

STACK EMISSIONS MONITORING REPORT



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A Standard Aero Company
Fareham Road
Gosport
Hampshire
PO13 0AA

Permit Reference:

EPR Permit: EPR/NP3930KB

Release Point:

A2 - Fume Scrubber Stack M2

Sampling Date(s):

11th April 2023

SOCOTEC Job Number:	LSW 230407
Report Date:	27th April 2023
Version:	1
Report By:	Owen May
MCERTS Number:	MM 10 1072
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	David May
MCERTS Number:	MM 07 862
Business Title:	MCERTS Level 2 - Operations Manager
Technical Endorsements:	1, 2, 3 & 4
Signature:	

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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Vector Aerospace International Limited operates a metal plating for aerospace components process at Gosport which is subject to EPR Permit EPR/NP3930KB, under the Environmental Permitting Regulations 2010.

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

The results of these tests shall be used to demonstrate compliance with a set of emission limit values for prescribed pollutants as specified in the Plant's EPR Permit, EPR/NP3930KB.

Plant

A2 - Fume Scrubber Stack M2

Operator

Vector Aerospace International Limited
A Standard Aero Company
Fareham Road
Gosport
Hampshire
PO13 0AA

EPR Permit: EPR/NP3930KB

Stack Emissions Monitoring Test House

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

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

The results of this testing relate only to the emission release point(s) listed in the report.

MCERTS accredited results will only be claimed where both the sampling and analytical stages are MCERTS accredited.

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

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	Units	Result	Calculated Uncertainty +/-	Emission Limit Value (ELV)	Accreditation
Cadmium	mg/m ³	0.0004	0.0001	0.05	MCERTS
Cadmium Emission Rate	g/hr	0.0176	0.0023	-	
Nickel & Chromium	mg/m ³	0.0244	0.0031	1.5	MCERTS
Nickel & Chromium Emission Rate	g/hr	1.0701	0.1380	-	
Total Volatile Organic Compounds	mg/m ³	0.44	1.32	20	MCERTS
Total Volatile Organic Compounds Emission Rate	g/hr	19.30	58.10	-	
Oxides of Nitrogen (as NO ₂)	mg/m ³	2.1	4.1	10	MCERTS
Oxides of Nitrogen (as NO ₂) Emission Rate	g/hr	93.3	179.7	-	
Moisture	%	3.76	0.10	-	MCERTS
Stack Gas Temperature	°C	22.6	-	-	MCERTS
Stack Gas Velocity	m/s	7.5	0.2	-	
Gas Volumetric Flow Rate (Actual)	m ³ /hr	47663.0	2454.4	-	
Gas Volumetric Flow Rate (STP, Wet)	m ³ /hr	43873.1	2259.2	-	
Gas Volumetric Flow Rate (STP, Dry)	m ³ /hr	42225.0	2174.4	-	
Gas Volumetric Flow Rate at Reference Conditions	m ³ /hr	43873.1	2259.2	-	

ND = None Detected,

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

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

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

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	Sampling Date(s)	Sampling Times	Sampling Duration
Heavy Metals Run 1	11 April 2023	13:45 - 14:52	64 minutes
Total Volatile Organic Compounds Run 1	11 April 2023	13:45 - 14:45	60 minutes
Combustion Gases	11 April 2023	13:45 - 14:45	60 minutes
Preliminary Stack Traverse	11 April 2023	11:40	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Metal plating for aerospace components
Continuous or batch	Continuous
Product Details	Aerospace components
Part of batch to be monitored (if applicable)	Any
Normal load, throughput or continuous rating	Normal
Fuel used during monitoring	None
Abatement	Wet scrubber
Plume Appearance	None visible from sample 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
Metals	SRM - BS EN 14385	AE 108	1015	MCERTS	0.001 mg/m ³	12.9%	0.2%
Total Volatile Organic Compounds	SRM - BS EN 12619:2013	AE 102	1015	MCERTS	0 mg/m ³	301%	6.6%
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	MCERTS	0.49 mg/m ³	192.6%	40.96%
Moisture	SRM - BS EN 14790	AE 105	1015	MCERTS	0.01%	2.7%	N/A - No ELV
Velocity	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	5 Pa	2.5%	N/A - No ELV
Volumetric Flow Rate	SRM - EN ISO 16911-1	AE 154	1015	MCERTS	-	5.1%	N/A - No ELV

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

EXECUTIVE SUMMARY

Analytical Methods

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

SAMPLING METHODS WITH SUBSEQUENT ANALYSIS							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	Analysis Accreditation	Analysis Lab	Analysis Report No. Date of Analysis	Archive Period
Heavy Metals	Inductively coupled Plasma - Mass Spectrometry	ASC/SOP/117	1252	MCERTS	SOCOTEC (Bretby)	ASC/57792 14 Apr 2023	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 Romford	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	39	Pa	≥ 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	6.9	m/s	-	-	-
Highest Gas Velocity	7.9	m/s	-	-	-
Ratio of Gas Velocities	1.2	: 1	$< 3 : 1$	Yes	BS EN 15259
Mean Velocity	7.5	m/s	-	-	-
Maximum angle of flow with regard to duct axis	< 15	$^{\circ}$	$< 15^{\circ}$	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259

DUCT CHARACTERISTICS		
	Value	Units
Shape	Circular	-
Depth	1.50	m
Width	-	m
Area	1.77	m ²
Port Depth	300	mm

SAMPLING LINES & POINTS		
	Isokinetic	Non-Iso & Gases
Sample port size	4" BSP	4" BSP
Number of lines used	2	2
Number of points / line	4	4
Duct orientation	Vertical	Vertical
Filtration	Out stack	Out stack

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

M1 Platform requirements	
Is there a sufficient working area so work can be performed in a compliant manner	Yes
Platform has 2 levels of handrails (approximately 0.5 m & 1.0 m high)	Yes
Platform has vertical base boards (approximately 0.25 m high)	Yes
Platform has removable chains / self closing gates at the top of ladders	Yes
Handrail / obstructions do not hamper insertion of sampling equipment	Yes
Depth of Platform = $>$ Stack depth / diameter + wall and port thickness + 1.5m	No

Sampling Platform Improvement Recommendations (if applicable)

The sampling location meets all the requirements as specified in EA Guidance Note M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

In this instance there were no deviations from the sampling and analytical methods employed.

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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
Metals	SRM - BS EN 14385	AE 108	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
Moisture	SRM - 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	P1757	Horiba PG-350 Analyser	P2938	Laboratory Balance	P3225
Box Thermocouples	P1757	FT-IR	-	Tape Measure	P2024
Meter In Thermocouple	P1757	FT-IR Oven Box	-	Stopwatch	P2370
Meter Out Thermocouple	P1757	Bernath 3006 FID	P1337	Protractor	-
Control Box Timer	-	Signal 3030 FID	-	Barometer	P1916
Oven Box	P2173	Servomex	-	Digital Micromanometer	P1599
Probe	-	JCT Heated Head Filter	-	Digital Temperature Meter	P1475
Probe Thermocouple	-	Thermo FID	-	Stack Thermocouple	P2997
Probe	P2930	Stackmaster	-	Mass Flow Controller	P3288
Probe Thermocouple	P2929	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	P2928	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysix NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P1952	Chiller (JCT/MAK 10)	P2903	1m Heated Line (3)	-
Last Impinger Arm	-	Heated Line Controller (1)	P2800	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	-	10m Heated Line (1)	-
Callipers	-	Site temperature Logger	P2208	10m Heated Line (2)	-
Small DGM	-			15m Heated Line (1)	-
Heater Controller	-			20m Heated Line (1)	P2781
Inclinometer (Swirl Device)	P3079			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 +/- %
Propane	CG 51	BOC	8.43	-	2.0
Nitric Oxide	SM 23	BOC	202	-	2.0
-	-	-	-	-	-

STACK EMISSIONS MONITORING TEAM

MONITORING TEAM								
Personnel	MCERTS Number	MCERTS		TE / H&S Qualifications and Expiry Date				
		Level	Expiry	TE1	TE2	TE3	TE4	H&S
Owen May	MM 10 1072	MCERTS Level 2	Jun-25	Sep-26	Jul-26	Feb-28	Mar-27	Jun-25
Warren Clark	MM 02 086	MCERTS Level 1	Sep-27	-	-	-	-	Sep-27

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS SOLID & VAPOUR PHASES COMBINED

TOTAL HEAVY METALS COMBINED					
Test	Sampling Times	Concentration mg/m ³	LOD mg/m ³	ELV mg/m ³	Emission Rate g/hr
Run 1	13:45 - 14:52 11 April 2023	0.025	0.0009	1.5	1.2
Field Blank	-	0.0067	-	-	-

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

INDIVIDUAL METALS SUMMARY - SOLID & VAPOUR PHASES COMBINED

Metals	LOD mg/m ³	Concentration mg/m ³	Emission Rate g/hr	Uncertainty %	UKAS Accredited
Chromium	0.00024	0.00963	0.449	15%	✓
Cadmium	0.00035	0.00040	0.019	161%	✓
Nickel	0.00028	0.01476	0.688	16%	✓
Sum of Heavy Metals (Excluding Cd / Tl)	0.00087	0.02479	1.156	12.9%	-

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS - RUN 1 SUMMARY

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m ³	Laboratory Result ug	Concentration mg/m ³	Stack LOD mg/m ³	Laboratory Result ug	Concentration mg/m ³
Chromium	0.00020	14.00	0.00921	0.00004	0.63000	0.00041
Cadmium	0.00033	0.50	0.00033	0.00002	0.11070	0.00007
Nickel	0.00026	20.00	0.01316	0.00002	2.42910	0.00160
Sum of Heavy Metals	0.00079	34.50	0.02271	0.00008	3.16980	0.00209
Volume Sampled m ³	1.5194			1.5194		

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS - BLANK SUMMARY

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m ³	Laboratory Result ug	Concentration mg/m ³	Stack LOD mg/m ³	Laboratory Result ug	Concentration mg/m ³
Chromium	0.00020	2.00	0.00132	0.00004	1.23	0.00081
Cadmium	0.00033	0.50	0.00033	0.00002	0.03	0.00002
Nickel	0.00026	6.40	0.00421	0.00002	0.03	0.00002
Sum of Heavy Metals	0.00079	8.90	0.00586	0.00008	1.29	0.00085
Volume Sampled m ³		1.5194			1.5194	

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS RUN 1				Heavy Metals	
Absolute pressure of stack gas, P_s			Molecular weight of dry gas, M_d		
Barometric pressure, P _b	kPa	101.00	CO ₂	%	0.03
Stack static pressure, P _{static}	Pa	-27.00	O ₂	%	20.90
P _s = P _b + (P _{static})	kPa	100.97	Total	%	20.93
			N ₂ (100 - Total)	%	79.07
			M _d = 0.44(%CO ₂)+0.32(%O ₂)+0.28(%N ₂)		28.84
Vol. of water vapour collected, V_{wstd}			Molecular weight of wet gas, M_s		
Moisture trap weight increase, V _{lc}	g	H ₂ O by Non Iso	M _s = M _d (1 - B _{w0}) + 18(B _{w0})	g/gmol	28.43
V _{wstd} = (0.001246)(V _{lc})	m ³	-	Velocity of stack gas, V_s		
Volume of gas metered dry, V_{mstd}			Velocity pressure coefficient, C _p		0.84
Volume of gas sample through gas meter, V _m	m ³	1.68	Mean of velocity heads, DP _{avg}	Pa	52.68
Gas meter correction factor, Y _d		0.94	Mean stack gas temperature, T _s	K	295.75
Mean dry gas meter temperature, T _m		294.94	Gas density (wet, ambient), ρ		
Mean pressure drop across orifice, DH	mmH ₂ O	52.55	ρ = (M _s *P _s)/(8.314*T _s)	kg/m ³	1.168
V _{mstd} = (0.3592)(V _m)(P _b +(DH/13.6))(Y _d)	m ³	1.46	Stack Velocity, V _s	$V_s = \frac{\sum_{i=1}^n V_i}{n}$ m/s	7.97
Volume of gas metered wet, V_{mstw}			Actual flow of stack gas, Q_a		
V _{mstw} = V _{mstd} + V _{wstd}	m ³	1.5194	Area of stack, A _s	m ²	1.77
Vol. of gas metered at O₂ Ref. Cond., V_{mstd@X%O2}			Q _a = (60)(A _s)(V _s)	m ³ /min	844.8
Is the process burning hazardous waste? (If yes, no favourable oxygen correction)	No		Total flow of stack gas, Q		
% oxygen measured in gas stream, act%O ₂	20.90		Conversion factor (K/mm.Hg)		
% oxygen reference condition	21		Q _{std} = (Q _a)P _s (0.3592)(1-B _{w0})	Dry	747.8
O ₂ Reference	O ₂ Ref = 21.0 - act%O ₂	No O ₂ Ref	Q _{std@O2} = (Q _a)P _s (0.3592)(1-B _{w0})(O ₂ REF)	@O2ref	No O ₂ Ref
Factor	21.0 - ref%O ₂		Q _{stw} = (Q _a)P _s (0.3592)	Wet	777
V _{mstd@X%oxygen} = (V _{mstd}) (O ₂ Ref)	m ³	No O ₂ Ref	Percent isokinetic, %I		
Moisture content, B_{w0}			Nozzle diameter, D _n	mm	8.1
B _{w0} = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0376	Nozzle area, A _n	mm ²	51.5
		3.76	Total sampling time, q	min	64.0
Moisture by FTIR			%I = $\frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{w0})}$	%	104.8
			Acceptable isokinetic range 95% to 115%		Yes

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS QA CHECKLIST

Leak Test Results	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 litre/min
Run 1	24.6	0.11	-	-406.4	0.49	Yes

Isokinetic Criterion Compliance	Isokinetic Variation %	Acceptable Isokineticity
Run 1	104.8	Yes

Filtration / Temp	Filter Material	Filter Size mm	Maximum Filtration Temperature °C	Temperature during storage / transit <25°C
Run 1	Quartz Fibre	90	180	Yes

Metals	Type of Absorbers - Metals	Absorption Solutions - Metals
Run 1	Glass	3.3% Nitric Acid, 1.5% Hydrogen Peroxide

HEAVY METALS ABSORPTION EFFICIENCY

Parameter		Total ug	3rd Absorber ug	Absorption Efficiency (%)	Required %	Pass / Fail
Chromium	Run 1	14.63000	0.15	99	90	N/A <30% ELV
Cadmium	Run 1	0.61070	ND	100	90	N/A <30% ELV
Nickel	Run 1	22.42910	0.09	100	90	N/A <30% ELV

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	13:45 - 14:45 11 April 2023	0.4	0.40	20	19.30

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

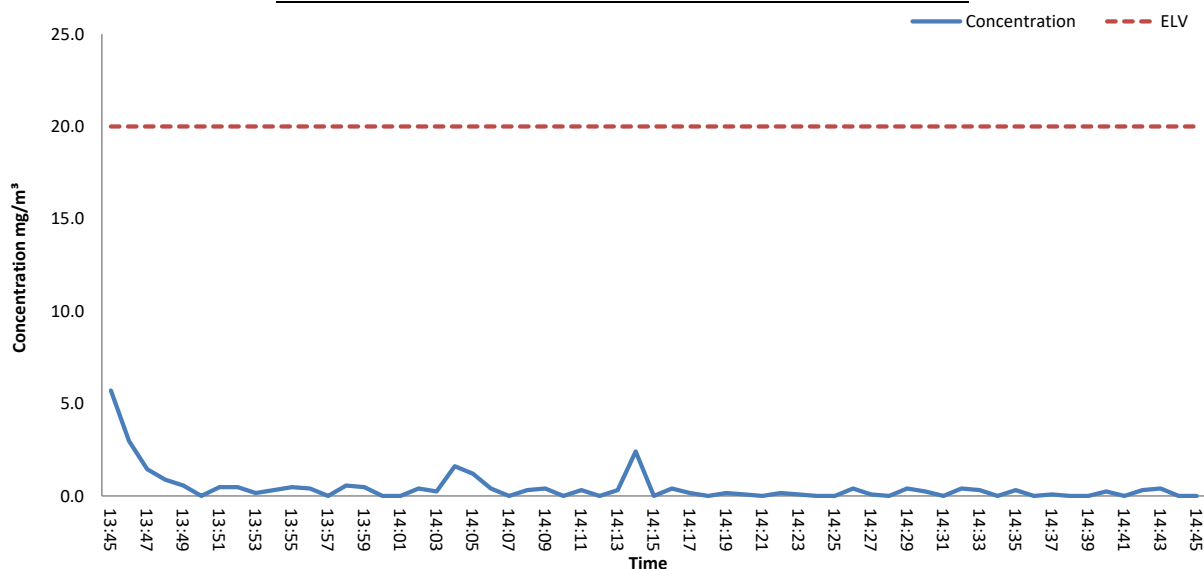
INSTRUMENTAL SPAN & ZERO CHECKS

PRE-SAMPLING CALIBRATION CHECKS								
Date	11 April 2023							
Start Time	11:30							
End Time	11:48							
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	8.4	100	0.00	8.4	0.00	0.02	8.5	-0.24

Zero and Span gas contained 10.06% Oxygen

POST-SAMPLING CALIBRATION CHECKS								
Date	11 April 2023							
Start Time	15:00							
End Time	15:08							
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	0.52	0.04	8.5	0.24	-0.24	x	x	N/A - not corrected

TOTAL VOLATILE ORGANIC COMPOUNDS EMISSIONS CHART



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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

COMBUSTION GASES SUMMARY

Test	Sampling Time and Date	Concentration mg/m ³	LOD mg/m ³	ELV mg/m ³	Emission Rate g/hr
Oxides of Nitrogen	13:45 - 14:45 11 April 2023	2.1	0.49	10	93

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

PRE-SAMPLING CALIBRATION DATA

Date	11 April 2023
Start Time	11:15
End Time	11:40

Chiller Temperature (°C)	3.0
Requirement	< 4°C
Compliant	Yes

Gas	Range (ppm / %)	Zero Reading at analyser	Span Reading at analyser	Zero Check at analyser	Zero Check down line	Span Check down line	Response Time (Secs)	Leak Rate %
Nitric Oxide	250	0.00	202.0	0.10	0.40	202.3	67	-0.15

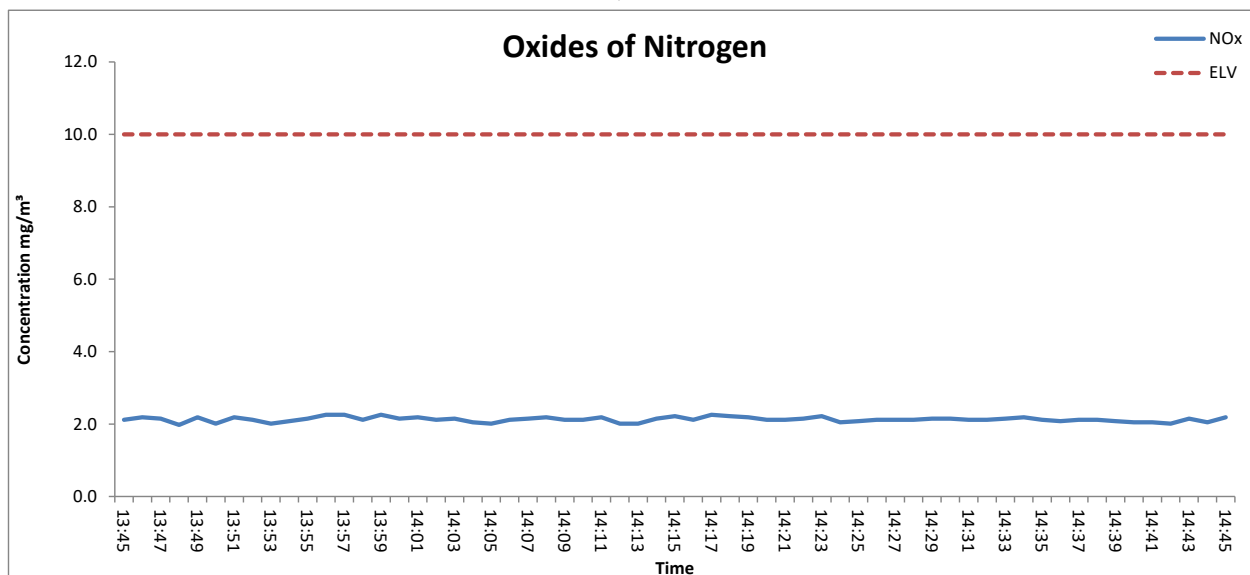
POST-SAMPLING CALIBRATION DATA

Date	11 April 2023
Start Time	15:00
End Time	15:08

Chiller Temperature (°C)	2.0
Requirement	< 4°C
Compliant	Yes

Gas	Zero Check at Analyser	Span Check at Analyser	Zero Drift (%)	Span Drift (%)	Corrected for Zero Drift	Corrected for Span Drift	Corrected Values ppm / %
Nitric Oxide	0.10	202.1	0.00	0.05	x	x	N/A - not corrected

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



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MOISTURE CALCULATIONS

Moisture Determination - Non Isokinetic							
Test Number	Sampling Time and Date	Start Weight kg	End Weight kg	Total gain kg	Concentration %	LOD %	Uncertainty %
Run 1	13:45:00 - 14:52 11 April 2023	3.3944	3.4438	0.0494	3.8	0.01	2.7

Moisture Quality Assurance							
Test Number	Sampling Duration mins	Total Volume Sampled l	Sampling Rate l/min	Start Leak Rate l/min	End Leak Rate l/min	Acceptable Leak Rate l/min	Leak Tests Acceptable?
Run 1	64	1577	24.6	0.11	0.20	0.49	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	1.50	m
Stack Width, W	-	m
Stack Area, A	1.77	m ²
Average stack gas temperature	23	°C
Stack static pressure	-0.027	kPa
Barometric Pressure	101	kPa

Stack Gas Composition & Molecular Weights								
Component	Molar Mass M	Density kg/m ³ p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m ³ pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m ³ pi
CO ₂	44	1.963059	0.028571	0.000286	0.000561	0.027498	0.000275	0.000540
O ₂	32	1.427679	20.900000	0.209000	0.298385	20.114897	0.201149	0.287176
N ₂	28	1.249219	79.071429	0.790714	0.987775	76.101131	0.761011	0.950670
H ₂ O	18	0.803070	-	-	-	3.756474	0.037565	0.030167

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

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2867	kg/m ³
Wet Density (STP), P_{STW}	1.2686	kg/m ³
Dry Density (Actual), P_{Actual}	1.1844	kg/m ³
Average Wet Density (Actual), $P_{ActualW}$	1.168	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	11 April 2023
Time of Survey	11:40
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	0.10	42.5	4.3	23	7.2	12.7	-	<15
2	0.38	49.0	5.0	23	7.7	13.6	-	<15
3	1.13	49.0	5.0	23	7.7	13.6	-	<15
4	1.40	49.0	5.0	23	7.7	13.6	-	<15
Mean	-	47.4	4.8	23	7.6	13.4	-	-

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	0.10	39.2	4.0	22	6.9	12.2	-	<15
2	0.38	42.5	4.3	22	7.2	12.7	-	<15
3	1.13	52.3	5.3	22	7.9	14.0	-	<15
4	1.40	49.0	5.0	23	7.7	13.6	-	<15
Mean	-	45.7	4.7	22	7.4	13.1	-	-

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	130	128	1.5	Pass	122	121	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 5 mins. A drop of less than 5% must be observed.

S-Type Pitot Stagnation Check				
Run	Stagnation (Pa)	Reference (Pa)	Difference (Pa)	Outcome (Permitted +/- 10 Pa)
Run 1	-27	-27	0.0	Pass

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY (CONTINUED)

Sampling Plane Validation Criteria				
EA Technical Guidance Note (Monitoring) M1	Result	Units	Requirement	Compliant
Lowest Average Differential Pressure	39	Pa	≥ 5 Pa	Yes
Lowest Gas Velocity	6.9	m/s	-	-
Highest Gas Velocity	7.9	m/s	-	-
Ratio of Gas Velocities	1.2	-	$< 3 : 1$	Yes
Maximum angle of flow with regard to duct axis	< 15	$^{\circ}$	$< 15^{\circ}$	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, $V = K_{pt} \times (1-e) \times \sqrt{2 \times DP_{pt} / \rho_{ActualW}}$		
Where: K_{pt} = Pitot tube calibration coefficient $(1-e)$ = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, V_a	7.5	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	23	0	$^{\circ}\text{C}$
Total Pressure	100.973	101.3	kPa
Oxygen	20.9	21	%
Moisture	3.76	3.76	%
Pitot tube calibration coefficient, K_{pt}	0.84		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (V_a)	7.49	m/s
Stack Area (A)	1.77	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	47662.96	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	43873.10	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	42225.01	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	43873.10	m^3/hr

Where:

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

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

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

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

Nomenclature:

T_s = Absolute Temperature, Standard Conditions, 273 K

P_s = Absolute Pressure, Standard Conditions, 101.3 kPa

T_a = Absolute Temperature, Actual Conditions, K

P_a = Absolute Pressure, Actual Conditions, kPa

Ma = Water vapour, Actual Conditions, % Vol

Ms = Water vapour, Reference Conditions, % Vol

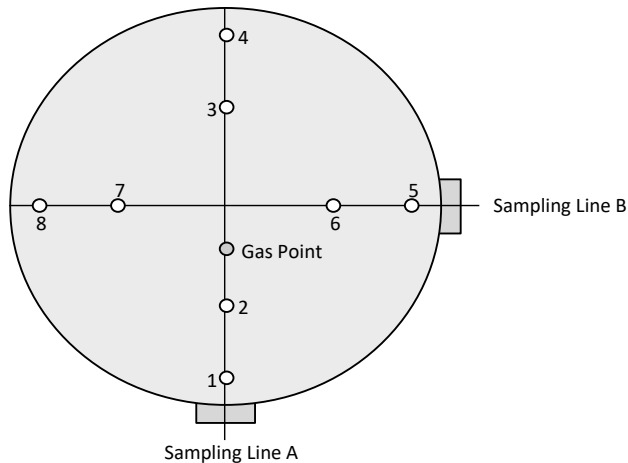
O_{2a} = Oxygen, Actual Conditions, % Vol

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK DIAGRAM

	Value	Units
Stack Depth	1.50	m
Stack Width	-	m
Area	1.77	m ²

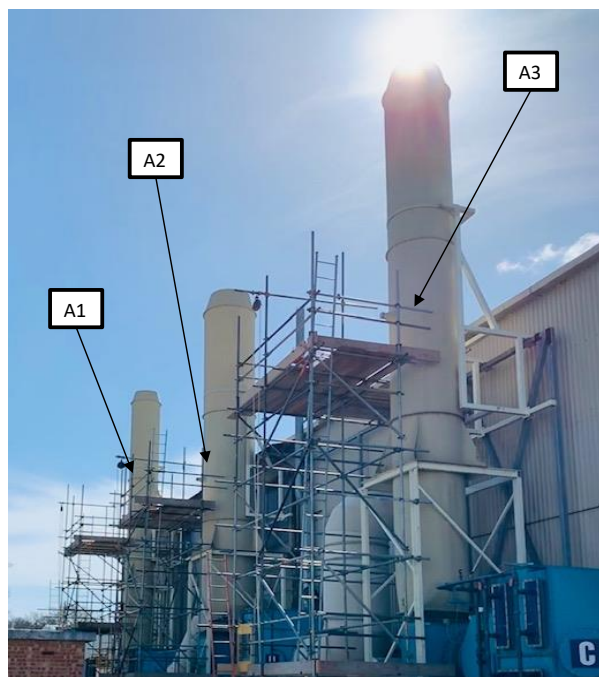


- Isokinetic sampling point
- Isokinetic sampling points not used
- Non Isokinetic/Gases sampling point

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	40	0.60	m

[illegible]

SAMPLING LOCATION



APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - HEAVY METALS

Run	Sampled Volume m ³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Concentration in impinger mg	Leak %
MU required	<=2%	<2.5 k	<=1%	<=1%	<=5%	<5%	<=2%
Run 1	0.003	2.0	0.50	1.0	0.10	0.00	-
as a %	0.20	0.73	0.50	1.0	-	3.00	0.45
compliant?	Yes	Yes	Yes	Yes	N/A	Yes	Yes

Run	Volume (STP) m ³	O2 Correction -	Mass of Heavy Metals mg	Leak mg/m ³	Lab Uncertainty mg	Combined uncertainty
Run 1	1.5149	-	37.6698	0.0001	-	-
MU as mg/m ³	0.0003	-	0.0009	0.0001	0.00130	0.0016
MU as %	1.3498	-	3.5201	0.2577	5.23750	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.003	mg/m³	12.92	% Result	0.21	% 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	0.000	2.0	0.50	1.0	N/A	-
as a %	0.03	0.68	0.50	1.0	N/A	0.45
compliant?	Yes	Yes	Yes	Yes	N/A	Yes

Run	Volume (STP) m ³	Mass Gained mg	O2 Correction -	Leak mg/m ³	Uncollected Mass mg	Combined uncertainty
Run 1	1.5	49400	1.0	80.7	58	-
MU as % v/v	0.05	0.01	-	0.01	0.00	0.05
MU as %	1.3	0.2	-	0.3	0.1	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.11	% v/v	2.70	%
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Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VOLATILE ORGANIC COMPOUNDS RUN 1

Measured Concentration	0.4	mg/m ³
Limit	20	mg/m ³
Calibration Gas Concentration	13.488	mg/m ³
Range	160	mg/m ³

Performance characteristics	Value	Units	specification	MU Met?
Response time	45	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	0.24	% full scale	<5% range / 24hr	Yes
Span drift	-0.24	% 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)	-0.24	% of value	< 2% of span gas value	Yes
Uncertainty of calibration gas	1.0	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	0.02
Standard deviation of repeatability at span level	urs	0.02
Lack of fit	ufit	0.65
Drift	u0dr	0.13
volume or pressure flow dependence	uspres	0.00
atmospheric pressure dependence	uapres	0.04
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	0.14
losses in the line (leak)	uleak	0.00
Uncertainty of calibration gas	ucalib	0.00
Uncertainty in factor	uf	0.00

Measurement uncertainty Measured Concentration	0.44	mg/m ³
Combined uncertainty	0.68	mg/m ³
Expanded uncertainty	1.32	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	6.62	% ELV
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Expanded uncertainty expressed with a level of confidence of 95%	1.32	mg/m ³
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Expanded uncertainty expressed with a level of confidence of 95%	301.02	% value
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Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXIDES OF NITROGEN

Limit value	10	mg/m ³
Concentration @ Ref conditions	2.1	mg/m ³
Cal gas conc	414	mg/m ³
Analyser Full Scale	513	mg/m ³

	Value	Units	specification	MU Met?
Response time	67	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	0.05	% full scale	<5% range / 24hr	Yes
volume or pressure flow dependence	0.25	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.25	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	0.00	% full scale/10K	<3% range / 10 K	Yes
Combined interference	-0.01	% range	<4% of Range	Yes
dependence on voltage	0.00	% 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	$U_{d,z}$	0.0000
short term span drift	$U_{d,s}$	0.0286
influence of Ambient Temp at Zero	$U_{t,z}$	0.0000
influence of Ambient Temp at Span	$U_{t,s}$	0.4500
influence of sample gas pressure	U_p	0.0000
influence of sample gas flow	U_{fit}	0.1732
influence of supply voltage	U_v	0.0024
Combined Interference	U_i	-0.0018
Uncertainty of Cal gas	U_{adj}	2.0200

Measurement uncertainty (Concentration Measured)	2.13	mg/m ³
Combined uncertainty	2.09	ma/m ³
Expanded at a 95% confidence interval	4.10	ma/m ³

Expanded uncertainty expressed with a level of confidence of 95%	40.96	% ELV
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Expanded uncertainty expressed with a level of confidence of 95%	4.1	mg/m ³
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Expanded uncertainty expressed with a level of confidence of 95%	192.6	% value
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MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	7.5	m/s
Measured Volumetric Flow rate at Actual Conditions	47663	m³/hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination	-	0.010		
Uncertainty of pitot tube coefficient	-	0.54		
Uncertainty of mean local dynamic pressures	-	0.591	minimum 3	Yes
Factor loading, function of the number of measurements.	3 readings	1000		
Range of measurement device	pa	1.00		
Resolution	pa	8.67	<1% of Value or 20 Pa whichever is greater	Yes
Calibration uncertainty	pa	0.10		
Drift	% range	0.06	<2% of value	Yes
Linearity	% range	0.00003		
Uncertainty of gas density determination	kg/mol	1.51	<1% of value	Yes
Uncertainty of molar mass determination	K	515		
Uncertainty of temperature measurement	pa	0.007		
Uncertainty of absolute pressure in the duct	kg/m³	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	0.09
Expanded uncertainty at a 95% Confidence Interval	0.18

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	1.3
Expanded uncertainty at a 95% Confidence Interval	2.5

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	1252
Expanded uncertainty at a 95% Confidence Interval	2454

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