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Stack Emissions Testing Report Commissioned by
Xaarjet Ltd

Installation Name & Address

Xaarjet Ltd
1 Hurricane Close
Ermine Business Park
Huntingdon
Cambridgeshire
PE29 6XX

PPC Permit: B22/11

Stack Reference

14 - Validation Lab

Dates of the Monitoring Campaign

24th January 2018

Job Reference Number

CAT-3936

Report Written by
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Executive Summary

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MONITORING OBJECTIVES

Xaarjet Ltd, Huntingdon

14 - Validation Lab

24th January 2018

Overall Aim of the Monitoring Campaign

Exova Catalyst were commissioned by Xaarjet Ltd to carry out stack emissions testing on the 14 - Validation Lab at Huntingdon.

The aim of the monitoring campaign was to demonstrate compliance with a set of emission limit values (ELVs) as specified in the Site's Permit.

Special Requirements

There were no special requirements.

Target Parameters

Total VOCs (as Carbon)

Executive Summary

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MONITORING RESULTS

Xaarjet Ltd, Huntingdon

14 - Validation Lab

24th January 2018

where MU = Measurement Uncertainty associated with the Result

Parameter	Concentration				Mass Emission			
	Units	Result	MU +/-	Limit	Units	Result	MU +/-	Limit
Total VOCs (as Carbon)	¹ mg/m ³	5.5	0.57	75	g/hr	16.6	1.9	-
Stack Gas Temperature	°C	35.3						
Stack Gas Velocity	m/s	6.0	0.17					
Volumetric Flow Rate (ACTUAL)	m ³ /hr	3442	183					
Volumetric Flow Rate (REF)	¹ m ³ /hr	3001	160					

NOTE: VOLUMETRIC FLOW RATE & VELOCITY DATA TAKEN FROM THE PRELIMINARY VELOCITY TRAVERSE.

¹ Reference Conditions (REF) are: 273K, 101.3kPa, without correction for water vapour content.



Executive Summary
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MONITORING DATE(S) & TIMES

Xaarjet Ltd, Huntingdon
14 - Validation Lab
24th January 2018

Parameter		Units	Concentration	Units	Mass Emission	Sampling Date(s)	Sampling Times	Duration mins
Total VOCs (as Carbon)	R1	mg/m³	5.8	g/hr	17.4	24/01/2018	11:03 - 11:33	30
Total VOCs (as Carbon)	R2	mg/m³	5.2	g/hr	15.5	24/01/2018	11:33 - 12:03	30
Total VOCs (as Carbon)	R3	mg/m³	5.7	g/hr	17.0	24/01/2018	12:03 - 12:33	30
Velocity Traverse	R1					24/01/2018	10:13 - 10:22	

All results are expressed at the respective reference conditions.

Executive Summary

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PROCESS DETAILS

Xaarjet Ltd, Huntingdon
14 - Validation Lab
24th January 2018

Standard Operating Conditions

Parameter	Value
Process Status	Plant Operational
Capacity (of 100%) and Tonnes / Hour	Normal Operation
Continuous or Batch Process	Continuous
Feedstock (if applicable)	N/A
Abatement System	None
Abatement System Running Status	N/A
Fuel	N/A
Plume Appearance	None Visible

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MONITORING & ANALYTICAL METHODS

Xaarjet Ltd, Huntingdon

14 - Validation Lab

24th January 2018

Parameter	Monitoring				Analysis				MCERTS Testing	LOD (Average)
	Standard	Technical Procedure	ISO 17025 Testing	Testing Lab	Analytical Procedure	Analytical Technique	ISO 17025 Analysis	Analysis Lab		
Total VOCs (as Carbon)	EN 12619:2013	CAT-TP-20	Yes	CAT	Flame Ionisation Detection by Sick 3006 FID				Yes	0.32 mg/m ³
Velocity & Vol. Flow Rate	EN 16911-1 (MID)	CAT-TP-41	Yes	CAT	Pitot Tube and Thermocouple				Yes	1.2 m/s

ANALYSIS LABORATORIES

(with short name reference as appears in the table above)

Exova Catalyst (CAT)	ISO 17025 Accreditation Number: 4279
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SUMMARY OF SAMPLING DEVIATIONS

Parameter	Run	Deviation
All Parameters	All	There are no deviations associated with the sampling employed.

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SUITABILITY OF SAMPLING LOCATION

Duct Characteristics

Parameter	Units	Value
Type	-	Circular
Depth	m	0.45
Width	m	-
Area	m ²	0.16
Port Depth	cm	0
Orientation of Duct	-	Vertical
Number of Ports	-	1
Sample Port Size	-	2" Hole

Location of Sampling Platform

General Platform Information	Value
Permanent / Temporary Platform	On Ground
Inside / Outside	Inside

Platform Details

EA Technical Guidance Note M1 / EN 15259 Platform Requirements	Value
Sufficient working area to manipulate probe and operate the measuring instruments	Yes
Platform has 2 levels of handrails (approx. 0.5m & 1.0m high)	N/A
Platform has vertical base boards (approx. 0.25m high)	N/A
Platform has chains / self closing gates at top of ladders	N/A
There are no obstructions present which hamper insertion of sampling equipment	Yes
Safe Access Available	Yes
Easy Access Available	Yes

Sampling Location / Platform Improvement Recommendations

The sampling location meets all the requirements specified in EA Guidance Note M1 and EN 15259, and therefore there are no improvement recommendations.

EN 15259 Homogeneity Test Requirements

There is no requirement to perform a EN 15259 Homogeneity Test on this Stack.

Sampling Plane Validation Criteria (from EN 15259)

Criteria in EN 15259	Units	Traverse 1		Required	Compliant
Lowest Differential Pressure	Pa	16.0		> 5 Pa	Yes
Mean Velocity	m/s	6.01		-	-
Lowest Gas Velocity	m/s	4.47		-	-
Highest Gas Velocity	m/s	7.84		-	-
Ratio of Above	: 1	1.75		< 3 : 1	Yes
Maximum Angle of Swirl	°	NM		< 15°	NM
No Local Negative Flow	-	Yes		-	Yes

Where NM = Not Measured as no Isokinetic sampling was performed.

Executive Summary

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PLANT PHOTOS

Photo 1



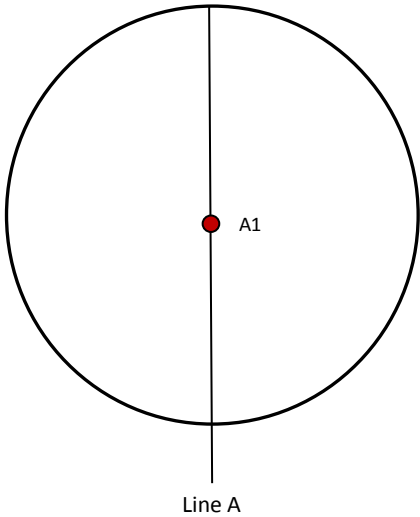
Photo 2



Photo 3



SAMPLE POINTS



- where

○ = isokinetic point sampled at

● = isokinetic point not sampled at

● = combustion gases sample point

○ = non-isokinetic sample point

APPENDICES

APPENDIX CONTENTS

APPENDIX 1 - Stack Emissions Monitoring Personnel, List of Equipment & Methods and Technical Procedures Used

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK EMISSIONS MONITORING PERSONNEL

Position	Name	MCERTS Accreditation	MCERTS Number	Technical Endorsements
Team Leader	Harpreet Badwal	MCERTS Level 2	MM 03 149	TE1 TE2 TE3 TE4
Technician	Mathew Miller	MCERTS Level 1	MM 14 1313	None

LIST OF EQUIPMENT

Extractive Sampling		Instrumental Analysers		Miscellaneous Items	
Equipment Type	Equipment I.D.	Equipment Type	Equipment I.D.	Equipment Type	Equipment I.D.
Control Box DGM (1)	-	Horiba PG-350E	-	Digital Manometer (1)	CAT 3.142
Control Box DGM (2)	-	Horiba PG-250	-	Digital Manometer (2)	CAT 3.144
Box Thermocouples (1)	-	Servomex 4900	-	Digital Temperature Meter	-
Box Thermocouples (2)	-	Eco Physics CLD 822Mh	-	Stopwatch	CAT 14.84
Umbilical (1)	-	ABB AO2020-URAS26	-	Barometer	CAT 13.40
Umbilical (2)	-	Testo 350 XL	-	Stack Thermocouple (1)	CAT 4.874
Oven Box (1)	-	Ankersmid APS 313	-	Stack Thermocouple (2)	CAT 4.870
Oven Box (2)	-	ProtiR 204M	-	Stack Thermocouple (3)	-
Heated Probe (1)	-	Gasmet Sampling System	-	1m Heated Line (1)	-
Heated Probe (2)	-	Bernath 3006 FID	CAT 8.31	1m Heated Line (2)	-
Heated Probe (3)	-	M&C PSS	CAT 12.107	1m Heated Line (3)	-
S-Pitot (1)	CAT 21S.57	Mass Flow Controller (1)	CAT 6.61	5m Heated Line (1)	-
S-Pitot (2)	-	Mass Flow Controller (2)	CAT 6.62	15m Heated Line (1)	CAT 20.117
L-Pitot	CAT 21L.44	Mass View (1)	-	20m Heated Line (1)	-
Site Balance	-	Mass View (2)	-	20m Heated Line (2)	-
500g / 1Kg Check Weights	-	Hioki 5043 (V)	CAT 11.69	Dual Channel Heater Controller	-
Last Impinger Arm	-	Easylogger EN-EL-12 Bit	-	Single Channel Heater Controller	CAT 20.117
Callipers	-	Bioaerosols Temperature Logger	-	Laboratory Balance	-
Tubes Kit Thermocouple	-	Electronic Refrigerator	-	Tape Measure	CAT 16.45

METHODS & TECHNICAL PROCEDURES USED

Parameter	Standard	Technical Procedure
Total VOCs (as Carbon)	EN 12619:2013	CAT-TP-20
Velocity & Vol. Flow Rate	EN 16911-1 (MID)	CAT-TP-41

PRELIMINARY STACK SURVEY: CALCULATIONS

General Stack Details

Stack Details (from Traverse)	Units	Value
Stack Diameter / Depth, D	m	0.45
Stack Width, W	m	-
Stack Area, A	m ²	0.16
Average Stack Gas Temperature, T _a	°C	35.3
Average Stack Gas Pressure	Pa	29.8
Average Stack Static Pressure, P _{static}	kPa	0.021
Average Barometric Pressure, P _b	kPa	99.7
Average Pitot Tube Calibration Coefficient, C _p	-	0.84

Stack Gas Composition & Molecular Weights

Component	Conc ppm	Conc Dry % v/v	Conc Wet % v/v	Volume Fraction r	Molar Mass M	Density kg/m ³ p	Conc kg/m ³ p _i
CO ₂ (Estimated)	-	0.06	0.06	0.0006	44.01	1.9635	0.00118
O ₂ (Estimated)	-	20.80	20.70	0.2080	32.00	1.4277	0.29696
N ₂	-	79.14	78.74	0.7914	28.01	1.2498	0.98913
Moisture (H ₂ O) (Estimated)	-	-	0.50	0.0050	18.02	0.8037	0.00402

NOTE: Moisture has been estimated as no moisture test was performed on the date(s) of testing

Where: $p = M / 22.41$

$p_i = r \times p$

Calculation of Stack Gas Densities

Determinand	Units	Result
Dry Density (STP), P _{STD}	kg/m ³	1.287
Wet Density (STP), P _{STW}	kg/m ³	1.285
Dry Density (Actual), P _{Actual}	kg/m ³	1.122
Average Wet Density (Actual), P _{ActualW}	kg/m ³	1.120

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

P_{STW} = sum of all wet concentrations / 100 x density, kg/m³ (including water vapour)

$P_{Actual} = P_{STD} \times (T_{STP} / (P_{STP})) \times ((P_{static} + P_b) / T_a)$

$P_{ActualW} \text{ (at each sampling point)} = P_{STW} \times (T_s / P_s) \times (P_a / T_a)$

Calculation of Stack Gas Volumetric Flowrate, Q

Duct gas flow conditions	Units	Actual	REF ¹
Temperature	°C	35.3	0.0
Total Pressure	kPa	99.7	101.3
Moisture	%	1.00	1.00

Gas Volumetric Flowrate (from Traverse)	Units	Result
Gas Volumetric Flowrate (Actual)	m ³ /hr	3442
Gas Volumetric Flowrate (STP, Wet)	m ³ /hr	3001
Gas Volumetric Flowrate (STP, Dry)	m ³ /hr	2971
Gas Volumetric Flowrate REF ¹	m ³ /hr	3001

PRELIMINARY STACK SURVEY: VELOCITY TRAVERSE TO EN 16911-1 (MID)

(1 of 1)

Parameter	Units	Value
Date of Survey	-	24/01/2018
Time of Survey	-	10:13 - 10:22
Atmospheric Pressure	kPa	99.7
Average Stack Static Pressure	Pa	21
Result of Pitot Stagnation Test	-	Pass
Are Water Droplets Present?	-	No
Device Used	S-Type Pitot with KIMO MP 210 (500Pa)	

Parameter	Units	Value
Initial Pitot Leak Check	-	Pass
Final Pitot Leak Check	-	Pass
Orientation of Duct	-	Vertical
Pitot Tube, C_p	-	0.84
Number of Lines Available	-	1
Number of Lines Used	-	1

Sampling Line A						
Traverse Point	Depth m	ΔP Pa	Temp °C	Wet Density kg/m ³	Velocity m/s	Swirl °
STATIC (Units: Pa)		21.0				
Mean		29.8	35.3	1.120	6.01	
1	0.02	34.0	34.8	1.122	6.52	
2	0.07	22.0	35.0	1.121	5.25	
3	0.13	16.0	35.2	1.120	4.47	
4	0.32	23.0	35.4	1.120	5.37	
5	0.38	35.0	35.5	1.119	6.62	
6	0.43	49.0	35.6	1.119	7.84	

PRELIMINARY STACK SURVEY: VELOCITY TRAVERSE TO EN 16911-1 (MID) - MEASUREMENT UNCERTAINTY

(1 of 1)

Performance characteristics (Uncertainty Components)	Uncertainty	Value	Units
Standard Uncertainty on the coefficient of the Pitot Tube	$u(k)$	0.005	-
Standard Uncertainty associated with the mean local dynamic pressures	$u(\Delta p_i)$	1.094	Pa
- Resolution	$u(res)$	0.00087	
- Calibration	$u(cal)$	0.093	
- Drift	$u(drift)$	0.083	
- Lack of Fit	$u(fit)$	0.021	
- Overall corrections to dynamic measurements	$u(C_f)$	0.198	
Standard uncertainty associated with the molar mass of the gas	$u(M)$	0.00003	-
- $\phi_{O_2,w}$	-	20.696	
- $\phi_{CO_2,w}$	-	0.060	
- Oxygen, dry	$u(\phi_{O_2,d})$	0.637	
- Carbon Dioxide, dry	$u(\phi_{CO_2,d})$	0.002	
- Water Vapour	$u(\phi_{H_2O})$	0.026	
- Oxygen, wet	$u(\phi_{O_2,w})$	0.634	
- Carbon Dioxide, wet	$u(\phi_{CO_2,w})$	0.002	
Standard uncertainty associated with the stack temperature	$u(T_c)$	1.573	K
Standard uncertainty associated with the absolute pressure in the duct	$u(p_c)$	175.695	Pa
- Atmospheric Pressure	$u(p_{atm})$	175.692	
- Static Pressure	$u(p_{stat})$	1.094	
Standard uncertainty associated with the density in the duct	$u(\rho)$	0.00605	-
Standard uncertainty associated with the local velocities	$u(v_i)$	0.139	Pa
Standard uncertainty associated with the mean velocity	$u(\bar{v})$	0.085	m/s
Standard uncertainty associated with the mean velocity (95% Confidence)	$U_c(v)$	0.167	m/s
Standard uncertainty associated with the mean velocity (95% Confidence), relative	$U_{c,rel}(v)$	2.79	%
Standard uncertainty associated with the volume flow rate (95% Confidence)	$U_c(qV,w)$	182.9	m ³ /hr
- $u^2(a)/a^2$	-	0.00053	
- $u^2(qV,w)/q^2V,w$	-	0.00074	
- $u^2(qV,w)$	-	8712	
- $u(qV,w)$	-	93.3	
Standard uncertainty associated with the volume flow rate (95% Confidence), relative	$U_{c,rel}(qV,w)$	5.32	%

TOTAL VOCs (as CARBON): RESULTS SUMMARY

Xaarjet Ltd, Huntingdon
14 - Validation Lab

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Mean
Concentration	mg/m ³	5.8	5.2	5.7	5.5
Uncertainty	±mg/m ³	0.57	0.57	0.57	0.57
Mass Emission	g/hr	17.4	15.5	17.0	16.6
Uncertainty	±g/hr	2.0	1.9	1.9	1.9

General Sampling Information

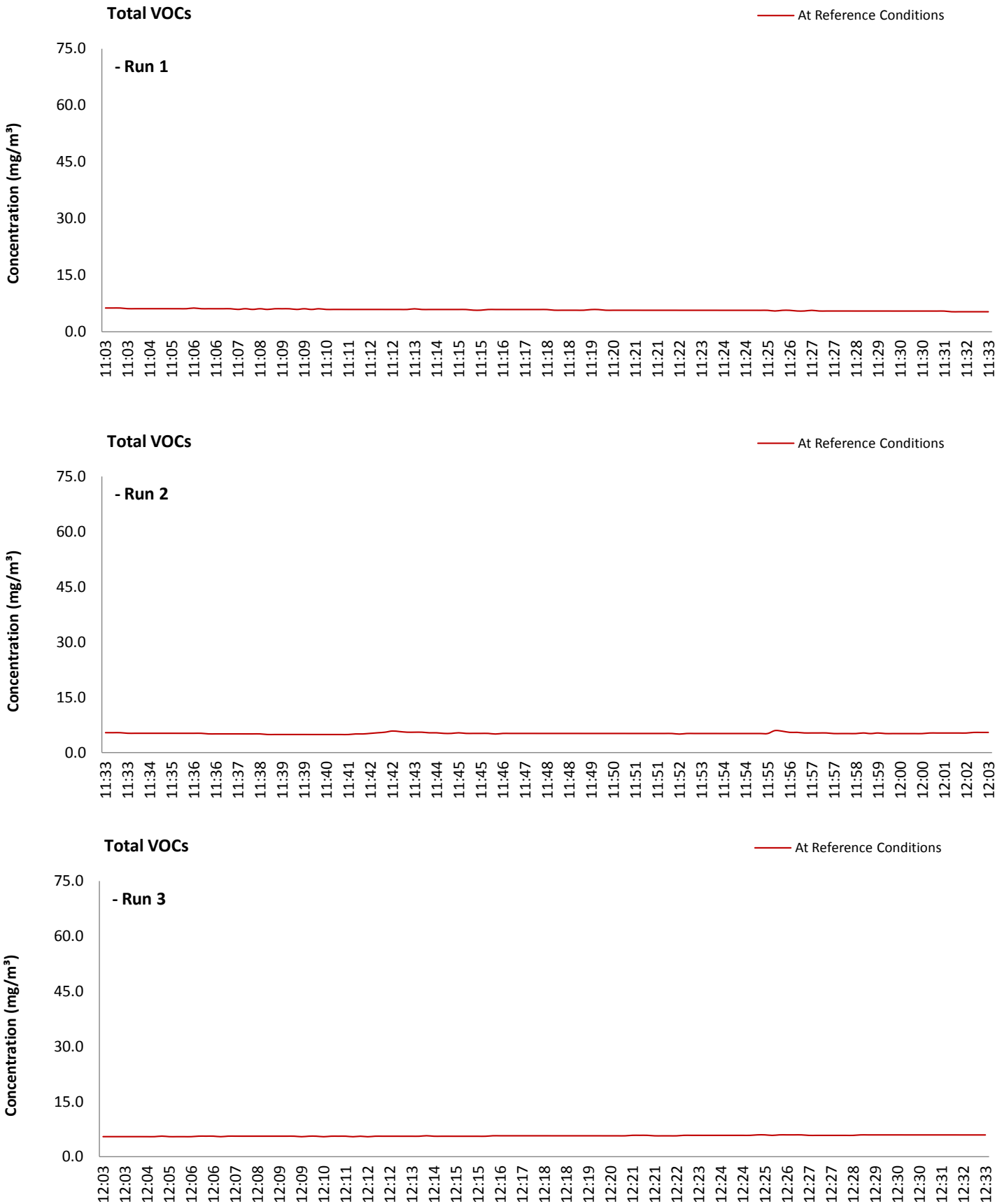
Parameter	Value	
Standard	EN 12619:2013	
Technical Procedure	CAT-TP-20	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Span Gas Type	Propane In Synthetic Air (5 Grade)	
Span Gas Reference Number	CYL 1.0293a	
Span Gas Expiry Date	12/09/2021	
Span Gas Start Pressure (bar)	70	
Gas Cylinder Concentration (ppm)	79.9	
Span Gas Set Point (ppm)	79.90	
Span Gas Uncertainty (%)	N/A	
Zero Gas Type	Synthetic Air (5 Grade)	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

Reference Conditions

Reference Conditions are: 273K, 101.3kPa, without correction for water vapour content.

TOTAL VOCs (as CARBON): DATA TREND

Graphical Trend of Data



TOTAL VOCs (as CARBON): SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	Run 2	Run 3
Sampling Times	-	11:03 - 11:33	11:33 - 12:03	12:03 - 12:33
Sampling Dates	-	24/01/2018	24/01/2018	24/01/2018
Instrument Range	ppm	100	100	100
Span Gas Value	ppm	79.9	79.9	79.9

Quality Assurance

Zero Drift		Units	Run 1	Run 2	Run 3
CAL 1	Zero Down Sampling Line (Pre)	ppm	0.00	0.00	0.00
	Zero Down Sampling Line (Post)	ppm	0.20	0.20	0.20
	Zero Drift	ppm	0.20	0.20	0.20
	Allowable Zero Drift	± ppm	4.00	4.00	4.00
	Zero Drift Acceptable	-	Yes	Yes	Yes
Span Drift		Units	Run 1	Run 2	Run 3
CAL 1	Span Down Sampling Line (Pre)	ppm	80.10	80.10	80.10
	Span Down Sampling Line (Post)	ppm	80.20	80.20	80.20
	Span Drift	ppm	0.10	0.10	0.10
	Allowable Span Drift	± ppm	4.00	4.00	4.00
	Span Drift Acceptable	-	Yes	Yes	Yes
Test Conditions		Units	Run 1	Run 2	Run 3
Run Ambient Temperature Range		°C	4 - 9	4 - 9	4 - 9

Method Deviations

Nature of Deviation (x = deviation applies to the associated run)	Run Number		
	1	2	3
There are no deviations associated with the sampling employed.	x	x	x

TOTAL VOCs (as CARBON): MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1	RUN 2	RUN 3	Units
Limit value	75.0	75.0	75.0	mg/m ³ (REF)
TGN M2 Allowable MU	15.0	15.0	15.0	%
Measured concentration	5.85	5.21	5.73	mg/m ³ (STP, dry)
Range Used	100.0	100.0	100.0	ppm
Range Used [A]	160.6	160.6	160.6	mg/m ³
Cal gas conc.	79.9	79.9	79.9	ppm
Conversion	1.61	1.61	1.61	ppm to mg/m ³
MCERTS Range [B]	15.0	15.0	15.0	mg/m ³
Lower of [A] or [B]	15.0	15.0	15.0	mg/m ³
Cal gas conc.	128.3	128.3	128.3	mg/m ³

Performance characteristics	RUN 1	RUN 2	RUN 3	Units
Response time	45	45	45	seconds
Number of readings in measurement	30	30	30	-
Repeatability at zero	2.00	2.00	2.00	% full scale
Repeatability at span level	0.00	0.00	0.00	% full scale
Deviation from linearity	0.00	0.00	0.00	% of value
Zero drift	0.25	0.25	0.25	% full scale
Span drift	0.12	0.12	0.12	% full scale
Volume or pressure flow dependence	1.60	1.60	1.60	% of full scale
Atmospheric pressure dependence	0.30	0.30	0.30	% of value/kPa
Ambient temperature dependence	1.40	1.40	1.40	% full scale/10K
Combined interference	0.45	0.45	0.45	% range
Dependence on voltage	0.50	0.50	0.50	% full scale/10V
Losses in the line (leak)	0.00	0.00	0.00	% of value
Uncertainty of calibration gas	2.00	2.00	2.00	% of value

Performance characteristic	RUN 1	RUN 2	RUN 3	Units
Standard deviation of repeatability at zero	use rep at span	use rep at span	use rep at span	mg/m ³
Standard deviation of repeatability at span level	0.00	0.00	0.00	mg/m ³
Lack of fit	0.00	0.00	0.00	mg/m ³
Drift	0.19	0.19	0.19	mg/m ³
Volume or pressure flow dependence	0.00	0.00	0.00	mg/m ³
Atmospheric pressure dependence	0.01	0.01	0.01	mg/m ³
Ambient temperature dependence	0.20	0.20	0.20	mg/m ³
Combined interference (from MCERTS Certificate)	0.04	0.04	0.04	mg/m ³
Dependence on voltage	0.06	0.06	0.06	mg/m ³
Losses in the line (leak)	0.00	0.00	0.00	mg/m ³
Uncertainty of calibration gas	0.07	0.06	0.07	mg/m ³

Measurement uncertainty	Result	RUN 1	RUN 2	RUN 3	Units
Combined uncertainty		5.85	5.21	5.73	mg/m ³
Expanded uncertainty	k = 1.96	0.30	0.29	0.30	mg/m ³
Uncertainty corrected to std conds. (O ₂)		0.58	0.58	0.58	mg/m ³ (REF)

	RUN 1	RUN 2	RUN 3	Units
Expanded uncertainty (no O ₂) - at 95% Confidence	9.93	11.08	10.12	% of Value
Expanded uncertainty (no O ₂) - at 95% Confidence	0.77	0.77	0.77	% at ELV
Overall Allowable uncertainty (no O ₂) - at 95% Confidence	15.0	15.0	15.0	% at ELV
Result of Compliance with Uncertainty Requirement in M2	COMPLIANT	COMPLIANT	COMPLIANT	-

	RUN 1	RUN 2	RUN 3	Units
Expanded uncertainty (with O ₂) - at 95% Confidence	N/A	N/A	N/A	% of Value
Expanded uncertainty (with O ₂) - at 95% Confidence	N/A	N/A	N/A	% at ELV
Overall Allowable uncertainty (with O ₂) - at 95% Confidence	N/A	N/A	N/A	% at ELV
Result of Compliance with Uncertainty Requirement in M2	N/A	N/A	N/A	-

Requirement for SRM is that Uncertainty should be <15% of the value at the ELV, on a dry gas basis, or if O₂ correction is applied less than 15% + the uncertainty associated with the O₂ correction (using sqrt of sum squares to add uncertainty components). Ref EA TGN M2.