

STACK EMISSIONS MONITORING REPORT



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Operator & Address:

Enovert
Port Tennent Landfill Site
Fabian Way
Port Tennent
Swansea
SA1 8PA

Permit Reference:

EPR Permit: BP3738LS

Release Point:

Jenbacher J320 Engine 1

Sampling Date(s):

11th March 2020

SOCOTEC UK Job Number:	LSO 200317
Report Date:	10th April 2020
Version:	1
Report By:	Jonathan Ward
MCERTS Number:	MM02 080
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Mike Davies
MCERTS Number:	MM 02 087
Business Title:	MCERTS Level 2 - Business Manager
Technical Endorsements:	1, 2, 3 & 4
Signature:	



1015



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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Enovert operates a power generation process at Port Tennent Landfill Site which is subject to EPR Permit BP3738LS, under the Environmental Permitting Regulations 2010.

SOCOTEC UK LTD were commissioned by Graham Ball 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, BP3738LS.

Plant

Jenbacher J320 Engine 1

Operator

Enovert
Port Tennent Landfill Site
Fabian Way
Port Tennent
Swansea
SA1 8PA

EPR Permit: BP3738LS

Stack Emissions Monitoring Test House

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

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

EMISSIONS SUMMARY					
Parameter	Units	Result	LFTGN 08[2010] Uncertainty +/-	Calculated Uncertainty +/-	Limit
Volatile Organic Compounds	mg/m ³	1748	699	73	1750
Volatile Organic Compounds ppm	ppm	773	309	32	
Oxides of Nitrogen (as NO ₂)	mg/m ³	631	189	9.3	650
Oxides of Nitrogen (as NO ₂) ppm	ppm	268	80	3.9	
Carbon Monoxide	mg/m ³	1804	361	23	1500
Carbon Monoxide ppm	ppm	1258	252	16	
Oxygen	% v/v	7.0	0.5	0.5	-
Moisture	%	12.8	0.4	0.40	-
Stack Gas Temperature	°C	511	-	-	-

ND - NoneDetected

The result is considered non compliant if the result minus the MU is above the limit (LFTGN 05 [2010])

The MU for the purposes of compliance assessment is calculated from values in LFTGN 05 [2010]. i.e. 20% of the result for CO, 30% of the result for NOx & 40% of the result for VOCs.

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

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	Sampling Date(s)	Sampling Times	Sampling Duration
Volatile Organic Compounds Run 1	11 March 2020	11:30 - 12:30	60 minutes
Combustion Gases	11 March 2020	11:30 - 12:30	60 minutes

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Power Generation
Maximim Rate KW/H	822
Actual Rate KW/H	701
Fuel used during monitoring	Landfill Gas
% Methane	46.08
% Carbon Dioxide	28.6
% Oxygen	0.4
Abatement	None

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard reference / alternative methods employed by SOCOTEC UK is determined, wherever possible by the hierarchy of method selection outlined in Environment Agency Technical Guidance Note (Monitoring) M2.

MONITORING METHODS						
Species	Method Standard Reference Method / Alternative Method	SOCOTEC UK Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Limit of Detection (LOD)	Calculated MU +/- %
VOCs	SRM - BS EN 12619:2013	AE 102	1015	Yes	0.31 mg/m ³	4.2%
NO _x	SRM - BS EN 14792:2017	AE 102	1015	Yes	1.18 mg/m ³	1.5%
CO	SRM - BS EN 15058:2017	AE 102	1015	Yes	1.58 mg/m ³	1.3%
O ₂	AM - BS EN 14789:2017	AE 102	1015	Yes	0.01%	7.0%
H ₂ O	SRM - BS EN 14790	AE 105	1015	Yes	0.1%	3.14%

EXECUTIVE SUMMARY

Analytical Methods

The following tables list the analytical methods employed together with the custody and archiving details:

SAMPLING METHODS WITH SUBSEQUENT ANALYSIS							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	UKAS Accredited Lab Analysis	Analysis Lab	Sample Archive Location	Archive Period
-	-	-	-	-	-	-	-

ON-SITE TESTING							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	MCERTS Accredited Analysis	Laboratory	Data Archive Location	Archive Period
VOCs	Flame Ionisation Detection	AE 102	1015	Yes	SOCOTEC UK - (Cirencester)	SOCOTEC UK - (Cirencester)	5 years
NO _x	Chemiluminescence	AE 102	1015	Yes	SOCOTEC UK - (Cirencester)	SOCOTEC UK - (Cirencester)	5 years
CO	Non Dispersive Infra Red	AE 102	1015	Yes	SOCOTEC UK - (Cirencester)	SOCOTEC UK - (Cirencester)	5 years
O ₂	Zirconia Cell	AE 102	1015	Yes	SOCOTEC UK - (Cirencester)	SOCOTEC UK - (Cirencester)	5 years
H ₂ O	Gravimetric	AE 105	1015	Yes	SOCOTEC UK - (Cirencester)	-	-

EXECUTIVE SUMMARY

DUCT CHARACTERISTICS		
	Value	Units
Shape	Circular	-
Depth	0.30	m
Width	-	m
Area	0.07	m ²
Port Depth	5mm	mm

SAMPLING LINES & POINTS		
	Isokinetic	Non-Iso & Gases
Sample port size	-	10mm Hole
Number of lines used	-	1
Number of points / line	-	1
Duct orientation	-	Vertical

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

Flow traverse

Due to the size and orientation of the sampling port it was not possible to perform a flow traverse, therefore mass emissions cannot be reported.

Unheated Probe

The sampling hole is of a relatively small diameter and as such it is not large enough for SOCOTEC UK to use a heated probe during the sampling of water vapour. However it should be noted that the stack temperature is C and the entire sampling train was weighed during

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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 UK Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Number of Samples
VOCs	SRM - BS EN 12619:2013	AE 102	1015	Yes	1
NOx	SRM - BS EN 14792:2017	AE 102	1015	Yes	1
CO	SRM - BS EN 15058:2017	AE 102	1015	Yes	1
O ₂	AM - BS EN 14789:2017	AE 102	1015	Yes	1
H ₂ O	SRM - BS EN 14790	AE 105	1015	Yes	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	-	Horiba PG-250 Analyser	P2759	Laboratory Balance	P66
Box Thermocouples	-	FT-IR Gasmet	-	Tape Measure	P1758
Meter In Thermocouple	-	FT-IR Oven Box	-	Stopwatch	P2241
Meter Out Thermocouple	-	Bernath 3006 FID	P1407	Protractor	-
Control Box Timer	-	Signal 3030 FID	-	Barometer	P2236
Oven Box	-	Servomex	-	Digital Micromanometer	-
Probe 3ft	-	JCT Heated Head Filter	-	Digital Temperature Meter	P1268
Probe Thermocouple	-	Thermo FID	-	Stack Thermocouple	P2017
Probe 5ft	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	Wet Gas Meter	-
S-Pitot	-	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Chiller (Testotherm)	-	1m Heated Line (2)	-
Site Balance	P1774	Chiller (JCT/MAK 10)	P2051	1m Heated Line (3)	-
Last Impinger Arm	-	Chiller (Horiba PCT100)	-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (Kletti)	P2382	10m Heated Line (Winkler)	P2437
Callipers	-	Heated Line Controller (O Brien)	-	10m Heated Line (2)	-
Small DGM	-		P2607	15m Heated Line (1)	-
Heater Controller	-		P2203	20m Heated Line (Kletti)	P2740
Inclinometer (Swirl Device)	-		-	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	CJ6	BOC	-	10.1	2.0
Propane	CJ6	BOC	780	-	2.0
Nitric Oxide	SB16	BOC	407	-	2.0
Carbon Monoxide	CJ6	BOC	814	-	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	MM02 080	MCERTS Level 2	Jun-20	Mar-23	Jun-23	Aug-21	Mar-21	Jun-20
Warren Clark	MM 02 086	MCERTS Level 2	Sep-22	-	-	-	-	Sep-22

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

VOLATILE ORGANIC COMPOUNDS SUMMARY

Test	Sampling Times	Concentration mg/m ³	LOD mg/m ³	Limit mg/m ³	Emission Rate g/hr
Run 1	11:30 - 12:30 11 March 2020	1747.8	0.22	1750	-

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

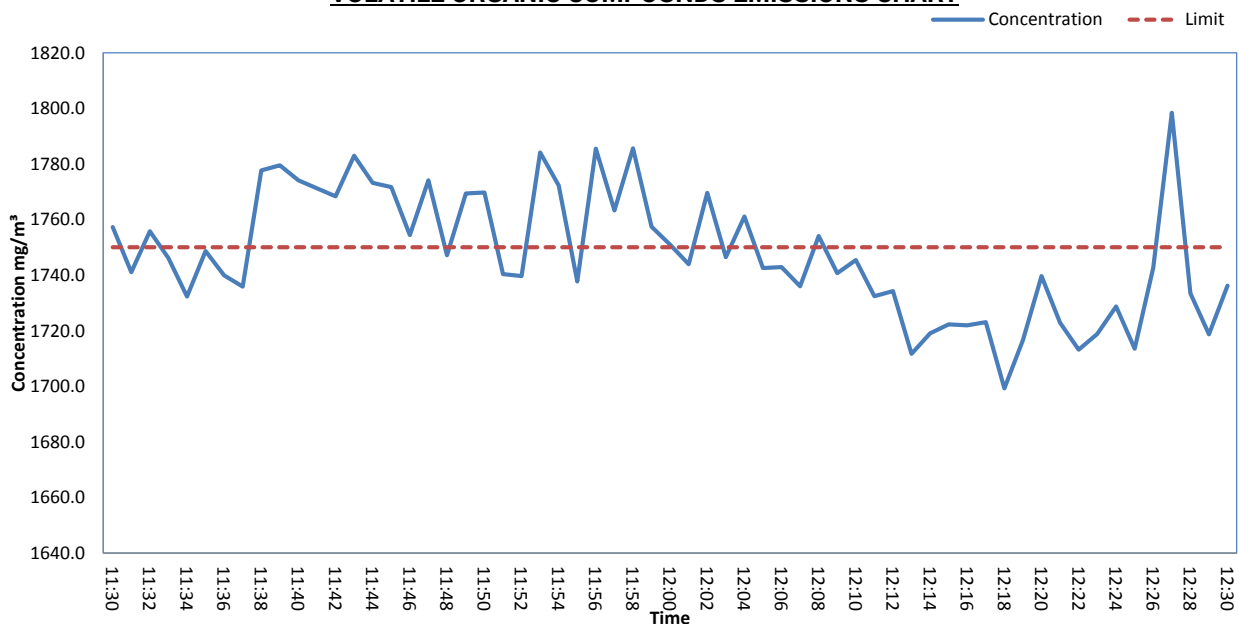
INSTRUMENTAL SPAN & ZERO CHECKS

PRE-SAMPLING CALIBRATION CHECKS								
Date	11 March 2020							
Start Time	10:20							
End Time	10:42							
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	780.0	1000	0.00	780.0	1.22	1.55	780.8	-0.10

Zero and Span gas contained 10.1% Oxygen

POST-SAMPLING CALIBRATION CHECKS				
Date	11 March 2020			
Start Time	12:42			
End Time	13:06			
Gas	Zero down line reading	Span down line reading	Zero Drift (%)	Span Drift (%)
Propane	1.82	783.2	0.03	0.27

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	Limit mg/m ³	Emission Rate g/hr
NO _x	11:30 - 12:30 11 March 2020	631	1.2	650	-
CO	11:30 - 12:30 11 March 2020	1804	1.6	1500	-

Test	Sampling Time and Date	Concentration %	LOD %
O ₂	11:30 - 12:30 11 March 2020	7.04	0.01

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

PRE-SAMPLING CALIBRATION DATA

Date	11 March 2020
Start Time	10:20
End Time	10:42

Chiller Temperature (°C)	1.0
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 %
NO	500	0.00	407.0	0.80	1.20	410.3	67	-0.81
CO	1000	0.00	814.0	2.00	1.00	812.0	54	0.25
O ₂	25	0.00	10.10	0.05	0.03	10.15	45	-0.50

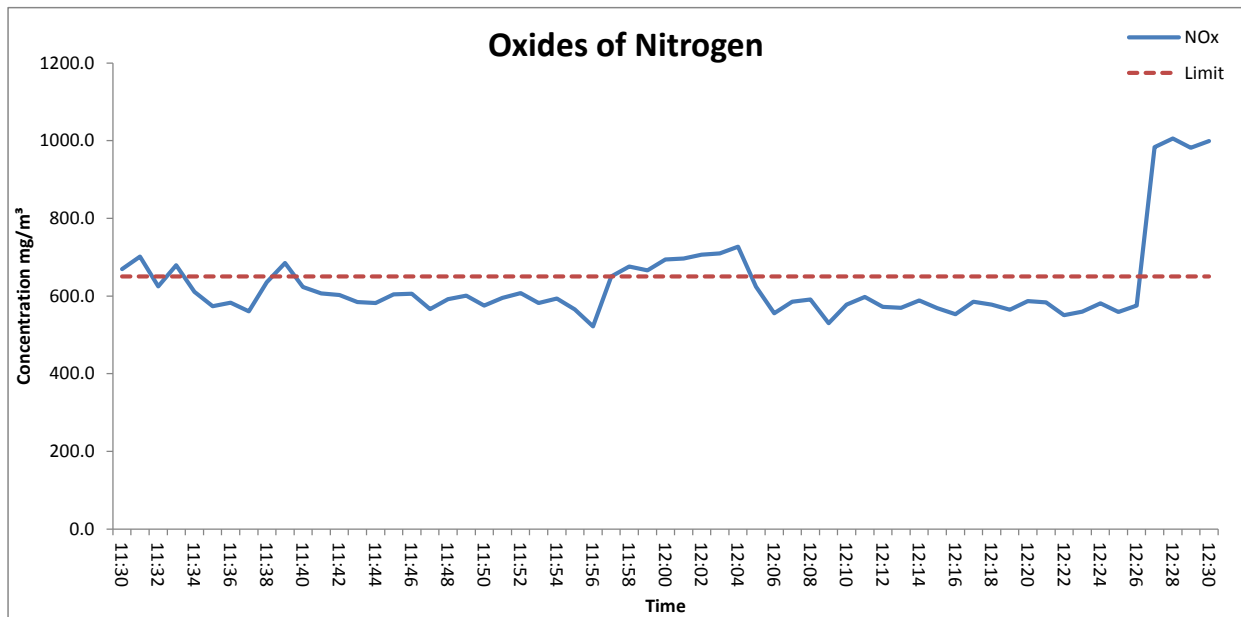
POST-SAMPLING CALIBRATION DATA

Date	11 March 2020
Start Time	12:42
End Time	13:06

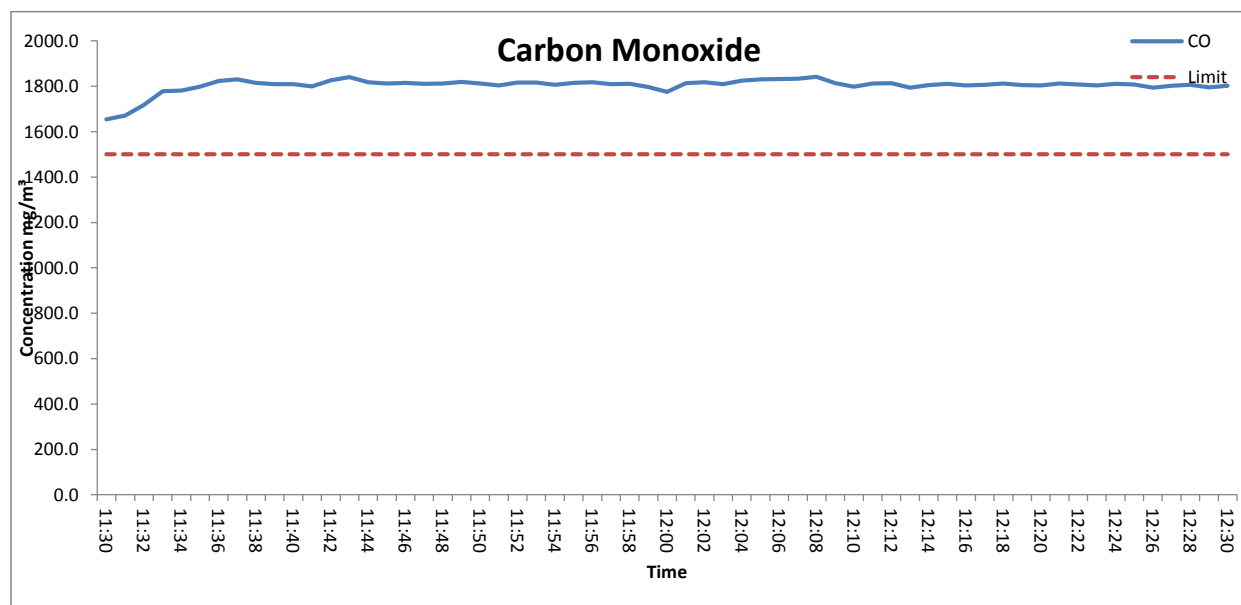
Chiller Temperature (°C)	1.0
Requirement	< 4°C
Compliant	Yes

Gas	Zero Check down line	Span Check down line	Zero Drift (%)	Span Drift (%)
NO	0.50	411.0	-0.14	0.28
CO	1.00	813.0	0.00	0.10
O ₂	0.05	10.24	0.08	0.28

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

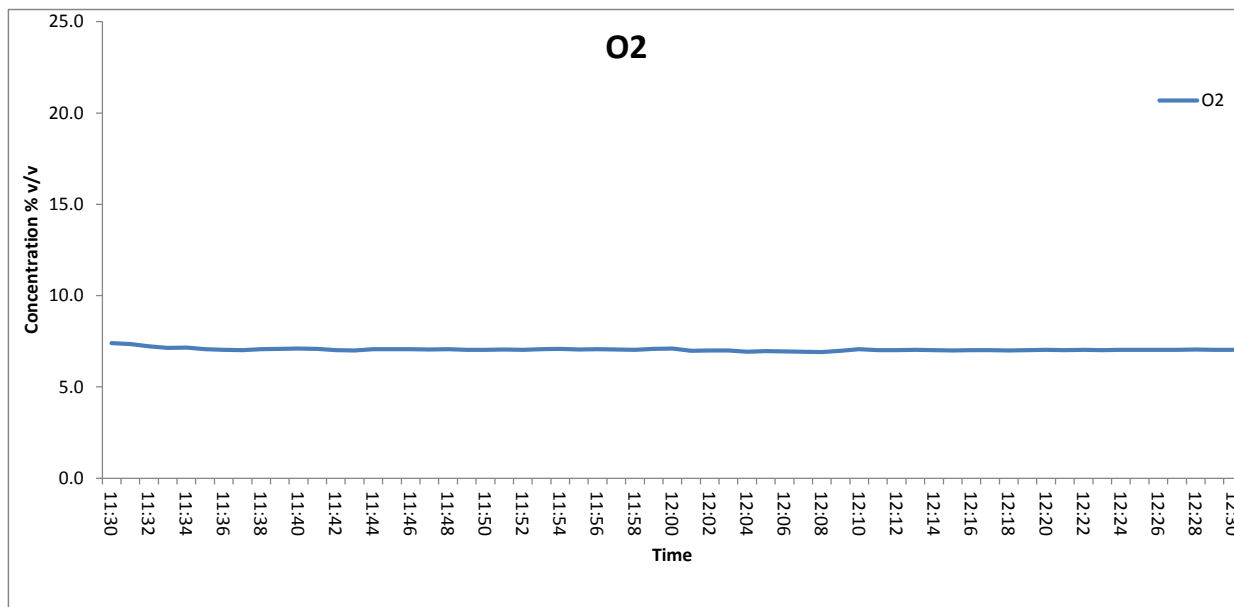


CARBON MONOXIDE EMISSIONS CHART



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

OXYGEN EMISSIONS CHART



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MOISTURE CALCULATIONS

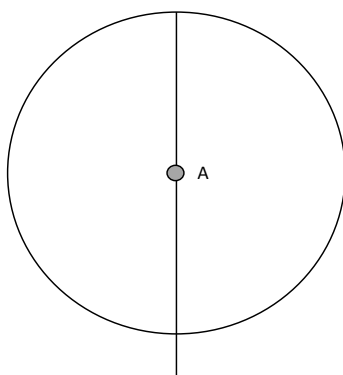
Moisture Determination - Non Isokinetic							
Test Number	Sampling Time and Date	Start Weight	End Weight	Total gain	Concentration	LOD	Uncertainty
		kg	kg	kg	%	%	%
Run 1	11:30-12:30 11 March 2020	3.1456	3.1601	0.0145	12.8	0.1	3.1

Moisture Quality Assurance							
Test Number	Sampling Duration	Total Volume Sampled	Sampling Rate	Start Leak Rate	End Leak Rate	Acceptable Leak Rate	Leak Tests Acceptable?
	mins	l	l/min	l/min	l/min	l/min	
Run 1	60	123	2.0	0.00	0.00	0.04	Yes

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK DIAGRAM

	Value	Units
Stack Depth	0.30	m
Stack Width	-	m
Area	0.07	m ²



Sampling Line

- 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	50	0.15	m

[illegible]

SAMPLING LOCATION



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	0.00004	2.0	0.50	1.0	0.1	-
as a %	0.03	0.26	0.49	1.0	1.42	0.00
compliant?	Yes	Yes	Yes	Yes	Yes	Yes

Run	Volume (STP) m ³	Mass Gained mg	O2 Correction -	Leak mg/m ³	Uncollected Mass mg	Combined uncertainty
Run 1	0.04	14500	1.1	0.00	58	-
MU as % v/v	0.17	0.10	0.07	0.00	0.06	0.22
MU as %	1.1	0.7	0.72	0.00	0.4	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.44	% v/v	3.14	%
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Reference – SOCOTEC UK Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VOLATILE ORGANIC COMPOUNDS RUN 1

Measured Concentration	1747.8	mg/m ³
Limit	1750	mg/m ³
Calibration Gas Concentration	1248	mg/m ³
Range	1600	mg/m ³

Performance characteristics	Value	Units	specification	MU Met?
Response time	32	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	0.03	% full scale	<2% range / 24hr	Yes
Span drift	0.27	% full scale	<2% 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)	-0.10	% 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	6.47
Drift	u0dr	0.24
volume or pressure flow dependence	uspres	0.01
atmospheric pressure dependence	uapres	0.39
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	1.38
losses in the line (leak)	uleak	-1.03
Uncertainty of calibration gas	ucalib	10.09
Uncertainty in factor	uf	35.06

Measurement uncertainty Measured Concentration	1747.82	mg/m ³
Combined uncertainty	37.09	mg/m ³
Expanded uncertainty	74.19	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	4.24	% ELV
Expanded uncertainty expressed with a level of confidence of 95%	74.19	mg/m ³
Expanded uncertainty expressed with a level of confidence of 95%	4.24	% value

Reference – SOCOTEC UK Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXIDES OF NITROGEN

Limit value	650	mg/m ³
Concentration @ Ref conditions	630.6	mg/m ³
Cal gas conc	834	mg/m ³
Analyser Full Scale	1025	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	-0.14	% full scale	<2% range / 24hr	Yes
Span drift	0.28	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.5	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.50	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	0.50	% full scale/10K	<3% range / 10 K	Yes
Combined interference	0.00	% range	<4% of Range	Yes
dependence on voltage	0.20	% 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)	0.20	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.004
lack of fit	U_{lof}	-0.231
short term zero drift	$U_{d,z}$	-0.081
short term span drift	$U_{d,s}$	0.162
influence of Ambient Temp at Zero	$U_{t,z}$	0.100
influence of Ambient Temp at Span	$U_{t,s}$	1.800
influence of sample gas pressure	U_p	0.000
influence of sample gas flow	U_{fit}	0.346
influence of supply voltage	U_v	1.182
Combined Interference	U_i	0.004
Uncertainty of Cal gas	U_{adj}	4.070

Measurement uncertainty (Concentration Measured)	630.60	mg/m ³
Combined uncertainty	4.63	mg/m ³
Expanded at a 95% confidence interval	9.26	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	1.4	% ELV
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Expanded uncertainty expressed with a level of confidence of 95%	9.3	mg/m ³
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Expanded uncertainty expressed with a level of confidence of 95%	1.5	% value
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Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - CARBON MONOXIDE

Limit value	1500	mg/m ³
Concentration @ Ref conditions	1804.2	mg/m ³
Cal gas conc	1017.5	mg/m ³
Analyser Full Scale	1250	mg/m ³

Performance characteristics	Value	Units	specification	MU Met?
Response time	54	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	0.00	% full scale	<2% range / 24hr	Yes
Span drift	0.10	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	1	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	2.2	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	1.8	% full scale/10K	<3% range / 10 K	Yes
Combined interference	0.03	% of Range	<4% of Range	Yes
dependence on voltage	-0.32	% full scale/10V	< 0.1%vol /10 volt	Yes
Influence of Vibration	N/A	% of upper limit of Cal range	<2%	N/A
losses in the line (leak)	0.00	% 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	$U_{d,s}$	0.00
influence of Ambient Temp zero	$U_{t,z}$	0.18
influence of Ambient Temp span	$U_{t,s}$	0.36
influence of sample gas pressure	U_p	0.00
influence of sample gas flow	U_{fit}	0.69
influence of supply voltage	U_v	-2.30
Combined Interference	U_i	9.04
Uncertainty of Cal gas	U_{adj}	4.07

Measurement uncertainty (Concentration Measured)	1572.3	mg/m ³
Combined uncertainty	10.2	mg/m ³
Expanded uncertainty	20.4	mg/m ³

Expanded uncertainty expressed with a level of confidence of 95%	1.4	% ELV
Expanded uncertainty expressed with a level of confidence of 95%	20.4	mg/m ³
Expanded uncertainty expressed with a level of confidence of 95%	1.3	% value

Developed for the STA by R Robinson, NPL

Reference – SOCOTEC UK Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXYGEN

Reference	5	%vol
Reported Concentration	7.04	%vol
Calibration gas	10.1	%vol
Analyser Full Scale	25	%vol

	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	0.13	% of value	<2 % range	Yes
Zero drift	0.08	% full scale	<2% range / 24hr	Yes
Span drift	0.28	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.03	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.05	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	-0.08	9	<3% range / 10 K	Yes
Combined interference	0.14	% range	<4% of Range	Yes
dependence on voltage	0.00	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	0.14	% of value	< 2% of value	Yes
Uncertainty of calibration gas	0.1	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.0083
lack of fit	U_{lof}	0.0751
short term zero drift	$U_{d,z}$	0.0462
short term span drift	$U_{d,s}$	0.1617
influence of Ambient Temp at Zero	$U_{t,z}$	0.0003
influence of Ambient Temp at Span	$U_{t,s}$	-0.1620
influence of sample gas pressure	U_p	0.0000
influence of sample gas flow	U_{fit}	0.0173
influence of supply voltage	U_v	0.0001
Combined Interference	U_i	0.0485
Uncertainty of Cal gas	U_{adj}	0.0505

Measurement uncertainty (Concentration Measured)	7.04	%
Combined uncertainty	0.26	%
Expanded uncertainty	0.50	%

Expanded uncertainty expressed with a level of confidence of 95%	0.5	%
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Expanded uncertainty expressed with a level of confidence of 95%	0.04	% vol
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END OF REPORT

Thank you for choosing SOCOTEC UK 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