

STACK EMISSIONS MONITORING REPORT



Units C & D
Bankside Trade Park
Cirencester
GL7 1YT
Tel: 01285 700 593

Your contact at SOCOTEC UK LTD

Mike Davies
Business Manager - South
Tel: 07976 297 465
Email: mike.davies@socotec.co.uk

Operator & Address:

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

Permit Reference:

N/A - Commissioning Test

Release Point:

Set 2-1

Sampling Date(s):

13th February 2025

SOCOTEC Job Number:	LSE3467
Report Date:	05-Mar-25
Version:	1
Report By:	Jonathan Ward
MCERTS Number:	MM 02 080
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Nik Agopian
MCERTS Number:	MM 08 902
Business Title:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Signature:	



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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Finning (UK) Limited operates a generator process at LON14 West Drayton

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.

Plant

Set 2-1

Operator

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

Stack Emissions Monitoring Test House

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

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.
The results of this testing relate only to the emission release point(s) listed in the report.
MCERTS accredited results will only be claimed where both the sampling and analytical stages are MCERTS accredited.
This test report shall not be reproduced, except in full, without written approval of SOCOTEC UK LTD.

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	Units	Result	Calculated Uncertainty +/-	Emission Limit Value (ELV)	Accreditation
Total Particulate Matter	mg/m ³	11.3	1.30	-	MCERTS
Particulate Emission Rate	g/hr	89	10.2	-	
PM ₁₀	mg/m ³	16.3	1.0	-	MCERTS
PM ₁₀ Emission Rate	g/hr	128	8.0	-	
PM _{2.5}	mg/m ³	15.3	0.74	-	MCERTS
PM _{2.5} Emission Rate	g/hr	120	5.8	-	
Total Volatile Organic Compounds	mg/m ³	2.4	0.31	-	MCERTS
Total Volatile Organic Compounds Emission Rate	g/hr	21.0	2.66	-	
Oxides of Nitrogen (as NO ₂)	mg/m ³	80	5.2	-	MCERTS
Oxides of Nitrogen (as NO ₂) Emission Rate	g/hr	661	43	-	
Carbon Monoxide	mg/m ³	148.2	1.62	-	MCERTS
Carbon Monoxide Emission Rate	g/hr	1222	13.3	-	
Carbon Dioxide	% v/v	7.71	0.28	-	MCERTS
Oxygen	% v/v	11.0	0.27	-	MCERTS
Moisture	%	7.17	0.25	-	MCERTS
Stack Gas Temperature	°C	367	-	-	MCERTS
Stack Gas Velocity	m/s	31.8	0.78	-	
Gas Volumetric Flow Rate (Actual)	m ³ /hr	33443	1719	-	
Gas Volumetric Flow Rate (STP, Wet)	m ³ /hr	14460	743	-	
Gas Volumetric Flow Rate (STP, Dry)	m ³ /hr	13423	690	-	
Gas Volumetric Flow Rate at Reference Conditions	m ³ /hr	8365	430	-	

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	13 February 2025	11:30 - 12:35	64 minutes
PM ₁₀ Run 1	13 February 2025	10:20 - 11:20	60 minutes
PM _{2.5} Run 1	13 February 2025	10:20 - 11:20	60 minutes
Total Volatile Organic Compounds Run 1	13 February 2025	10:20 - 11:20	60 minutes
Combustion Gases	13 February 2025	10:20 - 11:20	60 minutes
Preliminary Stack Traverse	13 February 2025	10:02	-

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	0.62 mg/m ³	11.5%	N/A - No ELV
PM ₁₀	SRM - BS EN 23210	AE 136	1015	MCERTS	0.44 mg/m ³	6.3%	N/A - No ELV
PM _{2.5}	SRM - BS EN 23210	AE 136	1015	MCERTS	0.31 mg/m ³	4.8%	N/A - No ELV
Total Volatile Organic Compounds	SRM - BS EN 12619:2013	AE 102	1015	MCERTS	0.51 mg/m ³	12.7%	N/A - No ELV
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	MCERTS	0.83 mg/m ³	6.5%	N/A - No ELV
Carbon Monoxide	SRM - BS EN 15058:2017	AE 102	1015	MCERTS	0.45 mg/m ³	1.1%	N/A - No ELV
Carbon Dioxide	SRM - CEN/TS 17405	AE 102	1015	MCERTS	0.2 %	3.6%	N/A - No ELV
Oxygen	SRM - BS EN 14789:2017	AE 102	1015	MCERTS	0.01%	2.4%	N/A - No ELV
Moisture	BS EN 14790	AE 105	1015	MCERTS	0.01%	3.4%	N/A - No ELV
Velocity	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	5 Pa	2.4%	N/A - No ELV
Volumetric Flow Rate	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	-	5.1%	N/A - No ELV

EXECUTIVE SUMMARY

Analytical Methods

The following tables list the analytical methods employed together with the custody details. Unless otherwise stated the samples are archived at the analysis lab location.

SAMPLING METHODS WITH SUBSEQUENT ANALYSIS							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	Analysis Accreditation	Analysis Lab	Analysis Report No. Date of Analysis	Archive Period
Total Particulate Matter	Gravimetric	AE 106	1015	MCERTS	SOCOTEC (Cirencester)	N/A	8 Weeks
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 (Cirencester)	SOCOTEC (Cirencester)	5 years
Oxides of Nitrogen	Chemiluminescence	AE 102	1015	MCERTS	SOCOTEC (Cirencester)	SOCOTEC (Cirencester)	5 years
Carbon Monoxide	Non Dispersive Infra Red	AE 102	1015	MCERTS	SOCOTEC (Cirencester)	SOCOTEC (Cirencester)	5 years
Carbon Dioxide	Non Dispersive Infra Red	AE 102	1015	MCERTS	SOCOTEC (Cirencester)	SOCOTEC (Cirencester)	5 years
Oxygen	Paramagnetism	AE 102	1015	MCERTS	SOCOTEC (Cirencester)	SOCOTEC (Cirencester)	5 years
Moisture	Gravimetric	AE 105	1015	MCERTS	SOCOTEC (Cirencester)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	Value	Units	Requirement	Compliant	Method
Lowest Differential Pressure	373	Pa	≥ 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	31.0	m/s	-	-	-
Highest Gas Velocity	32.6	m/s	-	-	-
Ratio of Gas Velocities	1.1	: 1	$< 3 : 1$	Yes	BS EN 15259
Mean Velocity	31.8	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	Quartz Fibre	15 Micron Sinter

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

PM10/2.5 sample run time

The PM10/2.5 sample run time was shortened from 3hrs to 1hr based on higher than expected particulate loading experienced during prior testing.

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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
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	P3145	Horiba PG-250 Analyser	-	Laboratory Balance	P3225
Box Thermocouples	P3145	Horiba PG-350P - AMS	P3419	Tape Measure	P2044
Meter Thermocouple	P3145	FT-IR	-	Stopwatch	P1776
Control Box Timer	P1776	FT-IR Oven Box	-	Barometer	P2236
Oven Box	-	Bernath 3006 FID	P3485	Digital Micromanometer (1)	P3072
Probe 2ft S Type Pitot	-	Servomex	-	Digital Micromanometer (2)	-
Probe Thermocouple	-	JCT Heated Head Filter	-	Digital Micromanometer (3)	-
Probe 3ft S Type Pitot	P3068	Thermo FID	-	Digital Temperature Meter (1)	P1226
Probe Thermocouple	P3153	Stackmaster	P3210	Digital Temperature Meter (2)	-
Probe 3ft S Type Pitot	-	Heated Pump	-	Stack Thermocouple	P1741
Probe Thermocouple	-	Chiller (JCT/Mach10)	-	Mass Flow Controller 1 litre	-
Probe 5ft S Type Pitot	-	Chiller (Horiba)	P3420	Mass Flow Controller 5 litre	-
Probe Thermocouple	-	Sick Heated Head	-	Unheated Pump	-
L-Pitot 900mm	-	Kletti Controller (1) 15M	P2544	Wet Gas Meter	-
L-Pitot 1500mm	-	O Brian Controller (1)	-	5m Heated Line Winkler	-
Site Balance	P3334	Kletti Controller (2) 20M	-	15m Heated Line Kletti	P2418
Last Impinger Arm	-			20m Heated Line Kletti	-
Dioxins Cond. Thermocouple	-			20m Heated Line Kletti	-
Inclinometer (Swirl Device)	P3076			20m Heated Line O Brien	-

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	CG69	BOC	-	10.15	2.0
Propane	CG69	BOC	8	-	2.0
Nitric Oxide	CB43	BOC	204.6	-	2.0
Carbon Monoxide	CG69	BOC	85	-	2.0
Carbon Dioxide	CG69	BOC	-	12.04	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
Jonathan Ward	MM 02 080	MCERTS Level 2	Jun-25	Mar-28	Jun-28	Aug-26	Mar-26	Jun-25
Alistair Holmes	MM 13 1218	MCERTS Level 1	Mar-28	-	-	-	-	Mar-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	11:30 - 12:35 13 February 2025	11.31	1.30	-	89
Blank	-	0.38	-	-	-

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	322092	0.10505	0.11204	0.00699	86.25840	86.26050	0.00210	0.00909

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	322091	0.10458	0.10461	0.00003	92.37990	92.38000	0.00010	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			Molecular weight of dry gas, M_d	
Barometric pressure, P _b	Kpa	102.3	CO ₂	% 7.71
Stack static pressure, P _{static}	pa	305.0	O ₂	% 11.17
P _s = P _b + P _{static}	Kpa	102.6	Total	% 18.88
			N ₂ (100 - Total)	% 81.12
Vol. of water vapour collected, V_{wstd}			M _d = 0.44(%CO ₂)+0.32(%O ₂)+0.28(%N ₂)	29.68
Moisture trap weight increase, V _{lc}	g	81.1	Molecular weight of wet gas, M_s	
V _{wstd} = (0.001246)(V _{lc})	m ³	0.1010506	M _s = M _d (1 - B _{wo}) + 18(B _{wo})	g/gmol 28.84
Volume of gas metered dry, V_{mstd}			Actual flow of stack gas, Q_a	
Volume of gas sample through gas meter, V _m		1.345	Area of stack, A _s	m ² 0.29
Gas meter correction factor, Y _d		0.999	Q _a = (60)(A _s)(V _s)	m ³ /min 574.1
Mean dry gas meter temperature, T _m		284	Total flow of stack gas, Q	
Mean pressure drop across orifice, DH mmH ₂ O		44.863	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	1.308	Q _{std} = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	Dry 213.5
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 131.15
V _{mstw} = V _{mstd} + V _{wstd}	m ³	1.4088	Q _{stw} = $\frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet 229.97
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 6.01
% oxygen measured in gas stream, act%O ₂		11.2	Nozzle area, A _n	mm ² 28.37
% oxygen reference condition		5	Total sampling time, q	min 64
O ₂ Reference O ₂ Ref = 21.0 - act%O ₂		0.61	%I = $\frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	% 98.6
Factor 21.0 - ref%O ₂			Acceptable isokinetic range 95% to 115%	Yes
V _{mstd@X%oxygen} = (V _{mstd}) (O ₂ Ref)	m ³	0.8035	Particulate Concentration, C	
Moisture content, B_{wo}			Mass collected on filter, M _f	g 0.00699
B _{wo} = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	7.17	Mass collected in probe, M _p	g 0.00210
Moisture by FTIR	%	-	Total mass collected, M _n	g 0.00909
Velocity of stack gas, V_s			C _{wet} = $\frac{M_n}{V_{mstw}}$	mg/m ³ 6.452
Velocity pressure coefficient, C _p		0.84	C _{dry} = $\frac{M_n}{V_{mstd}}$	mg/m ³ 6.951
Mean of velocity heads, DP _{avg}	Pa	392.00	C _{dry@X%O2} = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³ 11.314
Mean stack gas temperature, T _s	K	690	Particulate Emission Rates, E	
Gas density (wet, ambient), ρ			E = [(C _{wet})(Q _{stw})(60)] / 1000	89.03
p = (M _s *P _s)/(8.314*T _s)	kg/m ³	0.516		
Stack Velocity, V _s = $\frac{\sum_{i=1}^n V_i}{n}$	m/s	32.73		

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	21.00	0.21	-	-381	0.42	Yes

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

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	98.61	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	0.62	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	0.38	-	-	-

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	418	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	10:20 - 11:20 13 February 2025	16.3	0.44	-	128
Blank 1	-	0.618	-	-	-

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	10:20 - 11:20 13 February 2025	15.3	0.31	-	120
Blank 1	-	0.309	-	-	-

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	0432	15.4001	15.4010	0.00096	0431	32.3876	32.4025	0.01490
Blank 1	0450	14.72065	14.7201	-0.00055	0449	34.02704	34.02708	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	102.3	CO ₂	7.71
Stack static pressure, P _{static}	Pa	305.0	O ₂	11.17
P _s = P _b + (P _{static})	kPa	102.6	Total	18.88
Vol. of water vapour collected, V_{wstd}			N ₂ (100 - Total)	81.12
Moisture trap weight increase, V _{ic}	g	-	M _d = 0.44(%CO ₂) + 0.32(%O ₂) + 0.28(%N ₂)	29.68
V _{wstd} = (0.001246)(V _{ic})	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})	28.84
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		1.00	Area of stack, A _s	m ² 0.29
Mean dry gas meter temperature, T _m		284.00	Q _a = (60)(A _s)(V _s)	m ³ /min 557.4
Mean pressure drop across orifice, DH	mmH ₂ O	80.00	Q _{stw} = $\frac{(Q_a)P_s(0.3592)}{(T_s) + 273}$	Wet 228.51
V _{mstd} = $\frac{(0.3592)(V_m)(P_b + (DH/13.6))(Y_d)}{T_m + 273}$	m ³	1.581	Percent isokinetic, %I	
Volume of gas metered wet, V_{mstw}			Required Flow Rate @ DGM	l/min 29.70
V _{mstw} = V _{mstd} + V _{wstd}	m ³	1.703	Actual Flow Rate @ DGM	l/min 30.6
Vol. of gas metered at O₂ Ref. Cond., V_{mstd@X%O2}			Isokinetic Rate	103.11
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	11.17		Particulate Concentration, C_{PM10}	
% oxygen reference condition	5		Mass of particulate collected on PM ₁₀ filter, M _f	0.00096
O ₂ Reference O ₂ Ref = 21.0 - act%O ₂	0.61		Mass of particulate collected on PM _{2.5} filter, M _f	0.0149
Factor $\frac{21.0 - \text{ref}\%O_2}{21.0 - \text{act}\%O_2}$			C _{wet} = $\frac{M_n}{V_{mstw}}$	mg/m ³ 9.31
V _{mstd@X%oxygen} = (V _{mstd}) (O ₂ Ref)	m ³	0.971	C _{dry} = $\frac{M_n}{V_{mstd}}$	mg/m ³ 10.03
Moisture content, B_{wo}			C _{dry@X%O2} = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³ 16.33
B _{wo} = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0717	Particulate Emission Rates, E	
		7.17	E = [(C _{wet})(Q _{stw})(60)] / 1000	127.67
Moisture by FTIR			Particulate Concentration, C_{PM2.5}	
Velocity of stack gas, V_s			Mass of particulate collected on filter, M _f	0.01490
Velocity pressure coefficient, C _p		0.84	C _{wet} = $\frac{M_n}{V_{mstw}}$	mg/m ³ 8.7484
Mean of velocity heads, DP _{avg}	Pa	398.53	C _{dry} = $\frac{M_n}{V_{mstd}}$	mg/m ³ 9.4244
Mean stack gas temperature, T _s	K	674	C _{dry@X%O2} = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³ 15.3398
Gas density (wet, ambient), ρ	kg/m ³	0.528	Emission Rate, E	
p = (M _s *P _s)/(8.314*T _s)			E = [(C _{wet})(Q _{stw})(60)] / 1000	119.94
Stack Velocity, V _s $V_s = C_p \sqrt{\frac{\Delta DP_{avg}}{\rho}}$	m/s	31.78		
*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	30.63	0.10	0.08	-381	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	103.11	Yes	29.7	3.41	Yes

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	47	416	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	10:20 - 11:20 13 February 2025	2.4	0.30	-	20.95

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

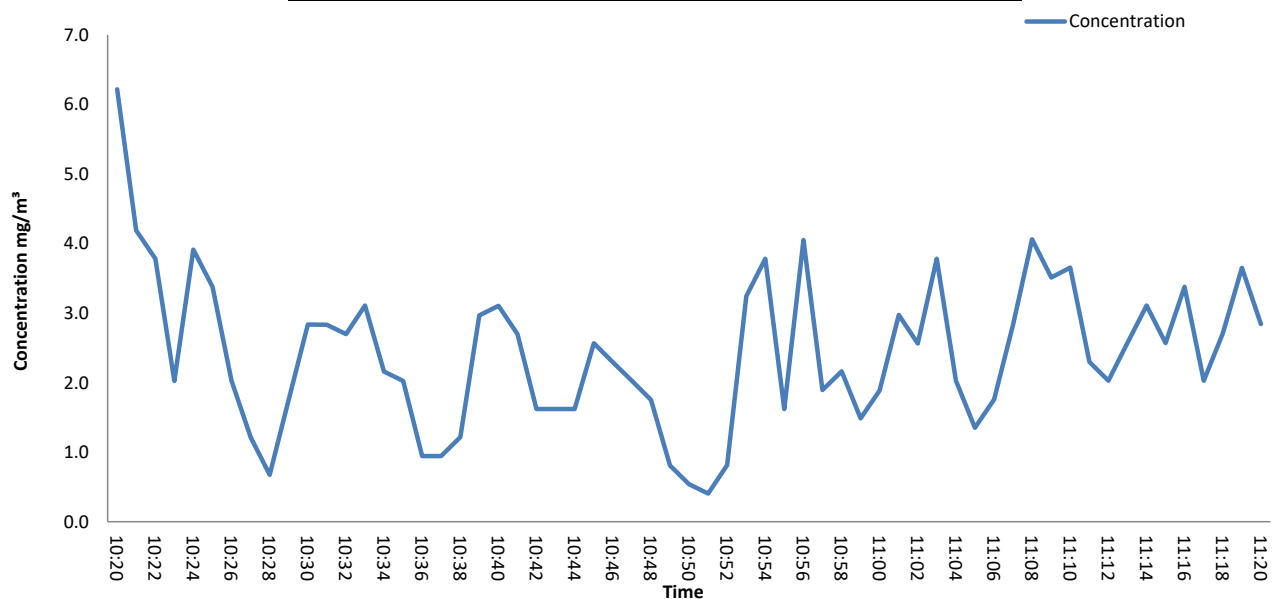
INSTRUMENTAL SPAN & ZERO CHECKS

PRE-SAMPLING CALIBRATION CHECKS								
Date	13 February 2025							
Start Time	08:42							
End Time	08:58							
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	8.0	10	0.00	8.0	0.15	0.20	8.1	-0.63

Zero and Span gas contained 10.15% Oxygen

POST-SAMPLING CALIBRATION CHECKS								
Date	13 February 2025							
Start Time	11:25							
End Time	11:41							
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	0.90	0.20	8.2	0.00	1.25	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	10:20 - 11:20 13 February 2025	80.2	0.83	-	661
Carbon Monoxide	10:20 - 11:20 13 February 2025	148.2	0.45	-	1221.73

Test	Sampling Time and Date	Concentration %	LOD %
Carbon Dioxide	10:20 - 11:20 13 February 2025	7.71	0.200
Oxygen	10:20 - 11:20 13 February 2025	11.17	0.01

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

PRE-SAMPLING CALIBRATION DATA

Date	13 February 2025
Start Time	08:42
End Time	08:58

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	250	0.00	204.6	0.30	0.40	205.1	48	-0.24
Carbon Monoxide	200	0.00	85.0	0.20	0.10	85.0	53	0.00
Carbon Dioxide	20	0.00	12.04	0.04	0.02	12.10	42	-0.50
Oxygen	25	0.00	10.15	0.01	0.04	10.19	43	-0.39

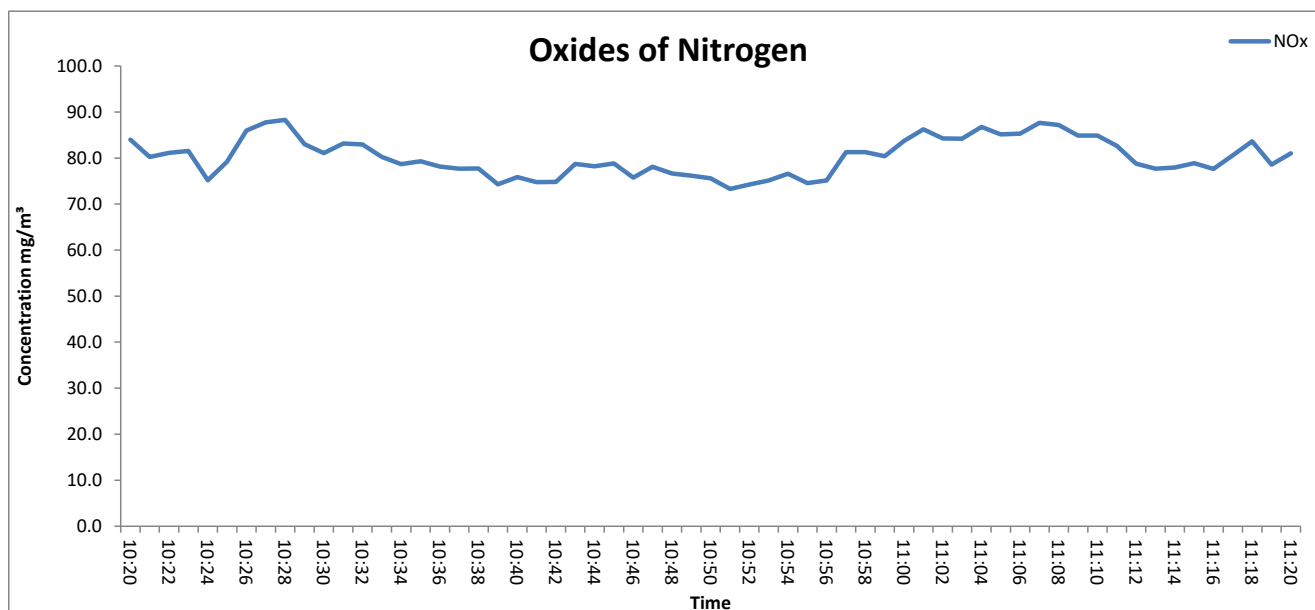
POST-SAMPLING CALIBRATION DATA

Date	13 February 2025
Start Time	11:25
End Time	11:41

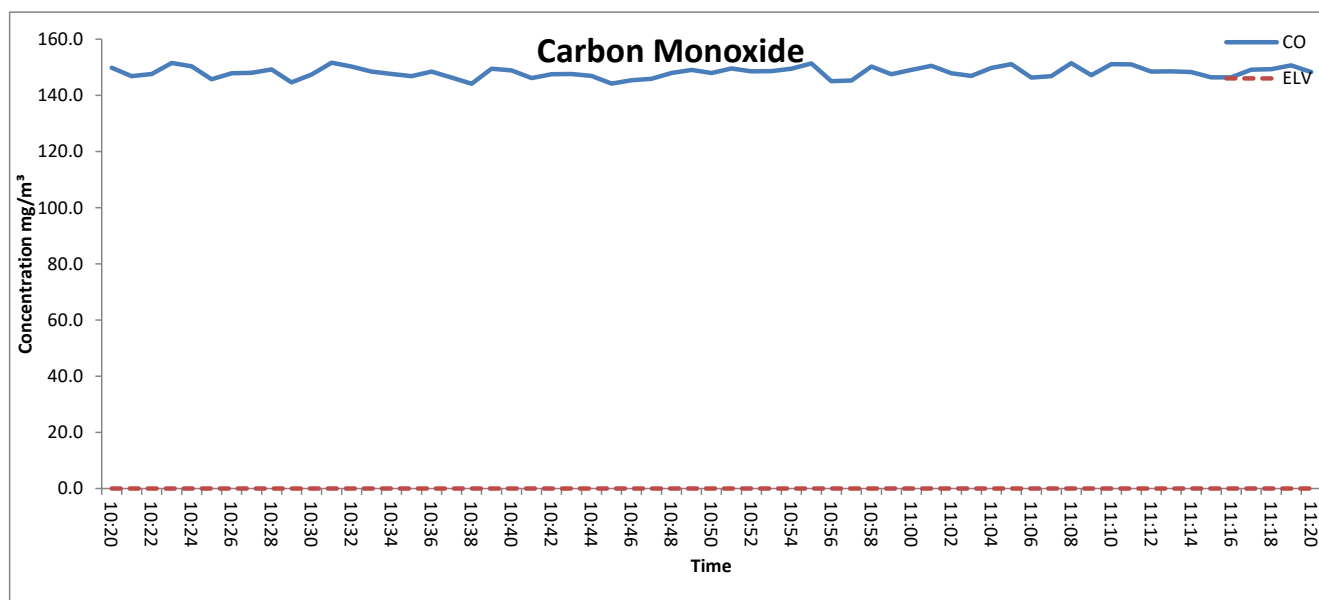
Chiller Temperature (°C)	2.2
Requirement	< 4°C
Compliant	Yes

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	0.30	204.1	0.00	-0.24	x	x	N/A - not corrected
Carbon Monoxide	0.40	84.8	0.24	-0.47	x	x	N/A - not corrected
Carbon Dioxide	0.01	12.02	-0.25	0.08	x	x	N/A - not corrected
Oxygen	-0.02	10.21	-0.29	0.89	x	x	N/A - not corrected

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

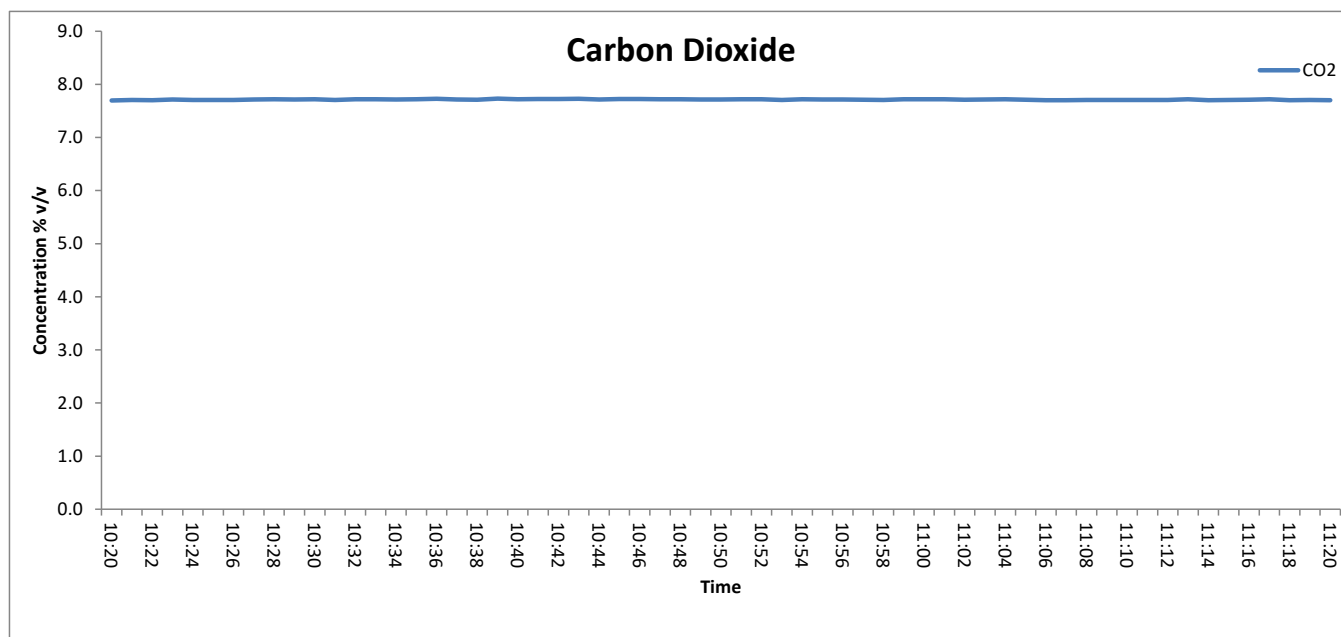


CARBON MONOXIDE EMISSIONS CHART

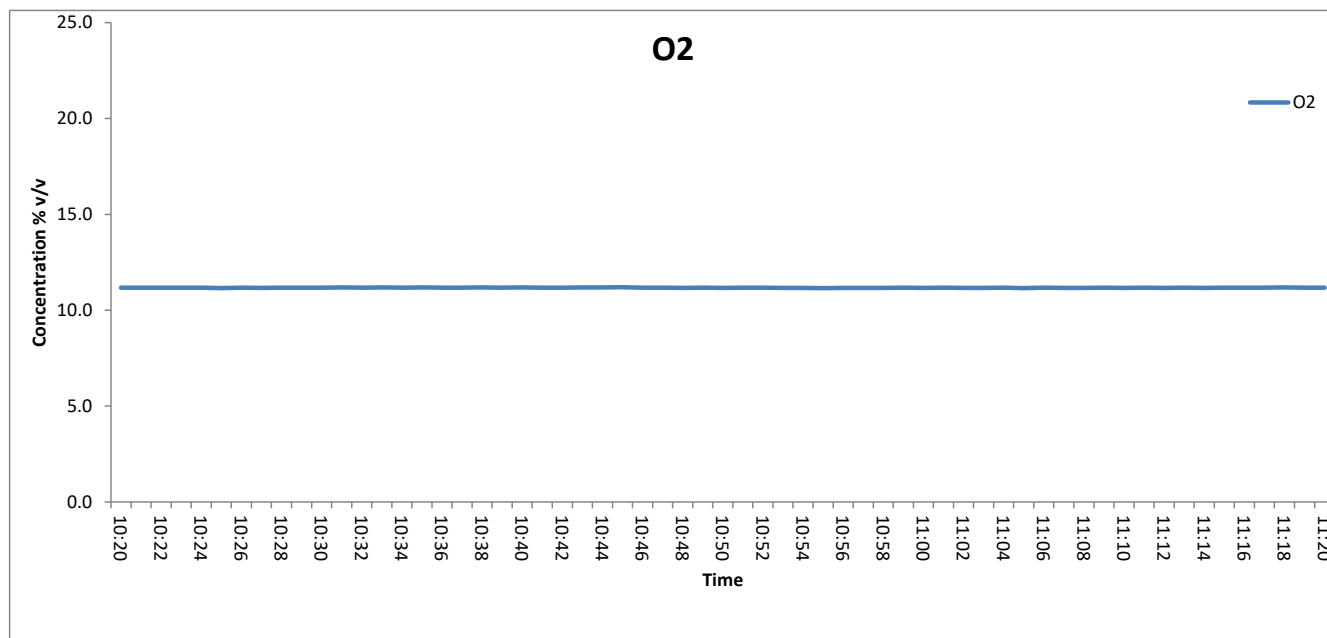


APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

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	11:30 - 12:35 13 February 2025	2.9971	3.0782	0.0811	7.2	0.01	3.4

Moisture Quality Assurance							
Test Number	Sampling Duration	Total Volume Sampled	Sampling Rate	Start Leak Rate	End Leak Rate	Acceptable Leak Rate	Leak Tests Acceptable?
	mins	l	l/min	l/min	l/min	l/min	
Run 1	64	1409	21.0	0.21	-	0.42	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	367	°C
Stack static pressure	0.305	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	7.713477	0.077135	0.151420	7.160208	0.071602	0.140559
O ₂	32	1.427679	11.029563	0.110296	0.157467	10.238440	0.102384	0.146172
N ₂	28	1.249219	81.256960	0.812570	1.015078	75.428601	0.754286	0.942269
H ₂ O	18	0.803070	-	-	-	7.172751	0.071728	0.057602

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

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.3240	kg/m ³
Wet Density (STP), P_{STW}	1.2866	kg/m ³
Dry Density (Actual), P_{Actual}	0.5725	kg/m ³
Average Wet Density (Actual), $P_{ActualW}$	0.556	kg/m ³

Where:

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

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

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

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	13 February 2025
Time of Survey	10:02
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	378.9	38.7	365	31.0	9.1	-	<15
2	0.52	411.6	42.0	366	32.3	9.4	-	<15
Mean	-	395.3	40.3	366	31.7	9.3	-	-

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	385.5	39.3	367	31.3	9.1	-	<15
2	0.52	418.1	42.7	368	32.6	9.5	-	<15
Mean	-	401.8	41.0	368	31.9	9.3	-	-

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	122	123	-0.8	Pass	131	132	-0.8	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	170	172	-2.0	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	379	Pa	$\geq 5 \text{ Pa}$	Yes
Lowest Gas Velocity	31.0	m/s	-	-
Highest Gas Velocity	32.6	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, $V = K_{pt} \times (1-e) \times \sqrt{2 \times DP_{pt} / P_{ActualW}}$		
Where: K_{pt} = Pitot tube calibration coefficient $(1-e)$ = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, V_a	31.8	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	367	0	$^{\circ}\text{C}$
Total Pressure	102.6	101.3	kPa
Oxygen	11.0	5	%
Moisture	7.17	0.00	%
Pitot tube calibration coefficient, K_{pt}	0.84		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (V_a)	31.78	m/s
Stack Area (A)	0.29	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	33443	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	14460	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	13423	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	8365	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

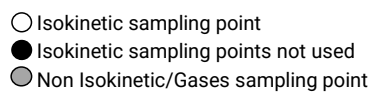
Ms = Water vapour, Reference Conditions, % Vol

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

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

STACK DIAGRAM

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	30	0.18	m

[illegible]

LSE3467 / Version 1
13th February 2025
N/A - Commissioning Test

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	0.0026	2.0	0.50	1.0	0.1	0.5000	-	-
as a %	0.20	0.29	0.49	1.0	0.90	N/A	1.00	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	0.52	9.0900	1.6	0.0653	0.0003	-
MU as mg/m ³	0.14	0.6223	0.12	0.0653	0.0004	0.65
MU as %	1.25	5.5006	-	0.577	0.0032	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	1.30	mg/m³	11.52	% 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	0.49	1.0	0.90	N/A	0.26
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	41.11	1.0295	10.03	1.000	-
MU as mg/m ³	0.20	0.4368	0.17	0.025	102.96
MU as %	1.25	102.9515	1.02	0.151	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	1.02	mg/m³	6.25	% 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	0.49	1.0	0.90	N/A	0.26
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	38.62	1.0295	9.42	1.000	-
MU as mg/m ³	0.19	0.3089	0.00	0.023	102.96
MU as %	1.25	102.9515	-	0.151	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.73	mg/m³	4.75	% 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	0.002615523	2.0	0.50	1.0	0.1	-
as a %	0.20	0.29	0.49	1.0	0.90	1.00
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	0.52	81100	1.6	358.06	58	-
MU as % v/v	0.10	0.01	0.08	0.05	0.006	0.13
MU as %	1.25	0.12	1.02	0.58	0.07	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.27	% v/v	3.44	%
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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VOLATILE ORGANIC COMPOUNDS RUN 1

Measured Concentration	2.4	mg/m ³
Limit	-	mg/m ³
Calibration Gas Concentration	12.8	mg/m ³
Range	16	mg/m ³

Performance characteristics	Value	Units	specification	MU Met?
Response time	37	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	0.00	% full scale	<5% range / 24hr	Yes
Span drift	1.25	% 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)	-0.63	% 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	0.14
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	-0.01
Uncertainty of calibration gas	ucalib	0.01
Uncertainty in factor	uf	0.03

Measurement uncertainty Measured Concentration	2.44	mg/m ³
Combined uncertainty	0.16	mg/m ³
Expanded uncertainty	0.31	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	-	% ELV
Expanded uncertainty expressed with a level of confidence of 95%	0.31	mg/m ³
Expanded uncertainty expressed with a level of confidence of 95%	12.71	% 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	80.2	mg/m ³
Cal gas conc	419	mg/m ³
Analyser Full Scale	513	mg/m ³

	Value	Units	specification	MU Met?
Response time	48	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	0.00	% full scale	<5% range / 24hr	Yes
Span drift	-0.24	% 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	0.02	% 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)	0.02	% 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	$U_{d,z}$	0.0002
short term span drift	$U_{d,s}$	-0.1411
influence of Ambient Temp at Zero	$U_{t,z}$	0.0000
influence of Ambient Temp at Span	$U_{t,s}$	1.6887
influence of sample gas pressure	U_p	0.0000
influence of sample gas flow	U_{fit}	0.1732
influence of supply voltage	U_v	0.0530
Combined Interference	U_i	-0.0018
Uncertainty of Cal gas	U_{adj}	2.0460

Measurement uncertainty (Concentration Measured)	80.20	mg/m ³
Combined uncertainty	2.67	mg/m ³
Expanded at a 95% confidence interval	5.24	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%	5.2	mg/m ³
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Expanded uncertainty expressed with a level of confidence of 95%	6.5	% 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	148.2	mg/m ³
Cal gas conc	106.3	mg/m ³
Analyser Full Scale	250	mg/m ³

Performance characteristics	Value	Units	specification	MU Met?
Response time	53	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	0.24	% full scale	<5% range / 24hr	Yes
Span drift	-0.47	% 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	$U_{d,z}$	0.35
short term span drift	$U_{d,s}$	0.14
influence of Ambient Temp zero	$U_{t,z}$	-0.12
influence of Ambient Temp span	$U_{t,s}$	0.14
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	-0.53
Uncertainty of Cal gas	U_{adj}	0.43

Measurement uncertainty (Concentration Measured)	91.0	mg/m ³
Combined uncertainty	0.8	mg/m ³
Expanded uncertainty	1.6	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	-	% ELV
Expanded uncertainty expressed with a level of confidence of 95%	1.6	mg/m ³
Expanded uncertainty expressed with a level of confidence of 95%	1.1	% 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	7.71
Calibration gas	12.04
Analyser Full Scale	20

Performance characteristics	Value	Units	specification	MU Met?
Response time	42	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)	0.01	% vol at zero level	<5% range / 24hr	Yes
Span drift (during measurement period)	-0.03	% 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)	-0.49833887	% 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	-0.005322954
volume or pressure flow dependence	uspres	0.0000
atmospheric pressure dependence	uapres	0.009776161
ambient temperature dependence	utemp	0.0005
Combined interference (from mcerts)	-	0.06466323
dependence on voltage	uvolt	0.086
losses in the line (leak)	uleak	-0.022192913
Uncertainty of calibration gas	ucalib	0.044533778

Measurement uncertainty (Concentration Measured)	7.71	% vol
Combined uncertainty	0.14	% vol
Expanded uncertainty	0.28	% vol

Expanded uncertainty expressed with a level of confidence of 95%	0.28	% vol
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Expanded uncertainty expressed with a level of confidence of 95%	3.58	% 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	11.17	%vol
Calibration gas	10.15	%vol
Analyser Full Scale	25	%vol

	Value	Units	specification	MU Met?
Response time	43	seconds	200	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	60	minutes	-	-
Number of readings in measurement	60	-	-	-
Repeatability at zero	0.01	% Vol	≤0.2% Vol	Yes
Repeatability at span level	0.01	% Vol	≤0.2% Vol	Yes
Deviation from linearity	0.11	% Vol	≤0.3% Vol	Yes
Zero drift	-0.02	% Vol	≤0.2% Vol	Yes
Span drift	0.08	% 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	-0.11	% 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)	0.00	% 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	$U_r = S_r$	0.0010
lack of fit	U_{lof}	0.0635
short term zero drift	$U_{d,z}$	-0.0115
short term span drift	$U_{d,s}$	0.0462
influence of Ambient Temp at Zero	$U_{t,z}$	-0.0025
influence of Ambient Temp at Span	$U_{t,s}$	0.0068
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}	0.1117

Measurement uncertainty (Concentration Measured)	11.17	% 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%	2.42	%
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Maximum permissible uncertainty is 6% of value or 0.3% by volume.

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	31.8	m/s
Measured Volumetric Flow rate at Actual Conditions	33443	m³/hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination	-	0.010		
Uncertainty of pitot tube coefficient	-	3.05		
Uncertainty of mean local dynamic pressures	3 readings	0.591	minimum 3	Yes
Factor loading, function of the number of measurements.	pa	1000		
Range of measurment device	pa	1.00		
Resolution	pa	59.37	<1% of Value or 20 Pa whichever is greater	Yes
Calibration uncertainty	% range	0.10		
Drift	% range	0.06	<2% of value	Yes
Linearity	kg/mol	0.00004		
Uncertainty of gas density determination	K	3.26	<1% of value	Yes
Uncertainty of molar mass determination	pa	523		
Uncertainty of temperature measurement	kg/m3	0.008		
Uncertainty of absolute pressure in the duct	-	0.0001		
Uncertainty associated with the calculation of density	-	0.0002		
Uncertainty associated with the measurement of local velocity				
Uncertainty associated with the measurement of mean velocity				

Measurement Uncertainty - Velocity	m/s
Combined uncertainty	0.40
Expanded uncertainty at a 95% Confidence Interval	0.78

Note - The expanded uncertainty uses a coverage factor of $k = 2$.

Expanded Measurement Uncertainty of Velocity at a 95% Confidence Interval	%
Expressed as a % of the Measured Velocity	1.2
Expanded uncertainty at a 95% Confidence Interval	2.4

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	877
Expanded uncertainty at a 95% Confidence Interval	1719

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