokinetic, %I				
Nozzle diameter, D _n	mm	4.89		
Nozzle area, A _n	mm ²	18.78		
Total sampling time, q	min	64		
%I = $\frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	98.0		
Acceptable isokinetic range 95% to 115%		Yes		
Particulate Concentration, C				
Mass collected on filter, M _f	g	0.00529		
Mass collected in probe, M _p	g	0.00990		
Total mass collected, M _n	g	0.01519		
C _{wet} = $\frac{M_n}{V_{mstw}}$	mg/m ³	18.065		
C _{dry} = $\frac{M_n}{V_{mstd}}$	mg/m ³	20.637		
C _{dry@X%O2} = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³	32.058		
Particulate Emission Rates, E				
E = [(C _{wet})(Q _{stw})(60)] / 1000		226.08		

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	12.00	0.21	-	-304.8	0.24	Yes

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

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	98.02	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	1.06	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 Limit Value mg/m ³	Acceptable Blank Value mg/m ³	Overall Blank Acceptable mg/m ³
Blank 1	0.68	-	-	-

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	160	180	160

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PM ₁₀ SUMMARY					
Test	Sampling Times	Concentration mg/m ³	LOD mg/m ³	ELV mg/m ³	Emission Rate g/hr
Run 1	12:40 - 13:40 23 January 2025	1.85	0.42	-	11.52
Blank 1	-	0.589	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas 5% Oxygen.

PM _{2.5} SUMMARY					
Test	Sampling Times	Concentration mg/m ³	LOD mg/m ³	ELV mg/m ³	Emission Rate g/hr
Run 1	12:40 - 13:40 23 January 2025	1.55	0.29	-	9.68
Blank 1	-	0.295	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas 5% Oxygen.

FILTER INFORMATION

Sample Run	PM ₁₀ SAMPLES WEIGHTS				PM _{2.5} SAMPLES WEIGHTS			
	PM ₁₀ Filter Number	Filter Start Weight g	Filter End Weight g	PM ₁₀ Mass Gained on Filter g	PM _{2.5} Filter Number	Filter Start Weight g	Filter End Weight g	PM _{2.5} Mass Gained on Filter g
Run 1	424	14.33	14.33	0.00015	423.00	32.08	32.08	0.00158
Blank 1	422	15.2462	15.24621	0.00001	421	32.41285	32.41289	0.00004

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS RUN 1			PM ₁₀ & PM _{2.5}	
Absolute pressure of stack gas, P_s			Molecular weight of dry gas, M_d	
Barometric pressure, P _b	kPa	100.3	CO ₂	7.82
Stack static pressure, P _{static}	Pa	300.0	O ₂	10.61
P _s = P _b + (P _{static})	kPa	100.6	Total	18.43
Vol. of water vapour collected, V_{wstd}			N ₂ (100 -Total)	81.57
Moisture trap weight increase, V _{lc}	g	-	M _d = 0.44(%CO ₂)+0.32(%O ₂)+0.28(%N ₂)	29.68
V _{wstd} = (0.001246)(V _{lc})	m ³	-	Molecular weight of wet gas, M_s	
Volume of gas metered dry, V_{mstd}			M _s = M _d (1 - B _{wo}) + 18(B _{wo})	28.22
Volume of gas sample through gas meter, V _m	m ³	1.62	Actual flow of stack gas, Q_a	
Gas meter correction factor, Y _d		1.02	Area of stack, A _s	m ² 0.29
Mean dry gas meter temperature, T _m		285.00	Q _a = (60)(A _s)(V _s)	m ³ /min 474.2
Mean pressure drop across orifice, DH	mmH ₂ O	70.00	Q _{stw} = $\frac{(Q_s)P_s(0.3592)}{(T_s) + 273}$	Wet 182.91
V _{mstd} = $\frac{(0.3592)(V_m)(P_b + (DH/13.6))(Y_d)}{T_m + 273}$	m ³	1.568	Percent isokinetic, %I	
Volume of gas metered wet, V_{mstw}			Required Flow Rate @ DGM	l/min 30.10
V _{mstw} = V _{mstd} + V _{wstd}	m ³	1.791	Actual Flow Rate @ DGM	l/min 30.7
Vol. of gas metered at O₂ Ref. Cond., V_{mstd@X%O2}			Isokinetic Rate	101.91
Is the process burning hazardous waste? (If yes, no favourable oxygen correction)	No		Acceptable 90% - 130%	Yes
% oxygen measured in gas stream, act%O ₂	10.61		Particulate Concentration, C_{PM10}	
% oxygen reference condition	5		Mass of particulate collected on PM ₁₀ filter, M _f	0.0003
O ₂ Reference O ₂ Ref = 21.0 - act%O ₂	0.65		Mass of particulate collected on PM _{2.5} filter, M _f	0.00158
Factor $\frac{21.0 - \text{ref}\%O_2}{21.0 - \text{act}\%O_2}$			C _{wet} = $\frac{M_n}{V_{mstw}}$	mg/m ³ 1.05
V _{mstd@X%oxygen} = (V _{mstd}) (O ₂ Ref)	m ³	1.018	C _{dry} = $\frac{M_n}{V_{mstd}}$	mg/m ³ 1.20
Moisture content, B_{wo}			C _{dry@X%O2} = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³ 1.85
B _{wo} = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.1246	Particulate Emission Rates, E	
	%	12.46	E = [(C _{wet})(Q _{stw})(60)] / 1000	11.52
Moisture by FTIR			Particulate Concentration, C_{PM2.5}	
Velocity of stack gas, V_s			Mass of particulate collected on filter, M _f	0.00158
Velocity pressure coefficient, C _p		0.84	C _{wet} = $\frac{M_n}{V_{mstw}}$	mg/m ³ 0.8822
Mean of velocity heads, DP _{avg}	Pa	290.73	C _{dry} = $\frac{M_n}{V_{mstd}}$	mg/m ³ 1.0078
Mean stack gas temperature, T _s	K	703	C _{dry@X%O2} = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³ 1.5520
Gas density (wet, ambient), ρ	kg/m ³	0.486	Emission Rate, E	
p = (M _s *P _s)/(8.314*T _s)			E = [(C _{wet})(Q _{stw})(60)] / 1000	9.68
Stack Velocity, V _s	m/s	27.04		
*Velocity taken from preliminary survey				

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PM₁₀ & PM_{2.5} 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	30.68	0.05	0.05	355.6	0.61	Yes

FLOW CRITERIA					
Run	Isokinetic Variation %	Acceptable Isokineticity (90% - 130%)	Nominal Flow Rate l/min	Maximum Flow Variation %	Acceptable Deviation from the Nominal Flow Rate (+/-5%)
Run 1	101.91	Yes	30.1	11.37	No

Acceptable Isokinetic rate 90 -130%

FILTERS					
Run	Filter Material	Filter Size mm	Max Filtration Temperature °C	Pre-conditioning Filter Temperature °C	Post conditioning Filtration Temperature °C
Run 1	Quartz Fibre	50	433	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	12:33 - 13:33 23 January 2025	0.61	0.30	-	4.37

Reference conditions are 273K, 101.3kPa, dry gas 5% Oxygen.

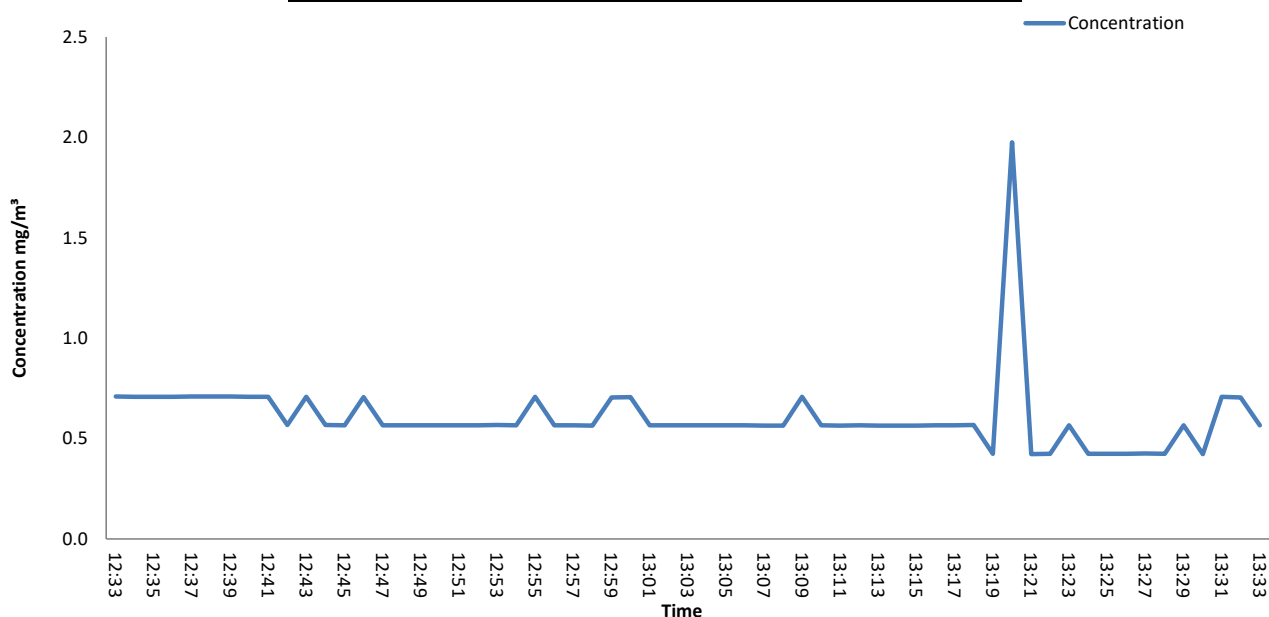
INSTRUMENTAL SPAN & ZERO CHECKS

PRE-SAMPLING CALIBRATION CHECKS								
Date	23 January 2025							
Start Time	10:00							
End Time	10:29							
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	8.3	10	0.00	8.3	0.00	0.00	8.2	1.20

Zero and Span gas contained 10.32% Oxygen

POST-SAMPLING CALIBRATION CHECKS								
Date	23 January 2025							
Start Time	13:36							
End Time	03:50							
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	0.22	0.10	8.2	1.20	-1.20	x	x	N/A - not corrected

TOTAL VOLATILE ORGANIC COMPOUNDS EMISSIONS CHART



Reference conditions are 273K, 101.3kPa, dry gas 5% Oxygen.

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	12:33 - 13:33 23 January 2025	14.28	0.79	-	102.8
Carbon Monoxide	12:33 - 13:33 23 January 2025	230.0	2.12	-	1655

Test	Sampling Time and Date	Concentration %	LOD %
Carbon Dioxide	12:33 - 13:33 23 January 2025	7.82	0.150
Oxygen	12:33 - 13:33 23 January 2025	10.61	0.01

Reference conditions are 273K, 101.3kPa, dry gas 5% Oxygen.

PRE-SAMPLING CALIBRATION DATA

Date	23 January 2025
Start Time	10:00
End Time	10:29

Chiller Temperature (°C)	2.4
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	200.8	0.10	0.10	200.2	20	0.30
Carbon Monoxide	1000	0.00	812.0	0.00	0.00	798.0	24	1.72
Carbon Dioxide	15	0.00	12.51	0.02	0.03	12.54	22	-0.24
Oxygen	15	0.00	10.06	0.01	0.10	10.13	21	-0.70

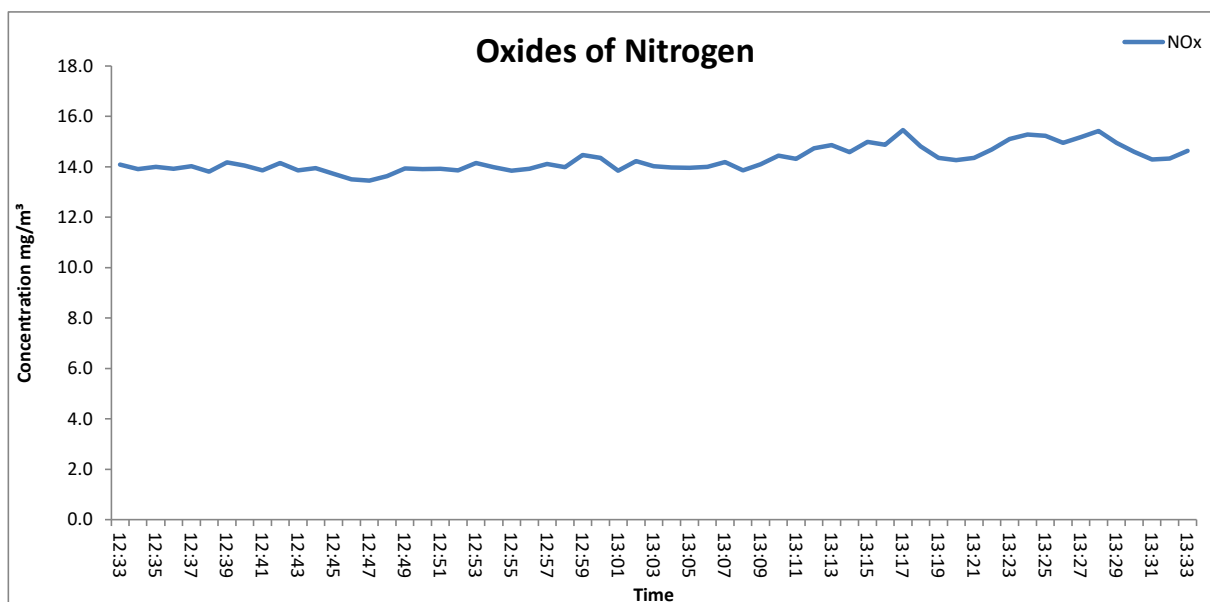
POST-SAMPLING CALIBRATION DATA

Date	23 January 2025
Start Time	13:36
End Time	13:50

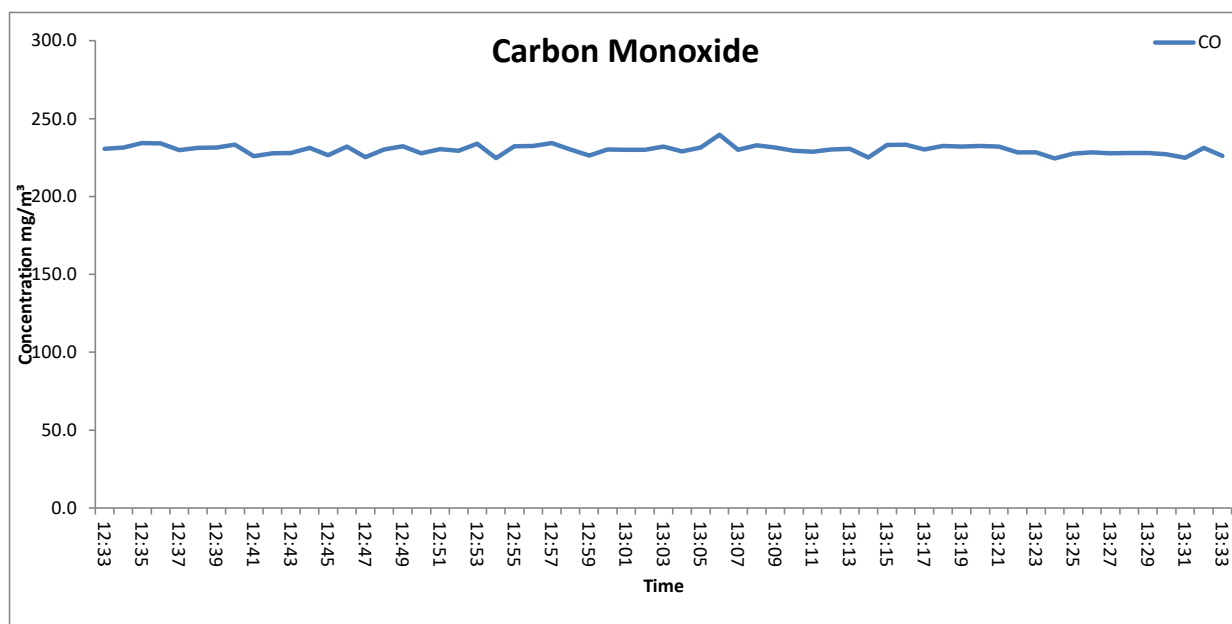
Chiller Temperature (°C)	2.4
Requirement	< 4°C
Compliant	Yes

Gas	Zero Check at Analyser	Span Check at Analyser	Zero Drift (% of Span Gas)	Span Drift (% of Span Gas)	Corrected for Zero Drift	Corrected for Span Drift	Corrected Values ppm / %
Nitric Oxide	0.00	200.3	-0.05	-0.20	x	x	N/A - not corrected
Carbon Monoxide	1.00	799.0	0.13	-1.72	x	x	N/A - not corrected
Carbon Dioxide	0.05	12.60	0.24	0.48	x	x	N/A - not corrected
Oxygen	0.13	10.12	1.20	-0.60	x	x	N/A - not corrected

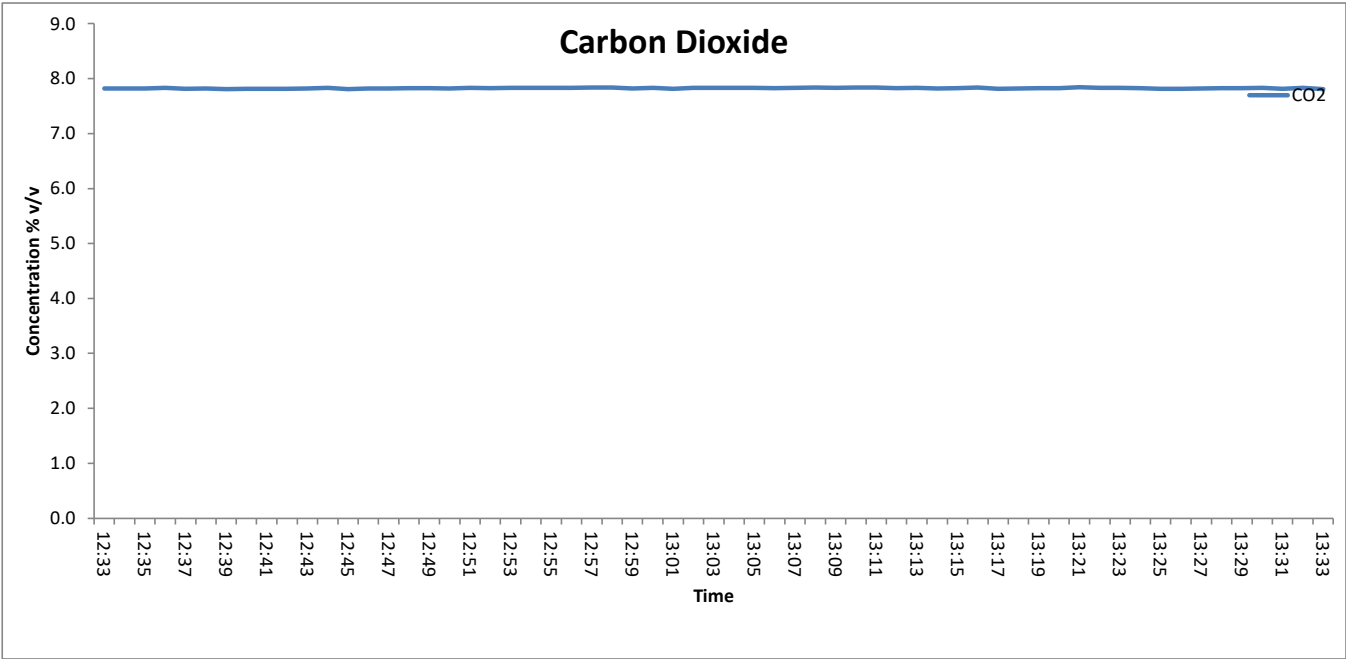
APPENDIX 2 - Summaries, Calculations, Raw Data and Charts
OXIDES OF NITROGEN (as NO₂) EMISSIONS CHART



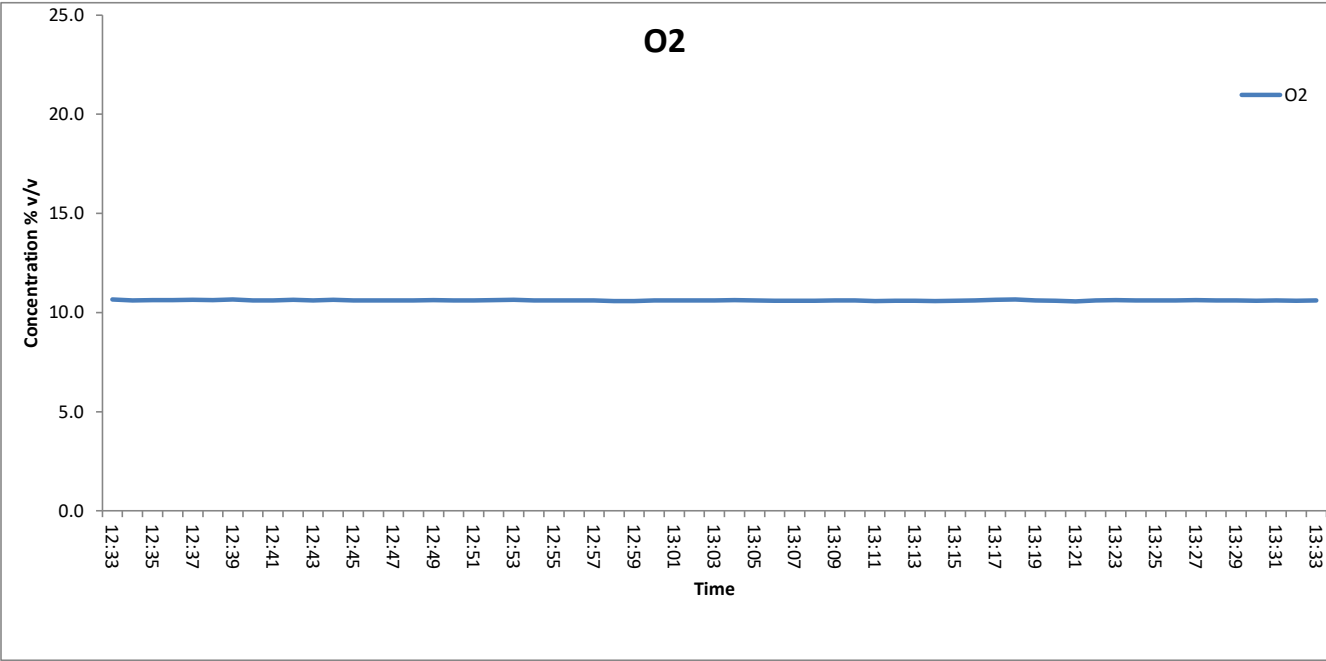
CARBON MONOXIDE EMISSIONS CHART



CARBON DIOXIDE 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	11:18 - 12:20 23 January 2025	3.2655	3.3496	0.0841	12.5	0.01	3.8

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	64	841	12.0	0.21	-	0.24	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.61	m
Stack Width, W	-	m
Stack Area, A	0.29	m ²
Average stack gas temperature	336	°C
Stack static pressure	0.28	kPa
Barometric Pressure	100.3	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	7.824796	0.078248	0.153605	6.849641	0.068496	0.134462
O ₂	32	1.427679	10.641240	0.106412	0.151923	9.315089	0.093151	0.132990
N ₂	28	1.249219	81.533964	0.815340	1.018538	71.372897	0.713729	0.891604
H ₂ O	18	0.803070	-	-	-	12.462373	0.124624	0.100082

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

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.3241	kg/m ³
Wet Density (STP), P_{STW}	1.2591	kg/m ³
Dry Density (Actual), P_{Actual}	0.5891	kg/m ³
Average Wet Density (Actual), $P_{ActualW}$	0.560	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	23 January 2025
Time of Survey	11:11
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	0.09	271.1	27.7	335	26.1	7.6	-	<15
2	0.52	271.1	27.7	335	26.1	7.6	-	<15
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	271.1	27.7	335	26.1	7.6	-	-

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 °
1	0.09	303.8	31.0	337	27.7	8.1	-	<15
2	0.52	316.9	32.3	338	28.2	8.3	-	<15
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	310.3	31.7	338	28.0	8.2	-	-

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	114	112	1.8	Pass	116	115	0.9	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 15 seconds. 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	280	277	3.0	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	271	Pa	≥ 5 Pa	Yes
Lowest Gas Velocity	26.1	m/s	-	-
Highest Gas Velocity	28.2	m/s	-	-
Ratio of Gas Velocities	1.1	-	$< 3 : 1$	Yes
Maximum angle of flow with regard to duct axis	< 15	$^{\circ}$	$< 15^{\circ}$	Yes
No local negative flow	No	-	-	No

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, $V = K_{pt} \times (1-e) \times \sqrt{2 \times DP_{pt} / \rho_{ActualW}}$		
Where: K_{pt} = Pitot tube calibration coefficient $(1-e)$ = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, V_a	27.0	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	336	0	$^{\circ}\text{C}$
Total Pressure	100.58	101.3	kPa
Oxygen	10.6	5	%
Moisture	12.46	0.00	%
Pitot tube calibration coefficient, K_{pt}	0.84		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (V_a)	27.04	m/s
Stack Area (A)	0.29	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	28453.86	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	12659.32	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	11081.67	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	7174.52	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

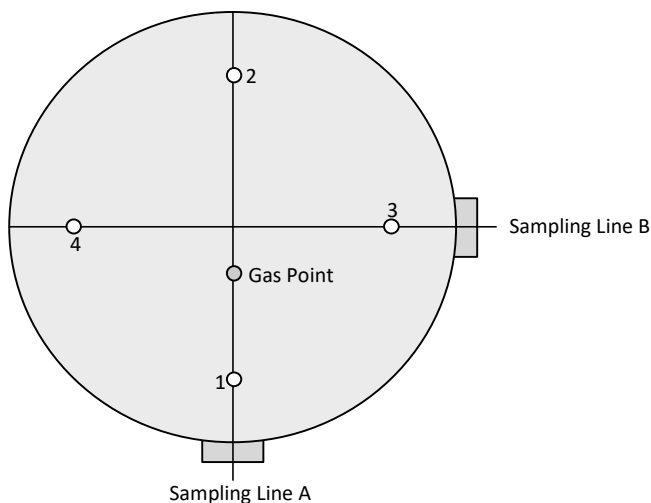
O_{2a} = Oxygen, Actual Conditions, % Vol

O_{2s} = Oxygen, Reference Conditions, % Vol

STACK DIAGRAM

	Value	Units
Stack Depth	0.61	m
Stack Width	-	m
Area	0.29	m ²

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	10	0.06	m



- Isokinetic sampling point
- Isokinetic sampling points not used
- Non Isokinetic/Gases sampling point

[illegible]

SAMPLING LOCATION



- 5" flange fittings behind panels

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	0.001	2.0	0.50	1.0	0.1	0.5000	-	-
as a %	0.20	0.30	0.50	1.0	0.93	N/A	1.75	N/A
compliant?	Yes	Yes	Yes	Yes	Yes	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	0.30	15.1900	1.6	0.3240	0.0003	-
MU as mg/m ³	0.40	1.0552	0.31	0.3240	0.0006	1.22
MU as %	1.26	3.2916	-	1.011	0.0019	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	2.43	mg/m³	7.59	% 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 - PM 10

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 %
MU required	≤ 2%	≤ 2%	≤ 1%	≤ 1%	≤ 10%	≤ 5% of ELV	≤ 2%
Run 1	0.002	2.0	0.50	1.0	0.1	0.42	-
as a %	0.20	0.3	0.50	1.0	0.94	N/A	0.16
compliant?	Yes	Yes	Yes	Yes	Yes	N/A	Yes

Run	Volume (STP) m ³	Mass of particulate mg	O2 Correction -	Leak mg/m ³	Combined uncertainty
Run 1	4.72	0.9823	1.20	1.000	-
MU as mg/m ³	0.02	0.4167	0.02	0.002	98.24
MU as %	1.26	98.2278	0.96	0.094	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.84	mg/m³	45.25	% 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 - PM 2.5

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 %
MU required	≤ 2%	≤ 2%	≤ 1%	≤ 1%	≤ 10%	≤ 5% of ELV	≤ 2%
Run 1	0.002	2.0	0.50	1.0	0.1	0.30	-
as a %	0.20	0.3	0.50	1.0	0.94	-	0.16
compliant?	Yes	Yes	Yes	Yes	Yes	N/A	Yes

Run	Volume (STP) m ³	Mass of particulate mg	O2 Correction -	Leak mg/m ³	Combined uncertainty
Run 1	3.96	0.9823	1.01	1.000	-
MU as mg/m ³	0.02	0.2947	0.00	0.001	98.24
MU as %	1.26	98.2278	-	0.094	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.59	mg/m³	38.06	% 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	0.001472103	2.0	0.50	1.0	0.1	-
as a %	0.20	0.30	0.50	1.0	0.93	1.75
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	0.30	84100	1.6	1154.79	58	-
MU as % v/v	0.18	0.02	0.14	0.15	0.010	0.27
MU as %	1.26	0.12	0.97	1.01	0.07	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.54	% v/v	3.78	%
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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VOLATILE ORGANIC COMPOUNDS RUN 1

Measured Concentration	0.6	mg/m ³
Limit	-	mg/m ³
Calibration Gas Concentration	13.28	mg/m ³
Range	16	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	1.20	% full scale	<5% range / 24hr	No
Span drift	-1.20	% 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)	1.20	% 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	0.06
Drift	u0dr	0.66
volume or pressure flow dependence	uspres	0.00
atmospheric pressure dependence	uapres	0.00
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	0.01
losses in the line (leak)	uleak	0.00
Uncertainty of calibration gas	ucalib	0.00
Uncertainty in factor	uf	0.01

Measurement uncertainty Measured Concentration	0.61	mg/m ³
Combined uncertainty	0.67	mg/m ³
Expanded uncertainty	1.31	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	-	% ELV
Expanded uncertainty expressed with a level of confidence of 95%	1.31	mg/m ³
Expanded uncertainty expressed with a level of confidence of 95%	215.43	% value

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	14.3	mg/m ³
Cal gas conc	412	mg/m ³
Analyser Full Scale	513	mg/m ³

	Value	Units	specification	MU Met?
Response time	20	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	-0.05	% full scale	<5% range / 24hr	Yes
Span drift	-0.20	% 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	0.00	% 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	$U_{d,z}$	-0.0288
short term span drift	$U_{d,s}$	-0.1150
influence of Ambient Temp at Zero	$U_{t,z}$	0.0000
influence of Ambient Temp at Span	$U_{t,s}$	1.1250
influence of sample gas pressure	U_p	0.0000
influence of sample gas flow	U_{fit}	0.1732
influence of supply voltage	U_v	0.0100
Combined Interference	U_i	-0.0018
Uncertainty of Cal gas	U_{adj}	2.0080

Measurement uncertainty (Concentration Measured)	14.28	mg/m ³
Combined uncertainty	2.32	mg/m ³
Expanded at a 95% confidence interval	4.55	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%	4.6	mg/m ³
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Expanded uncertainty expressed with a level of confidence of 95%	31.9	% value
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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	230.0	mg/m ³
Cal gas conc	1015.0	mg/m ³
Analyser Full Scale	1250	mg/m ³

Performance characteristics	Value	Units	specification	MU Met?
Response time	24	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	0.13	% full scale	<5% range / 24hr	Yes
Span drift	-1.72	% full scale	<5% range / 24hr	Yes
volume or pressure flow dependence	1	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	2.2	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	-4	% full scale/10K	<3% range / 10 K	Yes
Combined interference	-0.01	% of Range	<4% of Range	Yes
dependence on voltage	-0.32	% 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)	0.02	% 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	$U_{d,z}$	0.35
short term span drift	$U_{d,s}$	0.07
influence of Ambient Temp zero	$U_{t,z}$	-1.00
influence of Ambient Temp span	$U_{t,s}$	0.45
influence of sample gas pressure	U_p	0.00
influence of sample gas flow	U_{fit}	0.69
influence of supply voltage	U_v	-2.30
Combined Interference	U_i	-1.21
Uncertainty of Cal gas	U_{adj}	4.06

Measurement uncertainty (Concentration Measured)	149.3	mg/m ³
Combined uncertainty	5.0	mg/m ³
Expanded uncertainty	9.8	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	-	% ELV
Expanded uncertainty expressed with a level of confidence of 95%	9.8	mg/m ³
Expanded uncertainty expressed with a level of confidence of 95%	4.3	% 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	7.82
Calibration gas	12.51
Analyser Full Scale	15

Performance characteristics	Value	Units	specification	MU Met?
Response time	22	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)	0.05	% vol at zero level	<5% range / 24hr	Yes
Span drift (during measurement period)	0.04	% 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)	-0.239808153	% 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	0.001807392
Lack of fit	ufit	0.0751
Drift	u0dr	0.043312432
volume or pressure flow dependence	uspres	0.0000
atmospheric pressure dependence	uapres	0.007332121
ambient temperature dependence	utemp	0.0005
Combined interference (from mcerts)	-	0.048497423
dependence on voltage	uvolt	0.086
losses in the line (leak)	uleak	-0.010833689
Uncertainty of calibration gas	ucalib	0.045176482

Measurement uncertainty (Concentration Measured)	7.82	% vol
Combined uncertainty	0.14	% vol
Expanded uncertainty	0.27	% vol

Expanded uncertainty expressed with a level of confidence of 95%	0.27	% vol
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Expanded uncertainty expressed with a level of confidence of 95%	3.50	% value
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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 - OXYGEN

Reference	5	%vol
Reported Concentration	10.61	%vol
Calibration gas	10.06	%vol
Analyser Full Scale	15	%vol

	Value	Units	specification	MU Met?
Response time	21	seconds	200	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	60	minutes	-	-
Number of readings in measurement	60	-	-	-
Repeatability at zero	0.02	% Vol	≤0.2% Vol	Yes
Repeatability at span level	0.02	% Vol	≤0.2% Vol	Yes
Deviation from linearity	-0.10	% Vol	≤0.3% Vol	Yes
Zero drift	0.13	% Vol	≤0.2% Vol	Yes
Span drift	-0.07	% Vol	≤0.2% Vol	Yes
volume or pressure flow dependence	-0.01	% Vol for flow range	≤0.2% Vol	Yes
atmospheric pressure dependence	0.19	% Vol for 3kPa	≤0.2% Vol	Yes
ambient temperature dependence	-0.40	% Vol/20K	≤0.5% Vol	Yes
Combined interference	0.00	% Vol	≤0.4% Vol	Yes
dependence on voltage	0.02	% Vol	≤0.2% Vol	Yes
losses in the line (leak)	-0.01	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1.0	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.0020
lack of fit	U_{lof}	-0.0577
short term zero drift	$U_{d,z}$	0.0751
short term span drift	$U_{d,s}$	-0.0404
influence of Ambient Temp at Zero	$U_{t,z}$	-0.0030
influence of Ambient Temp at Span	$U_{t,s}$	-0.0011
influence of sample gas pressure	U_p	0.0000
influence of sample gas flow	U_{fit}	-0.0029
influence of supply voltage	U_v	0.0115
Combined Interference	U_i	0.0000
Uncertainty of Cal gas	U_{adj}	0.1061

Measurement uncertainty (Concentration Measured)	10.61	% vol
Combined uncertainty	0.15	% vol
Expanded uncertainty	0.29	% vol

Expanded uncertainty expressed with a level of confidence of 95%	0.29	% vol
Expanded uncertainty expressed with a level of confidence of 95%	2.74	%

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	27.0	m/s
Measured Volumetric Flow rate at Actual Conditions	28454	m ³ /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	-	2.26		
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	43.84	<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	0.00161		
Uncertainty of temperature measurement	K	3.11	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	513		
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	0.34
Expanded uncertainty at a 95% Confidence Interval	0.66

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	746
Expanded uncertainty at a 95% Confidence Interval	1463

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