REC Environmental Monitoring

a division of Resource and Environmental Consultants Ltd

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

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**Huntingdon**
Plant	**LEV 1**
Sampling Date	**15th January 2015**
Report Date	**26th February 2015**
Job Number	**EM02708**
Permit Number	**B22/11**

Report Prepared by:	***Print***	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**
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	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**

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Monitoring Objectives

The monitoring was undertaken to check compliance with authorised emission limits.

All monitoring procedures were carried out to the MCERTS requirements under the REC Environmental Monitoring quality system to ISO 17025: 2005.

Monitoring was undertaken for the listed emissions from the following sampling positions:

Sampling Location	Emission
LEV 1	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

Emission	Method number	Method standard
Gas velocity and volume flow	TPM/01A	BS EN ISO 16911-1:2013
TOC	TPM/13	BS EN 12619 : 2013

Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Xaarjet Ltd.**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at Huntingdon LEV 1		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
		Date	Start	End	mg/m³*	mg/m³*	mg/m³*	mg/m³*	g/h
TOC	Test 1	15/01/15	11:30	12:00	53.0	75	1.70	0.16	154.8
TOC	Test 2	15/01/15	12:00	12:30	50.8	75	1.67	0.16	148.5
TOC	Test 3	15/01/15	12:30	13:00	41.8	75	1.52	0.16	121.9

* at ref	Stack Gas Weight		0 °C	Wet Gas		
Conditions	29.00	Kg/kmol	101.3 kpa	Oxygen	None	%

Where applicable Oxides of nitrogen results are expressed as nitrogen dioxide
TOC results are expressed as total carbon

Throughout Report:

- * Reference conditions (see above)
- ** Analysis not required
- ND Non detectable
- s - Subcontracted laboratory analysis
- Nm³ 273 K, 101.3 kPa
- \# - UKAS accredited only
- \#\# - Not Accredited
- N/A Not applicable

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a 95% confidence level. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Operating Information

The tables below shows details of the operating information on each sampling date for: **LEV 1**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
15/01/2015	Production and cleaning of inkjet cartridges	Continuous	N/A	N/A	N/A	Normal

There are no CEMs present on this process

Comments & Monitoring Deviations

A waste gas homogeneity test to BS EN 15259:2007 (MID) is not required:-
The homogeneity test is not applicable to non-combustion processes.

All monitoring was performed in accordance with the relevant procedures.

The velocity and temperature profile at the sampling location met the requirements of BS EN 13284-1: 2002.

When the results are expressed as non-detected the mass emissions are calculated from the detection limit and therefore they are worst case results.

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Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

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Site	**Huntingdon**
Plant	**LEV 1**
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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013

Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.

Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Report authorised by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Team leader:	Chris Rhodes	MM02 117	-	30/09/2017	28/02/2018	28/02/2018	31/08/2018	31/12/2018
Technician:	Tom Clarkson	MM02 120	-	-	-	-	-	-

Equipment References

Equipment	Reference Number
FID	**VC09**
Heated Line	**HL24**
Data Logger	**DL14**
Stack Thermocouple	**PTTS138**
Barometer	**Met. Office**
Pitot	**PT138**

APPENDIX 2

Date	15/01/2015
Time	10:30
Pitot Cp	1.02

Barometric pressure	98.5	kPa
Duct static pressure	-0.08	kPa
Stack Area	0.126	m^2
Oxygen		%

Stack Diameter (circular)	0.40	m
		m
		m
Carbon dioxide		**%**

Traverse	Traverse	Depth	ΔP	T	Angle	velocity	Traverse	Depth	ΔP	T	Angle	velocity
Point	Line	cm	mmH_2O	^oC	o	m/s	Line	cm	mmH_2O	^oC	o	m/s
1	A	5.0					B	5.0				
2	A	5.0					B	5.0				
3	A	5.0	5.5	21	<15	9.8	B	5.0				
4	A	7.1	3.5	21	<15	7.9	B	7.1				
5	A	10.0	2.9	21	<15	7.1	B	10.0				
6	A	14.2	3.4	21	<15	7.7	B	14.2				
7	A	25.8	3.0	21	<15	7.2	B	25.8				
8	A	30.0	1.9	21	<15	5.8	B	30.0				
9	A	32.9	2.0	21	<15	6.0	B	32.9				
10	A	35.0	1.9	21	<15	5.8	B	35.0				
11	A	35.0					B	35.0				
12	A	35.0					B	35.0				

Average Pitot DP	2.93	mmH_2O
Average Temperature	294.2	K
Average Velocity	7.2	m/s
Average volumetric flow rate	0.90	m^3/s at stack conditions
Average volumetric flow rate	0.81	m^3/s (wet STP)
Average volumetric flow rate		m^3/s (dry STP)
Average volumetric flow rate		m^3/s (dry, STP, reference oxygen concentraion)

Sampling plane requirements Re: BS EN 13284-1:2001 5.2

a	Angel of gas flow less than 15^o with regard to duct axis	YES
b	No local negative flow	YES
c	Minimum pitot greater than 5Pa	YES
d	Ratio of highest to lowest local gas velocity less than 3:1	YES

Minimum local gas velocity	5.8
Maximum local gas velocity	9.8
Ratio of highest to lowest local gas velocity	1.70

Preliminary Velocity Traverse Data

Date 15/01/2015

From 11:30 to 12:00 30 minute mean

Volatile organic compounds	vppm, wet	32.97	mg/m³*	52.99

From 12:00 to 12:30 30 minute mean

Volatile organic compounds	vppm, wet	31.64	mg/m³*	50.84

.

From 12:30 to 13:00 30 minute mean

Volatile organic compounds	vppm, wet	25.98	mg/m³*	41.75

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity *k* = 2
Nitrogen	%	99.999	VC174989	-	± 2
Volatile organic compounds	vppm	78.8	VCSMG4537	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	11:18	Final Time	13:08
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	78.80	-0.70	75.92

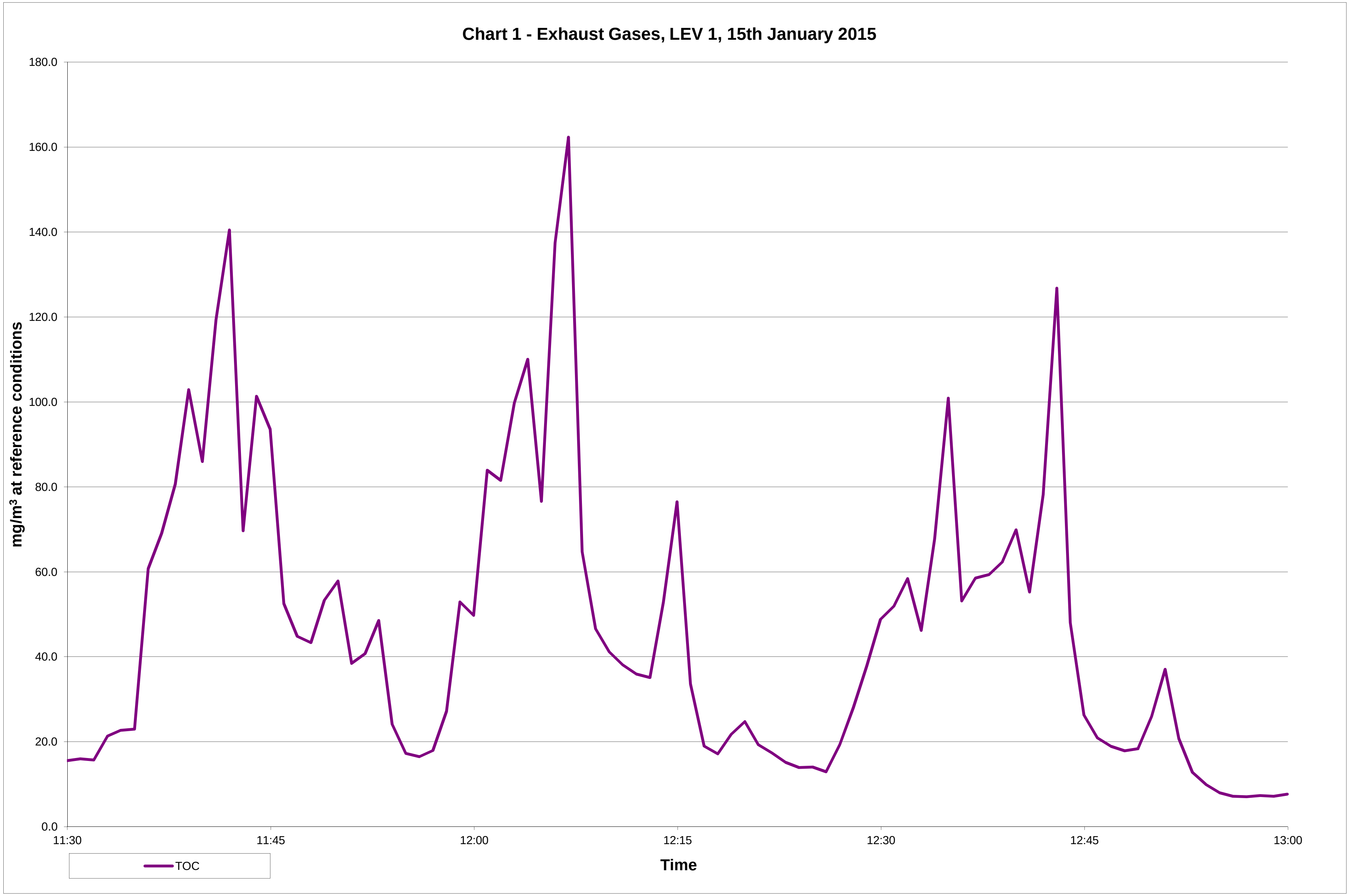
Chart 1 - Exhaust Gases, LEV 1, 15th January 2015
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
mg/m³ at reference conditions
11:30
11:45
12:00
12:15
12:30
12:45
13:00
Time
TOC

APPENDIX 3

Photograph Of The Sampling Location

General Calculations

Stack area:

$$Area\,of\;a\,circle = \frac{\pi . D^2}{4}$$

D = Diameter (m)
π = 3.142

Pressure conversion:

1mmH2O = 0.00980665 kPa
1mmH2O = 9.80665 Pa
1 mar = 0.1 kPa

Water vapour concentration:
From reference calculations (taken from BS EN 14790):

$$V_{WC(\%)} = \frac{\dfrac{m_{WC} . V_{mol(std)}}{M_W}}{\dfrac{m_{WC} . V_{mol(std)}}{M_W} + V_{m(std)}} \times 100$$

VWC (%) = Water vapour content on wet basis, in volume % (m^3 of water vapour in m^3 of wet gas)
Vm(std) = Dry gas volume measured, corrected to standard conditions (m^3)
mWC = Mass of water collected in the impingers (g)
Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)
Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)
From reference calculations (taken from BS EN 14790):

$$V_{m(std)} = y_d \times (V_2 - V_1) \times \frac{T_{std}}{T_m} \times \frac{p_m}{p_{std}}$$

Vm(std) = Dry gas meter volume at standard conditions (m^3)
yd = Gas meter calibration coefficient
(V2-V1) = Dry gas meter volume at actual conditions (m^3)
Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)
pm = Absolute pressure at the gas meter (kPa)
pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):
From reference calculations (taken from EA TGN M2):

$$IsokineticRatio(\%) = \frac{Velocity\ at\ the\ sampling\ nozzle}{Velocity\ of\ \ the\ stack\ gas} \times 100$$

Estimating Measurment Uncertainty
Uncertainty estimates are calculated using the general rule of uncertainty propagation. Guidance is taken from publications including UKAS document M3003 and ISO 20988:2007.

Flow Calculations

Velocity:
From reference calculations (taken from ISO 10780):

$$\bar{v} = KC\sqrt{\frac{T_s\,\Delta\bar{p}}{p_e\,M_s}}$$

$\bar{v} =$ Average velocity (m/s)
C = velocity calculation constant = 129
Ts = Average stack temperature (K)
Ms = Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol
K = Pitot calibration coefficient
Pe = Absolute gas pressure (kPa)
$\Delta\bar{p} =$ Average pitot tube pressure differencial (kPa)

Volume flow rate
From reference calculations (taken from ISO 10780):

$$q_{va} = \bar{v}A$$

qva = Average flow rate (m^3/s)
$\bar{v} =$ Average velocity (m/s)
A = Stack cross-sectional area (m^2)

Volume flow rate corrected for moisture
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(100 - H_a)}{(100 - H_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ha = Moisture at actual conditions (%volume)
Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(T_m\,p_a)}{(T_a\,p_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ta = Temperature at actual conditions (K)
Tm = Reference Temperatue (K)
pa = Absolute gas pressure at actual conditions (kPa)
pm = Reference pressure (kPa)

Volume flow rate corrected for oxygen
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(20.9 - O_{2,ref})}{(20.9 - O_{2,m})}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
O2,m = Actual oxygen concentration (%)
O2,ref = Reference oxygen concentration (%)

Concentration Calculations

Concentration:
From reference calculations (taken from BS EN 13284-1):

$$c = \frac{m}{V}$$

c = Concentration
m = Mass of substane
V = Volume sampled

Mass Emission

$$Mass\ emission = c \times q_m$$

c = Concentration
q = Volume flow rate

Concentration corrected for oxygen:
From reference calculations (taken from BS ISO 9096):

$$c_m = c_a \times \frac{20.9 - O_{2,ref}}{20.9 - O_{2,a}}$$

cm = Concentration at reference conditions
ca = Actual concentration
O2, ref = Reference oxygen (%)
O2, a= Actual Oxygen (%)

Concentration corrected for moisture:
From reference calculations (taken from BS ISO 9096):

Convert wet gas to dry gas

$$c_{dry} = c_{wet} \times \frac{100}{100 - H_a}$$

Convert dry gas to wet gas

$$c_{wet} = c_{dry} \times \frac{100 - H_a}{100}$$

cwet = Concentration wet gas
cdry = Concentration dry gas
Ha = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m^3
From reference calculations (taken from EA TGN M2):

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

When Converting TOC

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight\ of\ carbon\ in\ span\ gas(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

$$C_{ppm} = C_{reading} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{rep} + Corr_{adj} + \sum_{i=1}^{p} Corr_{\inf} + Corr_{\text{int}}$$

Where:

$C_{,ppm}$ = concentration in ppm

$C_{NO,reading}$ = concentration given by analyser

$Corr_{fit}$ = correction of lack of fit

$Corr_{0,dr}$ = correction of zero drift

$Corr_{s,dr}$ = correction of span drift

$Corr_{rep}$ = correction of repeatability of measurement

$Corr_{adj}$ = correction of adjustment

$Corr_{inf}$ = correction of influence quantities

$Corr_{int}$ = correction of interferents

Calculation of partial uncertainties

$$u(Corr_{fit}) = \frac{\left(\dfrac{X_{fit,\max}}{100 \times range}\right)}{\sqrt{3}}$$

Where:

$X_{fit,max}$ is the maximum allowable deviation from linearity

Expressed as % of the range and calculated by applying a rectangular probability distribution

$$u(Corr_{0,dr}) = \frac{X_{0,dr}}{\sqrt{3}} \qquad u(Corr_{s,dr}) = \frac{X_{s,dr}}{\sqrt{3}}$$

$u(Corr_{rep})$ = max ($S_{0,rep}$; S_{srep}) = S_{rep}

Where:

$S_{r,0}$ is the standard uncertainty at zero level

$S_{r,s}$ is the standard uncertainty at span level

$u(Corr_{adj})$ = $u(Corr_{loss}) + u(Corr_{cal})$

$$u(Corr_{loss}) = \frac{C_{j,loss}}{\sqrt{3}}$$

$$u(Corr_{cal}) = \frac{U_{cal}}{2}$$

Where:

$u(Corr_{loss})$ is the uncertainty due to losses in sample line

$u(Corr_{cal})$ is the uncertainty due to losses in sample line

$c_{j,loss}$ is the concentration of sample loss at span level

U_{cal} is the expanded uncertainty of the calibration gas

$$u(Corr_{inf}) = c_j \sqrt{\frac{\left(x_{j,\max} - x_{j,adj}\right)^2 + \left(x_{j,\min} - x_{j,adj}\right) \times \left(x_{j,\max} - x_{j,adj}\right) + \left(x_{j,\min} - x_{j,adj}\right)^2}{3}}$$

Where:

c_j is the sensitivity coefficient of the influence quantity

$x_{j,min}$ is the minimum value of the influence quantity during monitoring

$x_{j,max}$ is the maximum value of the influence quantity during monitoring

$x_{j,adj}$ is the value of the influence quantity during adjustment

$$u(Corr_{int}) = \frac{c_j}{Int_{j,test}} \sqrt{\frac{Int_{j,\max}{}^2 + Int_{j,\min} \times Int_{j,\max} + Int_{j,\min}{}^2}{3}}$$

and

$$u(\Sigma Corr_{int}) = \max\left\lfloor S_{Int,p} ; S_{Int,n} \right\rfloor$$

Where:

c_j is the sensitivity coefficient of the interferent j

$Int_{j,test}$ is the concentration of the interferent j used to determine c_j

$Int_{j,min}$ is the minimum value of the interferent j quantity during monitoring

$Int_{j,max}$ is the maximum value of the interferent j quantity during monitoring

$Int_{j,adj}$ is the concentration of the interferent j in the cal gas used to adjust the analyser

$S_{int,p}$ is the sum of interferents with positive impact

$S_{int,n}$ is the sum of interferents with negative impact

Combined uncertainty

$u(C,_{ppm})$ =

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + S_{Int}{}^2}$$

Overall expanded uncertainty (k = 2) $U(C_m) = u(C_m) \times k$

Uncertainty of NOx measurements

$$u(C_{NOx,conv}) = \frac{C_{NOx} \times R \times \eta}{\sqrt{3}}$$

Where:

C_{NOx} is the concentration of NOx measured by the analyser

R is the ratio of NO:Nox in the stack gas

η is the NOx converter efficiency

Combined uncertainty NOx measurements

$u(C_{NOx,stack})$ =

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + S_{Int}{}^2 + u^2(corr_{NOx,conv})}$$

Uncertainty of mass concentration at oxygen reference concentration

$u(C,_{O2\,ref})$ =

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + S_{Int}{}^2 + \left(\frac{u^2(O_{2,meas,dry})}{(21 - O_{2,meas,dry})^2}\right)}$$

Where:

$u(C,O_{2,ref})$ = uncertainty associated with the mass concentration at O_2 ref. concentration in mg/m^3

$C,O_{2,ref}$ = mass concentration at O_2 reference concentration in mg/m^3

$O_{2,meas}$ = O_2 measured concentration in % volume

$u((O_{2,meas)dry)})$ = uncertainty associated to the measured O_2 concentration in % (relative to $O_{2\,meas}$)

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon BS EN12619:2013

Analyser Type/Model	Sick Maihak	
Reference Oxygen %	0	(0 = No correction)

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	33.0	31.6	26.0
Measured concentration	mg/m^3	53.0	50.8	41.8
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A

Calibration gas	ppm	78.8	78.8	78.8
Calibration gas	mg/m^3	126.6	126.6	126.6
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0

Correction of Lack of Fit

Lack of fit	% range	2.0	2.0	2.0
	u(Corr,$_{fit}$)	0.11	0.11	0.11

Corrections of Zero and Span Drift (*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))

Zero Drift	% range	0.00	0.00	0.00
	u(Corr,$_{0dr}$)	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	u(Corr,$_{sdr}$)	0.00	0.00	0.00

Correction of Repeatability of Measurement

Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	u(Corr,$_{rep}$)	0.00	0.00	0.00

Correction of adjustment

losses in the line	% range	1.04	1.04	1.04
	u(Corr,$_{loss}$)	0.20	0.19	0.16
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	u(Corr,$_{cal}$)	0.33	0.32	0.26

Correction of Influence of Interferents

N_2O	% range			
	u(Corr,$_{N2O}$)	0.00	0.00	0.00
CO_2	% range			
	u(Corr,$_{CO2}$)	0.00	0.00	0.00
CH_4	% range			
	u(Corr,$_{CH4}$)	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
u(ΣCorrint) = $\max\left[S_{Int,p};S_{Int,n}\right]$	*u(ΣCorr $_{int}$)*	0.16	0.16	0.16

Correction of Influence Quantities

Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	u(Corr,$_{flow}$)	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	u(Corr,$_{press}$)	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	u(Corr,$_{temp}$)	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	u(Corr,$_{volt}$)	0.10	0.10	0.10

Oxygen reference concentration

Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!
Overall uncertainty of O_2 measurement	*U* (O_2,$_{meas}$)	#REF!	#REF!	#REF!
	u(Corr,$_{O2}$)	N/A	N/A	N/A

Maximum standard uncertainty	u(Corr,$_{max}$)	0.33	0.32	0.26
5% of maximum standard uncertainty	u(Corr,$_{5\%}$)	0.02	0.02	0.01

Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
CH_4 range	0	10	0	50	mg/m^3
N_2O range	0	0	0	20	mg/m^3
CO_2 range	8	12	0	15	mg/m^3
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m^3

Influence Quantitiy Variations

	Minimum	Maximum	Value at cal	Performance	Units
Sensitivity to sample volume flow	55	65	60	5	l/h
Sensitivity to atmospheric pressure	99	100	99	1	kPa
Sensitivity to ambient temperature	278	313	288	10	K
Sensitivity to electrical voltage	187	250	230	5	V

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.53	0.52	0.47
Combined uncertainty	mg/m^3	0.85	0.83	0.76
Combined uncertainty at oxygen reference	mg/m^3	0.85	0.83	0.76

Expanded uncertainty expressed with a level of confidence of 95%, k=2

Overall uncertainty	ppm	1.1	1.0	0.9
Overall uncertainty	mg/m^3	1.7	1.7	1.5
Overall uncertainty relative to measured value	%	3.2	3.3	3.7
Overall uncertainty relative to range	%	11.4	11.1	10.2
Overall uncertainty relative to ELV	%	1.3	1.3	1.2

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2

Overall uncertainty	mg/m^3	N/A	N/A	N/A
Overall uncertainty relative to measured value	%	N/A	N/A	N/A
Overall uncertainty relative to range	%	N/A	N/A	N/A
Overall uncertainty relative to ELV	%	N/A	N/A	N/A

The uncertainty evaluation has been carried out in accordance with UKAS requirements.

REC Environmental Monitoring

a division of Resource and Environmental Consultants Ltd

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

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**Huntingdon**
Plant	**LEV 2**
Sampling Date	**15th January 2015**
Report Date	**26th February 2015**
Job Number	**EM02708**
Permit Number	**B22/11**

Report Prepared by:	***Print***	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***	EBuffam ……………………………………….	
	Print	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**

REC Environmental Monitoring
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Company Registration No 03133832

mCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

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Monitoring Objectives

The monitoring was undertaken to check compliance with authorised emission limits.

All monitoring procedures were carried out to the MCERTS requirements under the REC Environmental Monitoring quality system to ISO 17025: 2005.

Monitoring was undertaken for the listed emissions from the following sampling positions:

Sampling Location	Emission
LEV 2	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

Emission	Method number	Method standard
Gas velocity and volume flow	TPM/01A	BS EN ISO 16911-1:2013
TOC	TPM/13	BS EN 12619 : 2013

Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Xaarjet Ltd.**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at Huntingdon LEV 2		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
		Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	Test 1	15/01/15	11:30	12:00	11.9	75	1.23	0.16	16.8
TOC	Test 2	15/01/15	12:00	13:03	7.34	75	1.19	0.16	10.4
TOC	Test 3	15/01/15	13:03	13:33	5.54	75	1.18	0.16	7.85

* at ref Conditions	Stack Gas Weight	0 °C	Wet Gas
	29.00 Kg/kmol	101.3 kpa	Oxygen None %

Where applicable Oxides of nitrogen results are expressed as nitrogen dioxide
TOC results are expressed as total carbon

Throughout Report:				
	*	Reference conditions (see above)	Nm³	273 K, 101.3 kPa
	**	Analysis not required	# - UKAS accredited only	
	ND	Non detectable	## - Not Accredited	
	s - Subcontracted laboratory analysis		N/A	Not applicable

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a 95% confidence level. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Operating Information

The tables below shows details of the operating information on each sampling date for: **LEV 2**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
15/01/2015	Production and cleaning of inkjet cartridges	Continuous	N/A	N/A	N/A	Normal

There are no CEMs present on this process

Comments & Monitoring Deviations

A waste gas homogeneity test to BS EN 15259:2007 (MID) is not required:-
The homogeneity test is not applicable to non-combustion processes.

All monitoring was performed in accordance with the relevant procedures.

The velocity and temperature profile at the sampling location met the requirements of BS EN 13284-1: 2002.

When the results are expressed as non-detected the mass emissions are calculated from the detection limit and therefore they are worst case results.

The data logger lead was not working between 12:22 and 12:55, this data was removed from the test.

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Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

Client	Xaarjet Ltd.
Site	Huntingdon
Plant	LEV 2
Sampling Date	15th January 2015
Report Date	26th February 2015
Job Number	EM02708
Permit Number	B22/11

Report Prepared by:	*Print*	Emily Buffam	
	MCERTS No.	MM04 502	Level 2 TE: 1,2,3,4
Report Approved by:	*Sign*	EBuffam ……………………………………….	
	Print	Emily Buffam	
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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013

Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.

Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Report authorised by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Team leader:	Chris Rhodes	MM02 117	-	30/09/2017	28/02/2018	28/02/2018	31/08/2018	31/12/2018
Technician:	Tom Clarkson	MM02 120	-	-	-	-	-	-

Equipment References

Equipment	Reference Number
FID	**VC12**
Heated Line	**HL24**
Data Logger	**DL14**
Stack Thermocouple	**PTTS138**
Barometer	**Met. Office**
Pitot	**PT138**

APPENDIX 2

Date	15/01/2015	Barometric pressure	98.5	kPa	Stack Diameter (circular)	0.305	m
Time	10:00	Duct static pressure	-0.14	kPa			m
Pitot Cp	1.02	Stack Area	0.073	m^2			m
		Oxygen		%	Carbon dioxide		%

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle °	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle °	velocity m/s
1	A	5.0					B	5.0				
2	A	5.0					B	5.0				
3	A	5.0	3.7	22	<15	8.0	B	5.0				
4	A	5.4	3.5	22	<15	7.9	B	5.4				
5	A	7.6	2.1	22	<15	6.0	B	7.6				
6	A	10.9	1.8	22	<15	5.6	B	10.9				
7	A	19.6	2.2	22	<15	6.2	B	19.6				
8	A	22.9	1.6	22	<15	5.2	B	22.9				
9	A	25.1	1.3	22	<15	4.8	B	25.1				
10	A	25.5	1.0	22	<15	4.2	B	25.5				
11	A	25.5					B	25.5				
12	A	25.5					B	25.5				

Average Pitot DP	2.04	mmH_2O
Average Temperature	295.2	K
Average Velocity	6.0	m/s
Average volumetric flow rate	0.44	m^3/s at stack conditions
Average volumetric flow rate	0.39	m^3/s (wet STP)
Average volumetric flow rate		m^3/s (dry STP)
Average volumetric flow rate		m^3/s (dry, STP, reference oxygen concentraion)

Sampling plane requirements Re: BS EN 13284-1:2001 5.2

a	Angel of gas flow less than 15^o with regard to duct axis		YES
b	No local negative flow		YES
c	Minimum pitot greater than 5Pa		YES
d	Ratio of highest to lowest local gas velocity less than 3:1		YES
	Minimum local gas velocity	4.2	
	Maximum local gas velocity	8.0	
	Ratio of highest to lowest local gas velocity	1.93	

Date 15/01/2015

From 11:30 to 12:00 30 minute mean

Volatile organic compounds	vppm, wet	7.41	mg/m³*	11.90

From 12:00 to 13:03 30 minute mean

Volatile organic compounds	vppm, wet	4.57	mg/m³*	7.34

.

From 13:03 to 13:33 30 minute mean

Volatile organic compounds	vppm, wet	3.45	mg/m³*	5.54

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity *k* = 2
Nitrogen	%	99.999	VC174989	-	± 2
Volatile organic compounds	vppm	78.8	VCSMG4537	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	11:18	Final Time	13:39
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	78.79	-0.71	79.44

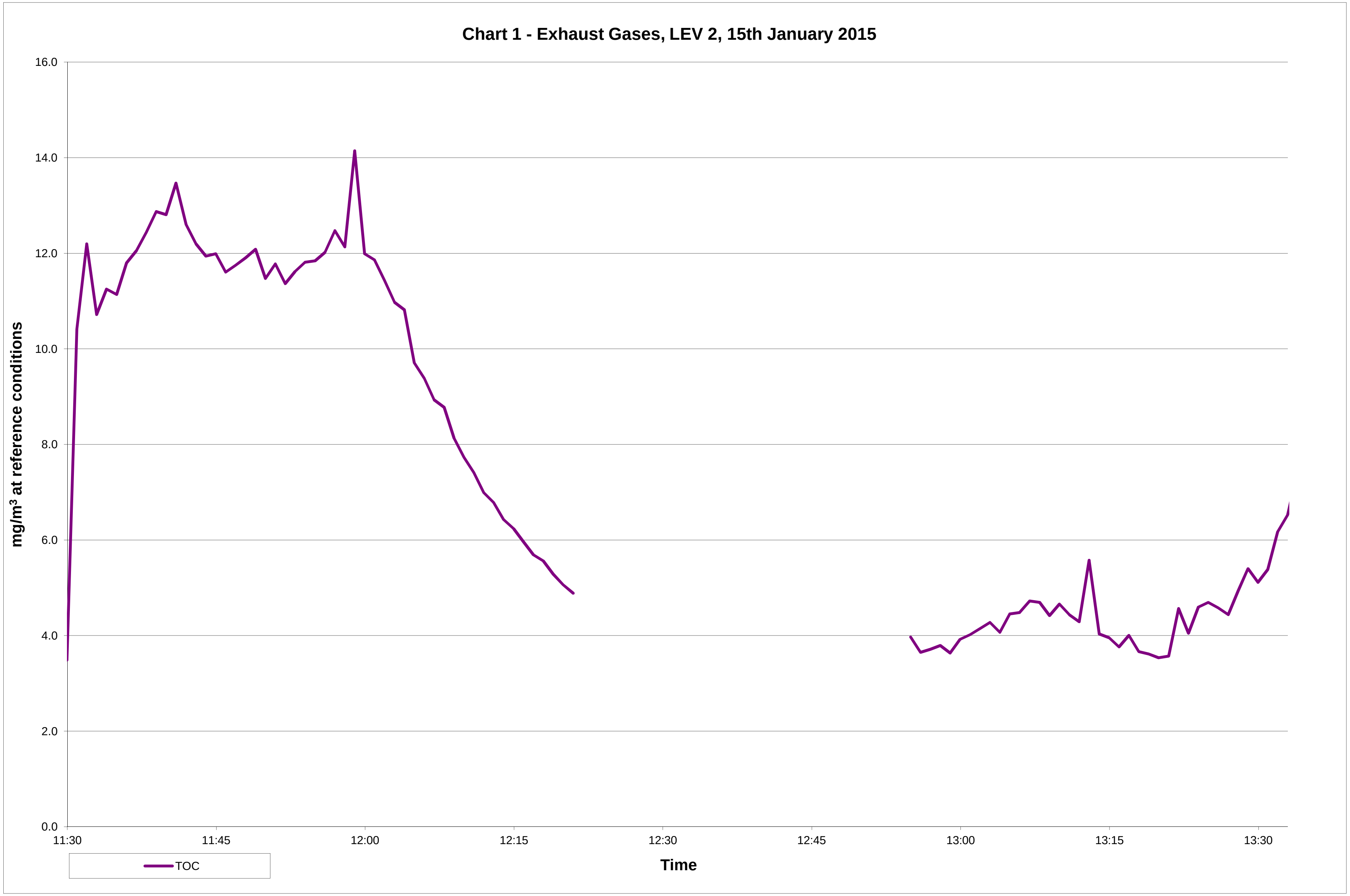
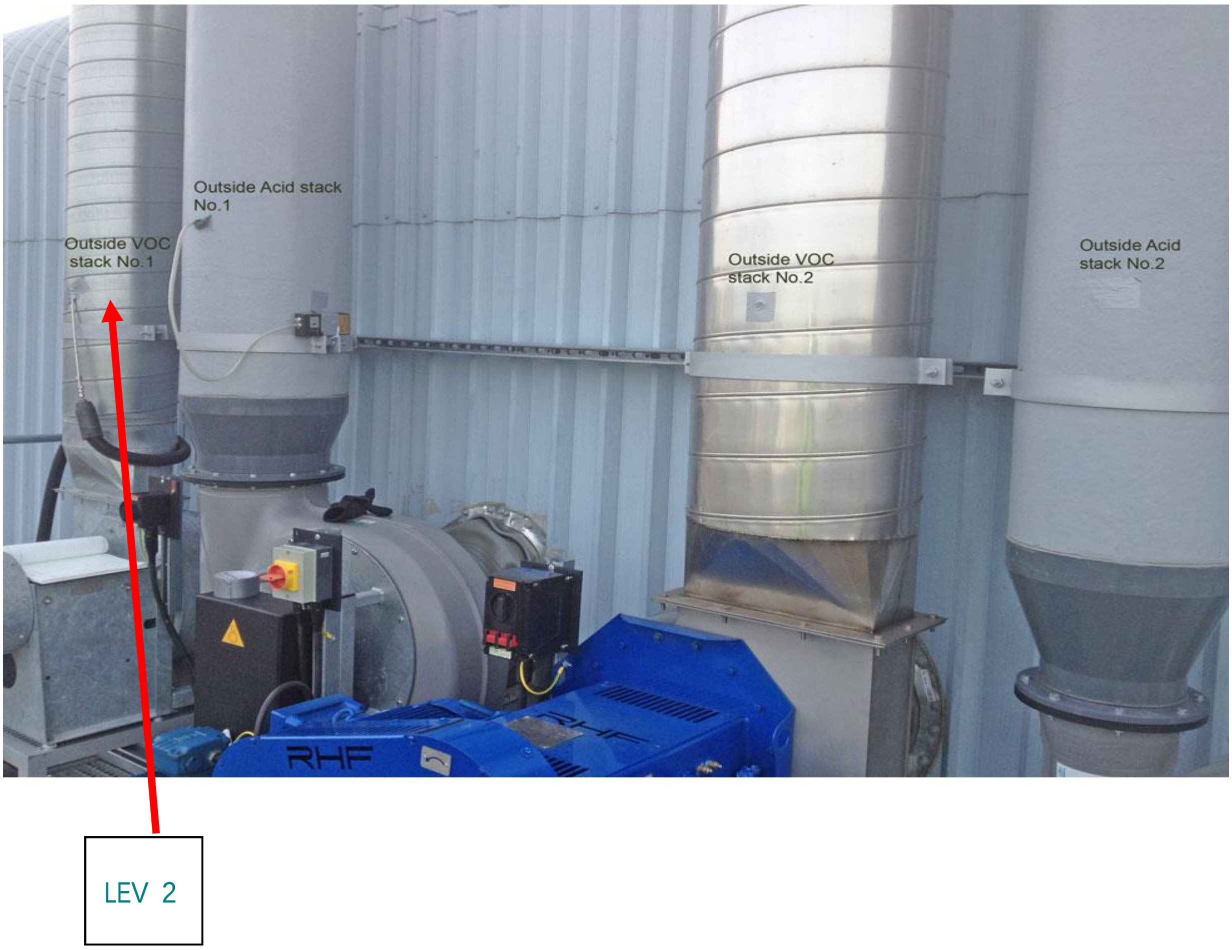


Chart 1 - Exhaust Gases, LEV 2, 15th January 2015
mg/m³ at reference conditions
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
11:30
11:45
12:00
12:15
12:30
12:45
13:00
13:15
13:30
Time
TOC

APPENDIX 3

Photograph Of The Sampling Location



General Calculations

Stack area:

$$Area\,of\;a\,circle = \frac{\pi . D^2}{4}$$

D = Diameter (m)
π = 3.142

Pressure conversion:

1mmH2O = 0.00980665 kPa
1mmH2O = 9.80665 Pa
1 mar = 0.1 kPa

Water vapour concentration:
From reference calculations (taken from BS EN 14790):

$$V_{WC(\%)} = \frac{\frac{m_{WC} . V_{mol(std)}}{M_W}}{\frac{m_{WC} . V_{mol(std)}}{M_W} + V_{m(std)}} \times 100$$

VWC (%) = Water vapour content on wet basis, in volume % (m^3 of water vapour in m^3 of wet gas)
Vm(std) = Dry gas volume measured, corrected to standard conditions (m^3)
mWC = Mass of water collected in the impingers (g)
Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)
Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)
From reference calculations (taken from BS EN 14790):

$$V_{m(std)} = y_d \times (V_2 - V_1) \times \frac{T_{std}}{T_m} \times \frac{p_m}{p_{std}}$$

Vm(std) = Dry gas meter volume at standard conditions (m^3)
yd = Gas meter calibration coefficient
(V2-V1) = Dry gas meter volume at actual conditions (m^3)
Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)
pm = Absolute pressure at the gas meter (kPa)
pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):
From reference calculations (taken from EA TGN M2):

$$IsokineticRatio(\%) = \frac{Velocity\ at\ the\ sampling\ nozzle}{Velocity\ of\ the\ stack\ gas} \times 100$$

Estimating Measurment Uncertainty
Uncertainty estimates are calculated using the general rule of uncertainty propagation. Guidance is taken from publications including UKAS document M3003 and ISO 20988:2007.

Flow Calculations

Velocity:
From reference calculations (taken from ISO 10780):

$$\bar{v} = KC\sqrt{\frac{T_s\,\Delta\bar{p}}{p_e\,M_s}}$$

$\bar{v}$ = Average velocity (m/s)
C = velocity calculation constant = 129
Ts = Average stack temperature (K)
Ms = Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol
K = Pitot calibration coefficient
Pe = Absolute gas pressure (kPa)
$\Delta\bar{p}$ = Average pitot tube pressure differencial (kPa)

Volume flow rate
From reference calculations (taken from ISO 10780):

$$q_{va} = \bar{v}A$$

qva = Average flow rate (m^3/s)
$\bar{v}$ = Average velocity (m/s)
A = Stack cross-sectional area (m^2)

Volume flow rate corrected for moisture
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(100 - H_a)}{(100 - H_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ha = Moisture at actual conditions (%volume)
Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(T_m\,p_a)}{(T_a\,p_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ta = Temperature at actual conditions (K)
Tm = Reference Temperatue (K)
pa = Absolute gas pressure at actual conditions (kPa)
pm = Reference pressure (kPa)

Volume flow rate corrected for oxygen
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(20.9 - O_{2,ref})}{(20.9 - O_{2,m})}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
O2,m = Actual oxygen concentration (%)
O2,ref = Reference oxygen concentration (%)

Concentration Calculations

Concentration:
From reference calculations (taken from BS EN 13284-1):

$$c = \frac{m}{V}$$

c = Concentration
m = Mass of substane
V = Volume sampled

Mass Emission

$$Mass\ emission = c \times q_m$$

c = Concentration
q = Volume flow rate

Concentration corrected for oxygen:
From reference calculations (taken from BS ISO 9096):

$$c_m = c_a \times \frac{20.9 - O_{2,ref}}{20.9 - O_{2,a}}$$

cm = Concentration at reference conditions
ca = Actual concentration
O2, ref = Reference oxygen (%)
O2, a= Actual Oxygen (%)

Concentration corrected for moisture:
From reference calculations (taken from BS ISO 9096):

Convert wet gas to dry gas

$$c_{dry} = c_{wet} \times \frac{100}{100 - H_a}$$

Convert dry gas to wet gas

$$c_{wet} = c_{dry} \times \frac{100 - H_a}{100}$$

cwet = Concentration wet gas
cdry = Concentration dry gas
Ha = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m^3
From reference calculations (taken from EA TGN M2):

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

When Converting TOC

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight\ of\ carbon\ in\ span\ gas(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

$$C_{ppm} = C_{reading} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{rep} + Corr_{adj} + \sum_{i=1}^{p} Corr_{\inf} + Corr_{\text{int}}$$

Where:

$C_{,ppm}$ = concentration in ppm
$C_{NO,reading}$ = concentration given by analyser
$Corr_{fit}$ = correction of lack of fit
$Corr_{0,dr}$ = correction of zero drift
$Corr_{s,dr}$ = correction of span drift
$Corr_{rep}$ = correction of repeatability of measurement
$Corr_{adj}$ = correction of adjustment
$Corr_{inf}$ = correction of influence quantities
$Corr_{int}$ = correction of interferents

Calculation of partial uncertainties

$$u(Corr_{fit}) = \frac{\left(\dfrac{X_{fit,\max}}{100 \times range}\right)}{\sqrt{3}}$$

Where:

$X_{fit,max}$	is the maximum allowable deviation from linearity

Expressed as % of the range and calculated by applying a rectangular probability distribution

$$u(Corr_{0,dr}) = \frac{X_{0,dr}}{\sqrt{3}} \qquad u(Corr_{s,dr}) = \frac{X_{s,dr}}{\sqrt{3}}$$

$$u(Corr_{rep}) = \max(S_{0,rep}\,;\,S_{srep}) = S_{rep}$$

Where:

$S_{r,0}$	is the standard uncertainty at zero level
$S_{r,s}$	is the standard uncertainty at span level

$$u(Corr_{adj}) = u(Corr_{loss}) + u(Corr_{cal})$$

$$u(Corr_{loss}) = \frac{C_{j,loss}}{\sqrt{3}}$$

$$u(Corr_{cal}) = \frac{U_{cal}}{2}$$

Where:

$u(Corr_{loss})$	is the uncertainty due to losses in sample line
$u(Corr_{cal})$	is the uncertainty due to losses in sample line
$cj_{,loss}$	is the concentration of sample loss at span level
U_{cal}	is the expanded uncertainty of the calibration gas

$$u(Corr_{inf}) = c_j\sqrt{\frac{(x_{j,\max}-x_{j,adj})^2 + (x_{j,\min}-x_{j,adj})\times(x_{j,\max}-x_{j,adj}) + (x_{j,\min}-x_{j,adj})^2}{3}}$$

Where:

c_j	is the sensitivity coefficient of the influence quantity
$x_{j,min}$	is the minimum value of the influence quantity during monitoring
$x_{j,max}$	is the maximum value of the influence quantity during monitoring
$x_{j,adj}$	is the value of the influence quantity during adjustment

$$u(Corr_{int}) = \frac{c_j}{Int_{j,test}}\sqrt{\frac{Int_{j,\max}^{\ 2} + Int_{j,\min}\times Int_{j,\max} + Int_{j,\min}^{\ 2}}{3}}$$

and

$$u(\Sigma Corr_{int}) = \max\left\lfloor S_{Int,p}\,;\,S_{Int,n}\right\rfloor$$

Where:

c_j	is the sensitivity coefficient of the interferent j
$Int_{j,test}$	is the concentration of the interferent j used to determine c_j
$Int_{j,min}$	is the minimum value of the interferent j quantity during monitoring
$Int_{j,max}$	is the maximum value of the interferent j quantity during monitoring
$Int_{j,adj}$	is the concentration of the interferent j in the cal gas used to adjust the analyser
$S_{int,p}$	is the sum of interferents with positive impact
$S_{int,n}$	is the sum of interferents with negative impact

Combined uncertainty

$u(C_{,ppm})$ =

$$\sqrt{u^2(corr_{fit})+u^2(corr_{0,dr})+u^2(corr_{s,dr})+u^2(corr_{rep})+u^2(corr_{s,vf})+u^2(corr_{a,press})+u^2(corr_{temp})+u^2(corr_{volt})+u^2(corr_{adj})+S_{Int}^{\ 2}}$$

Overall expanded uncertainty (k = 2) $U(C_m) = u(C_m)\times k$

Uncertainty of NOx measurements

$$u(C_{NOx,conv}) = \frac{C_{NOx}\times R\times\eta}{\sqrt{3}}$$

Where:

C_{NOx}	is the concentration of NOx measured by the analyser
R	is the ratio of NO:Nox in the stack gas
η	is the NOx converter efficiency

Combined uncertainty NOx measurements

$u(C_{NOx,stack})$ =

$$\sqrt{u^2(corr_{fit})+u^2(corr_{0,dr})+u^2(corr_{s,dr})+u^2(corr_{rep})+u^2(corr_{s,vf})+u^2(corr_{a,press})+u^2(corr_{temp})+u^2(corr_{volt})+u^2(corr_{adj})+S_{Int}^{\ 2}+u^2(corr_{NOx,conv})}$$

Uncertainty of mass concentration at oxygen reference concentration

$u(C_{,O2\,ref})$ =

$$\sqrt{u^2(corr_{fit})+u^2(corr_{0,dr})+u^2(corr_{s,dr})+u^2(corr_{rep})+u^2(corr_{s,vf})+u^2(corr_{a,press})+u^2(corr_{temp})+u^2(corr_{volt})+u^2(corr_{adj})+S_{Int}^{\ 2}+\left(\frac{u^2(O_{2,meas,dry})}{(21-O_{2,meas,dry})^2}\right)}$$

Where:

$u(C,O_{2,ref})$	=	uncertainty associated with the mass concentration at O_2 ref. concentration	in	mg/m^3
$C,O_{2,ref}$	=	mass concentration at O_2 reference concentration	in	mg/m^3
$O_{2,meas}$	=	O_2 measured concentration	in	% volume
$u((O_{2,meas})_{dry})$	=	uncertainty associated to the measured O_2 concentration	in	% (relative to $O_{2\ meas}$)

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon BS EN12619:2013

Analyser Type/Model	Sick Maihak
Reference Oxygen %	0 (0 = No correction)

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	7.4	4.6	3.4
Measured concentration	mg/m^3	11.9	7.3	5.5
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A

Calibration gas	ppm	78.8	78.8	78.8
Calibration gas	mg/m^3	126.6	126.6	126.6
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0

Correction of Lack of Fit

Lack of fit	% range	2.0	2.0	2.0
	u(Corr,$_{fit}$)	0.11	0.11	0.11

Corrections of Zero and Span Drift (*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))

Zero Drift	% range	0.00	0.00	0.00
	u(Corr,$_{0dr}$)	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	u(Corr,$_{sdr}$)	0.00	0.00	0.00

Correction of Repeatability of Measurement

Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	u(Corr,$_{rep}$)	0.00	0.00	0.00

Correction of adjustment

losses in the line	% range	1.97	1.97	1.97
	u(Corr,$_{loss}$)	0.08	0.05	0.04
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	u(Corr,$_{cal}$)	0.07	0.05	0.03

Correction of Influence of Interferents

N_2O	% range			
	u(Corr,$_{N2O}$)	0.00	0.00	0.00
CO_2	% range			
	u(Corr,$_{CO2}$)	0.00	0.00	0.00
CH_4	% range			
	u(Corr,$_{CH4}$)	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
u(ΣCorrint) = $\max\left[S_{Int,p};S_{Int,n}\right]$	*u(ΣCorr $_{int}$)*	0.16	0.16	0.16

Correction of Influence Quantities

Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	u(Corr,$_{flow}$)	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	u(Corr,$_{press}$)	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	u(Corr,$_{temp}$)	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	u(Corr,$_{volt}$)	0.10	0.10	0.10

Oxygen reference concentration

Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!
Overall uncertainty of O_2 measurement	*U* ($O_{2,meas}$)	#REF!	#REF!	#REF!
	u(Corr,$_{O2}$)	N/A	N/A	N/A

Maximum standard uncertainty	u(Corr,$_{max}$)	0.11	0.11	0.11
5% of maximum standard uncertainty	u(Corr,$_{5\%}$)	0.01	0.01	0.01

Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
CH_4 range	0	10	0	50	mg/m^3
N_2O range	0	0	0	20	mg/m^3
CO_2 range	8	12	0	15	mg/m^3
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m^3

Influence Quantitiy Variations

	Minimum	Maximum	Value at cal	Performance	Units
Sensitivity to sample volume flow	55	65	60	5	l/h
Sensitivity to atmospheric pressure	99	100	99	1	kPa
Sensitivity to ambient temperature	278	313	288	10	K
Sensitivity to electrical voltage	187	250	230	5	V

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.38	0.37	0.37
Combined uncertainty	mg/m^3	0.61	0.60	0.59
Combined uncertainty at oxygen reference	mg/m^3	0.61	0.60	0.59

Expanded uncertainty expressed with a level of confidence of 95%, k=2

Overall uncertainty	ppm	0.8	0.7	0.7
Overall uncertainty	mg/m^3	1.2	1.2	1.2
Overall uncertainty relative to measured value	%	10.3	16.2	21.4
Overall uncertainty relative to range	%	8.2	8.0	7.9
Overall uncertainty relative to ELV	%	1.0	0.9	0.9

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2

Overall uncertainty	mg/m^3	N/A	N/A	N/A
Overall uncertainty relative to measured value	%	N/A	N/A	N/A
Overall uncertainty relative to range	%	N/A	N/A	N/A
Overall uncertainty relative to ELV	%	N/A	N/A	N/A

The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**Huntingdon**
Plant	**LEV 9**
Sampling Date	**16th January 2015**
Report Date	**26th February 2015**
Job Number	**EM02708**
Permit Number	**B22/11**

Report Prepared by:	***Print***	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***	EBuffam ………………………………………	
	Print	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**

1783

REC Environmental Monitoring
10 Broad Lane
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Company Registration No 03133832

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Monitoring Objectives

The monitoring was undertaken to check compliance with authorised emission limits.

All monitoring procedures were carried out to the MCERTS requirements under the REC Environmental Monitoring quality system to ISO 17025: 2005.

Monitoring was undertaken for the listed emissions from the following sampling positions:

Sampling Location	Emission
LEV 9	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

Emission	Method number	Method standard
Gas velocity and volume flow	TPM/01A	BS EN ISO 16911-1:2013
TOC	TPM/13	BS EN 12619 : 2013

Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Xaarjet Ltd.**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at Huntingdon		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
LEV 9		Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	Test 1	16/01/15	09:50	10:20	31.2	75	1.36	0.16	68.7
TOC	Test 2	16/01/15	10:20	10:50	42.1	75	1.49	0.16	92.6
TOC	Test 3	16/01/15	11:35	12:05	77.6	75	2.07	0.16	170.8

* at ref	Stack Gas Weight		0 °C	Wet Gas		
Conditions	29.00	Kg/kmol	101.3 kpa	Oxygen	None	%

Where applicable Oxides of nitrogen results are expressed as nitrogen dioxide
TOC results are expressed as total carbon

Throughout Report:

*	Reference conditions (see above)	Nm³	273 K, 101.3 kPa
**	Analysis not required	# - UKAS accredited only	
ND	Non detectable	## - Not Accredited	
s - Subcontracted laboratory analysis		N/A	Not applicable

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a 95% confidence level. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Operating Information

The tables below shows details of the operating information on each sampling date for: **LEV 9**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
16/01/2015	Production and cleaning of inkjet cartridges	Continuous	N/A	N/A	N/A	Normal

There are no CEMs present on this process

Comments & Monitoring Deviations

A waste gas homogeneity test to BS EN 15259:2007 (MID) is not required:-
The homogeneity test is not applicable to non-combustion processes.

All monitoring was performed in accordance with the relevant procedures.

The velocity and temperature profile at the sampling location met the requirements of BS EN 13284-1: 2002.

When the results are expressed as non-detected the mass emissions are calculated from the detection limit and therefore they are worst case results.

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Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

Client	Xaarjet Ltd.
Site	Huntingdon
Plant	LEV 9
Sampling Date	16th January 2015
Report Date	26th February 2015
Job Number	EM02708
Permit Number	B22/11

Report Prepared by:	*Print*	Emily Buffam	
	MCERTS No.	MM04 502	Level 2 TE: 1,2,3,4
Report Approved by:	*Sign*	EBuffam ……………………………………….	
	Print	Emily Buffam	
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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013

Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.

Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Report authorised by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Team leader:	Chris Rhodes	MM02 117	-	30/09/2017	28/02/2018	28/02/2018	31/08/2018	31/12/2018
Technician:	Tom Clarkson	MM02 120	-	-	-	-	-	-

Equipment References

Equipment	Reference Number
FID	VC09
Heated Line	HL24
Data Logger	DL14
Stack Thermocouple	PTTS138
Barometer	Met. Office
Pitot	PT138

APPENDIX 2

Date	16/01/2015
Time	09:00
Pitot Cp	1.02

Barometric pressure	100.4	kPa
Duct static pressure	0.97	kPa
Stack Area	0.071	m^2
Oxygen		%

Stack Diameter (circular)	0.30	m
		m
		m
Carbon dioxide		**%**

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s
1	A	5.0					B	5.0				
2	A	5.0					B	5.0				
3	A	5.0					B	5.0				
4	A	5.3	2.7	20	<15	6.7	B	5.3				
5	A	7.5	3.7	20	<15	7.9	B	7.5				
6	A	10.7	4.9	20	<15	9.1	B	10.7				
7	A	19.3	6.0	20	<15	10.1	B	19.3				
8	A	22.5	6.3	20	<15	10.3	B	22.5				
9	A	24.7	7.8	20	<15	11.5	B	24.7				
10	A	25.0					B	25.0				
11	A	25.0					B	25.0				
12	A	25.0					B	25.0				

Average Pitot DP	5.08	mmH_2O
Average Temperature	293.2	K
Average Velocity	9.3	m/s
Average volumetric flow rate	0.66	m^3/s at stack conditions
Average volumetric flow rate	0.61	m^3/s (wet STP)
Average volumetric flow rate		m^3/s (dry STP)
Average volumetric flow rate		m^3/s (dry, STP, reference oxygen concentraion)

Sampling plane requirements Re: BS EN 13284-1:2001 5.2

a	Angel of gas flow less than 15^o with regard to duct axis	YES
b	No local negative flow	YES
c	Minimum pitot greater than 5Pa	YES
d	Ratio of highest to lowest local gas velocity less than 3:1	YES
	Minimum local gas velocity	6.7
	Maximum local gas velocity	11.5
	Ratio of highest to lowest local gas velocity	1.72

Preliminary Velocity Traverse Data

Date 16/01/2015

From 09:50 to 10:20 30 minute mean

Volatile organic compounds	vppm, wet	19.43	mg/m³*	31.23

From 10:20 to 10:50 30 minute mean

Volatile organic compounds	vppm, wet	26.19	mg/m³*	42.09

From 11:35 to 12:05 30 minute mean

Volatile organic compounds	vppm, wet	48.30	mg/m³*	77.63

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity *k* = 2
Nitrogen	%	99.999	VC174989	-	± 2
Volatile organic compounds	vppm	78.8	VCSMG4537	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	09:27	Final Time	12:30
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	78.80	-0.49	80.46

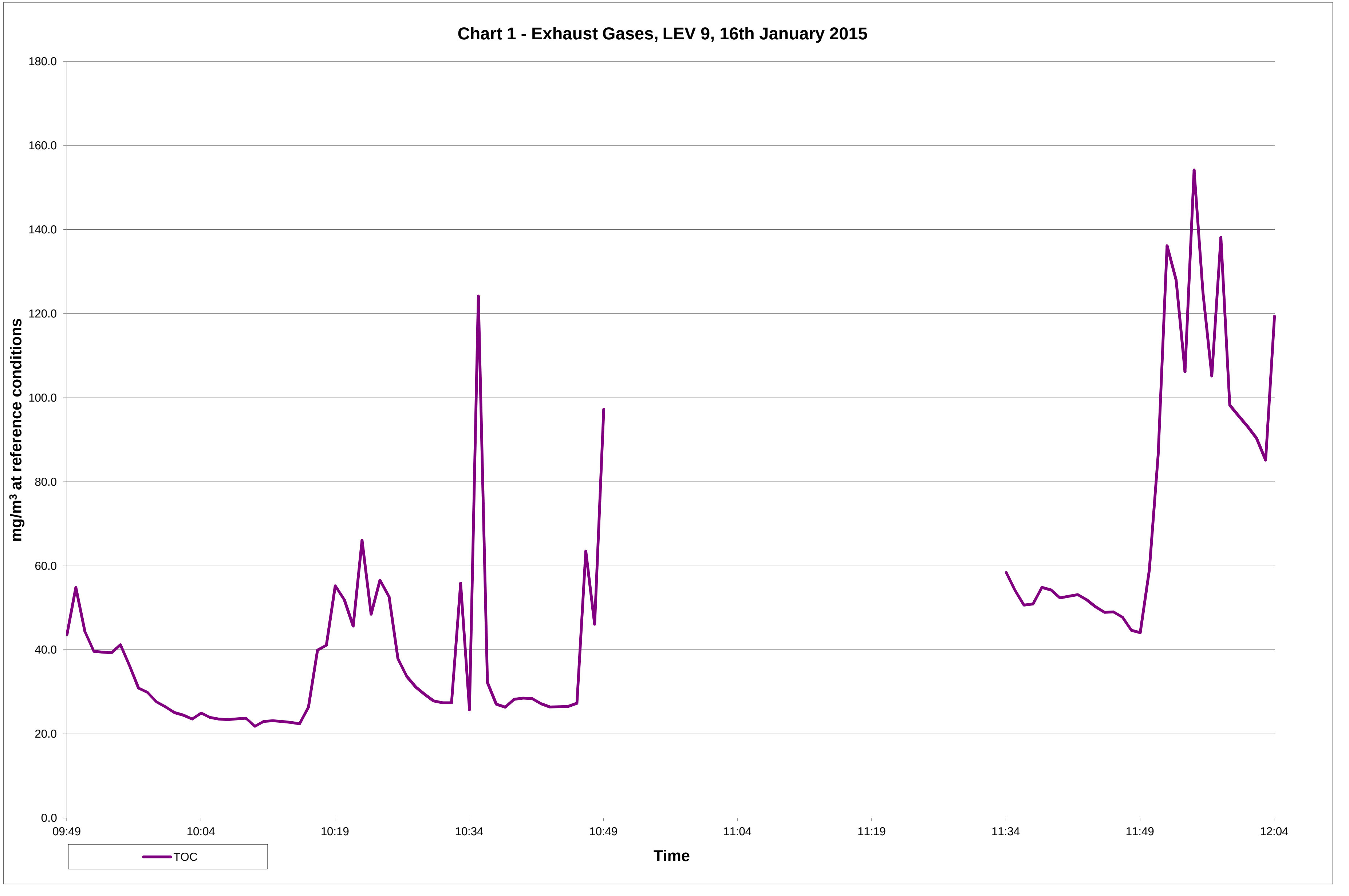
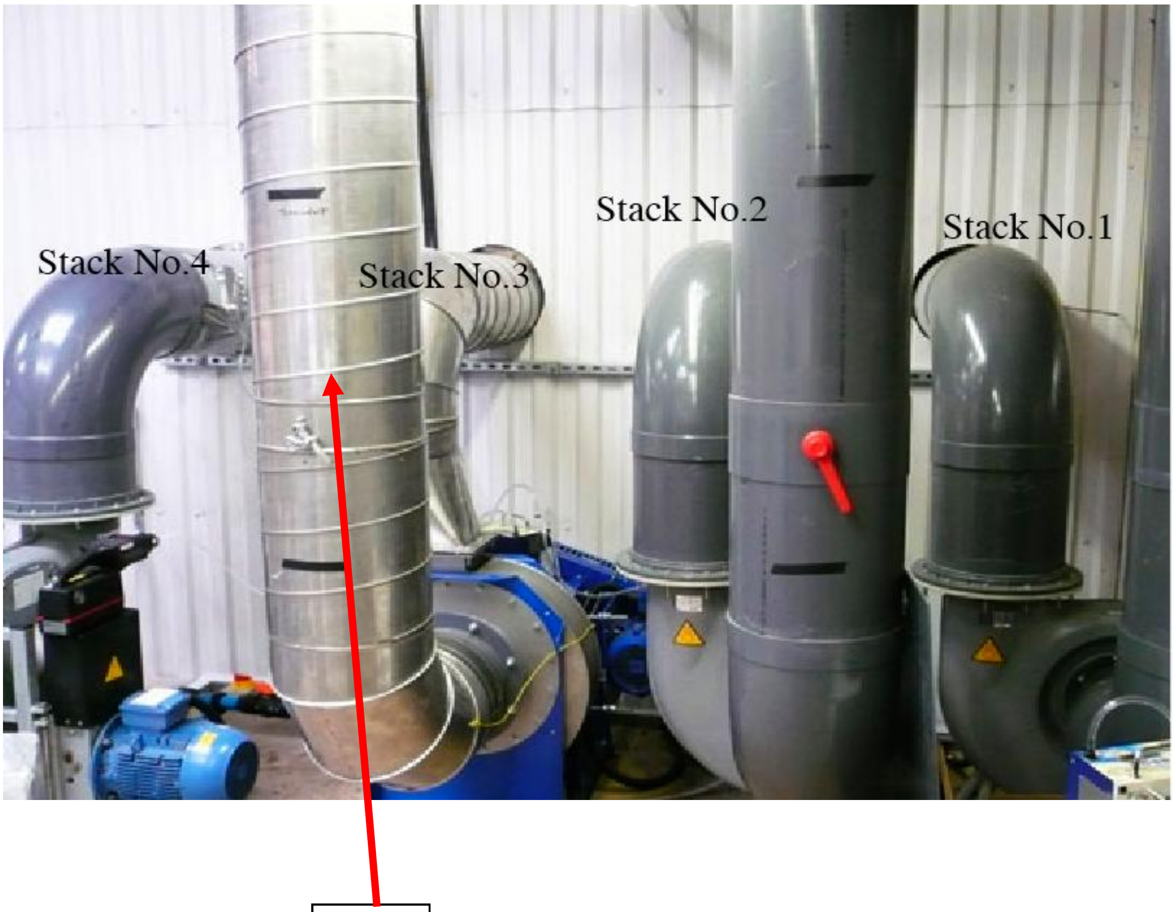


Chart 1 - Exhaust Gases, LEV 9, 16th January 2015
mg/m³ at reference conditions
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
09:49
10:04
10:19
10:34
10:49
11:04
11:19
11:34
11:49
12:04
Time
TOC

APPENDIX 3

Photograph Of The Sampling Location



LEV 9

General Calculations

Stack area:

$$Area\,of\ a\,circle = \frac{\pi.D^2}{4}$$

D = Diameter (m)
π = 3.142

Pressure conversion:

1mmH2O = 0.00980665 kPa
1mmH2O = 9.80665 Pa
1 mar = 0.1 kPa

Water vapour concentration:
From reference calculations (taken from BS EN 14790):

$$V_{WC(\%)} = \frac{\dfrac{m_{WC}.V_{mol(std)}}{M_W}}{\dfrac{m_{WC}.V_{mol(std)}}{M_W} + V_{m(std)}} \times 100$$

VWC (%) = Water vapour content on wet basis, in volume % (m^3 of water vapour in m^3 of wet gas)
Vm(std) = Dry gas volume measured, corrected to standard conditions (m^3)
mWC = Mass of water collected in the impingers (g)
Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)
Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)
From reference calculations (taken from BS EN 14790):

$$V_{m(std)} = y_d \times (V_2 - V_1) \times \frac{T_{std}}{T_m} \times \frac{p_m}{p_{std}}$$

Vm(std) = Dry gas meter volume at standard conditions (m^3)
yd = Gas meter calibration coefficient
(V2-V1) = Dry gas meter volume at actual conditions (m^3)
Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)
pm = Absolute pressure at the gas meter (kPa)
pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):
From reference calculations (taken from EA TGN M2):

$$IsokineticRatio(\%) = \frac{Velocity\ at\ the\ sampling\ nozzle}{Velocity\ of\ the\ stack\ gas} \times 100$$

Estimating Measurment Uncertainty
Uncertainty estimates are calculated using the general rule of uncertainty propagation. Guidance is taken from publications including UKAS document M3003 and ISO 20988:2007.

Flow Calculations

Velocity:
From reference calculations (taken from ISO 10780):

$$\bar{v} = KC\sqrt{\frac{T_s \, \Delta\bar{p}}{p_e \, M_s}}$$

$\bar{v} =$ Average velocity (m/s)
C = velocity calculation constant = 129
Ts = Average stack temperature (K)
Ms = Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol
K = Pitot calibration coefficient
Pe = Absolute gas pressure (kPa)
$\Delta\bar{p} =$ Average pitot tube pressure differencial (kPa)

Volume flow rate
From reference calculations (taken from ISO 10780):

$$q_{va} = \bar{v}A$$

qva = Average flow rate (m^3/s)
$\bar{v} =$ Average velocity (m/s)
A = Stack cross-sectional area (m^2)

Volume flow rate corrected for moisture
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\,\frac{(100 - H_a)}{(100 - H_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ha = Moisture at actual conditions (%volume)
Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\,\frac{(T_m \, p_a)}{(T_a \, p_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ta = Temperature at actual conditions (K)
Tm = Reference Temperatue (K)
pa = Absolute gas pressure at actual conditions (kPa)
pm = Reference pressure (kPa)

Volume flow rate corrected for oxygen
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\,\frac{(20.9 - O_{2,ref})}{(20.9 - O_{2,m})}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
O2,m = Actual oxygen concentration (%)
O2,ref = Reference oxygen concentration (%)

Concentration Calculations

Concentration:
From reference calculations (taken from BS EN 13284-1):

$$c = \frac{m}{V}$$

c = Concentration
m = Mass of substane
V = Volume sampled

Mass Emission

$$Mass\ emission = c \times q_m$$

c = Concentration
q = Volume flow rate

Concentration corrected for oxygen:
From reference calculations (taken from BS ISO 9096):

$$c_m = c_a \times \frac{20.9 - O_{2,ref}}{20.9 - O_{2,a}}$$

cm = Concentration at reference conditions
ca = Actual concentration
O2, ref = Reference oxygen (%)
O2, a= Actual Oxygen (%)

Concentration corrected for moisture:
From reference calculations (taken from BS ISO 9096):

Convert wet gas to dry gas

$$c_{dry} = c_{wet} \times \frac{100}{100 - H_a}$$

Convert dry gas to wet gas

$$c_{wet} = c_{dry} \times \frac{100 - H_a}{100}$$

cwet = Concentration wet gas
cdry = Concentration dry gas
Ha = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m^3
From reference calculations (taken from EA TGN M2):

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

When Converting TOC

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight\ of\ carbon\ in\ span\ gas(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

$$C_{ppm} = C_{reading} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{rep} + Corr_{adj} + \sum_{i=1}^{p} Corr_{\inf} + Corr_{\text{int}}$$

Where:

$C_{,ppm}$ = concentration in ppm
$C_{NO,reading}$ = concentration given by analyser
$Corr_{fit}$ = correction of lack of fit
$Corr_{0,dr}$ = correction of zero drift
$Corr_{s,dr}$ = correction of span drift
$Corr_{rep}$ = correction of repeatability of measurement
$Corr_{adj}$ = correction of adjustment
$Corr_{inf}$ = correction of influence quantities
$Corr_{int}$ = correction of interferents

Calculation of partial uncertainties

$u(Corr_{fit})$ = $$\frac{\left(\frac{X_{fit,\max}}{100 \times range}\right)}{\sqrt{3}}$$

Where:

$X_{fit,max}$	is the maximum allowable deviation from linearity

Expressed as % of the range and calculated by applying a rectangular probability distribution

$u(Corr_{0,dr})$ = $\dfrac{X_{0,dr}}{\sqrt{3}}$ $u(Corr_{s,dr})$ = $\dfrac{X_{s,dr}}{\sqrt{3}}$

$u(Corr_{rep})$ = max ($S_{0,rep}$; S_{srep}) = S_{rep}

Where:

$S_{r,0}$	is the standard uncertainty at zero level
$S_{r,s}$	is the standard uncertainty at span level

$u(Corr_{adj})$ = $u(Corr_{loss})$ + $u(Corr_{cal})$

$u(Corr_{loss})$ = $\dfrac{C_{j,loss}}{\sqrt{3}}$

$u(Corr_{cal})$ = $\dfrac{U_{cal}}{2}$

Where:

$u(Corr_{loss})$	is the uncertainty due to losses in sample line
$u(Corr_{cal})$	is the uncertainty due to losses in sample line
$cj_{,loss}$	is the concentration of sample loss at span level
U_{cal}	is the expanded uncertainty of the calibration gas

$u(Corr_{inf})$ =

$$c_j \sqrt{\frac{\left(x_{j,\max} - x_{j,adj}\right)^2 + \left(x_{j,\min} - x_{j,adj}\right) \times \left(x_{j,\max} - x_{j,adj}\right) + \left(x_{j,\min} - x_{j,adj}\right)^2}{3}}$$

Where:

c_j	is the sensitivity coefficient of the influence quantity
$x_{j,min}$	is the minimum value of the influence quantity during monitoring
$x_{j,max}$	is the maximum value of the influence quantity during monitoring
$x_{j,adj}$	is the value of the influence quantity during adjustment

$u(Corr_{int})$ = $$\frac{c_j}{Int_{j,test}} \sqrt{\frac{Int_{j,\max}{}^2 + Int_{j,\min} \times Int_{j,\max} + Int_{j,\min}{}^2}{3}}$$

and

$u(\Sigma Corr_{int})$ = $\max\left\lfloor S_{Int,p} ; S_{Int,n} \right\rfloor$

Where:

c_j	is the sensitivity coefficient of the interferent j
$Int_{j,test}$	is the concentration of the interferent j used to determine c_j
$Int_{j,min}$	is the minimum value of the interferent j quantity during monitoring
$Int_{j,max}$	is the maximum value of the interferent j quantity during monitoring
$Int_{j,adj}$	is the concentration of the interferent j in the cal gas used to adjust the analyser
$S_{int,p}$	is the sum of interferents with positive impact
$S_{int,n}$	is the sum of interferents with negative impact

Combined uncertainty

$u(C_{,ppm})$ =

$$\sqrt{u^2\left(corr_{fit}\right) + u^2\left(corr_{0,dr}\right) + u^2\left(corr_{s,dr}\right) + u^2\left(corr_{rep}\right) + u^2\left(corr_{s,vf}\right) + u^2\left(corr_{a,press}\right) + u^2\left(corr_{temp}\right) + u^2\left(corr_{volt}\right) + u^2\left(corr_{adj}\right) + S_{Int}{}^2}$$

Overall expanded uncertainty (k = 2) $U\left(C_m\right) = u\left(C_m\right) \times k$

Uncertainty of NOx measurements

$u(C_{NOx,conv})$ = $\dfrac{C_{NOx} \times R \times \eta}{\sqrt{3}}$

Where:

C_{NOx}	is the concentration of NOx measured by the analyser
R	is the ratio of NO:Nox in the stack gas
η	is the NOx converter efficiency

Combined uncertainty NOx measurements

$u(C_{NOx,stack})$ =

$$\sqrt{u^2\left(corr_{fit}\right) + u^2\left(corr_{0,dr}\right) + u^2\left(corr_{s,dr}\right) + u^2\left(corr_{rep}\right) + u^2\left(corr_{s,vf}\right) + u^2\left(corr_{a,press}\right) + u^2\left(corr_{temp}\right) + u^2\left(corr_{volt}\right) + u^2\left(corr_{adj}\right) + S_{Int}{}^2 + u^2\left(corr_{NOx,conv}\right)}$$

Uncertainty of mass concentration at oxygen reference concentration

$u(C_{,O2\,ref})$ =

$$\sqrt{u^2\left(corr_{fit}\right) + u^2\left(corr_{0,dr}\right) + u^2\left(corr_{s,dr}\right) + u^2\left(corr_{rep}\right) + u^2\left(corr_{s,vf}\right) + u^2\left(corr_{a,press}\right) + u^2\left(corr_{temp}\right) + u^2\left(corr_{volt}\right) + u^2\left(corr_{adj}\right) + S_{Int}{}^2 + \left(\frac{u^2\left(O_{2,meas,dry}\right)}{\left(21 - O_{2,meas,dry}\right)^2}\right)}$$

Where:

$u(C,O_{2,ref)}$	=	uncertainty associated with the mass concentration at O_2 ref. concentration	in	mg/m^3
$C,O_{2,ref}$	=	mass concentration at O_2 reference concentration	in	mg/m^3
$O_{2,meas}$	=	O_2 measured concentration	in	% volume
$u((O_{2,meas)dry)}$	=	uncertainty associated to the measured O_2 concentration	in	% (relative to $O_{2\,meas}$)

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon BS EN12619:2013

Analyser Type/Model	Sick Maihak	
Reference Oxygen %	0	(0 = No correction)

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	19.4	26.2	48.3
Measured concentration	mg/m^3	31.2	42.1	77.6
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A

Calibration gas	ppm	78.8	78.8	78.8
Calibration gas	mg/m^3	126.6	126.6	126.6
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0

Correction of Lack of Fit

Lack of fit	% range	2.0	2.0	2.0
	u(Corr,$_{fit}$)	0.11	0.11	0.11

Corrections of Zero and Span Drift (*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))

Zero Drift	% range	0.00	0.00	0.00
	u(Corr,$_{0dr}$)	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	u(Corr,$_{sdr}$)	0.00	0.00	0.00

Correction of Repeatability of Measurement

Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	u(Corr,$_{rep}$)	0.00	0.00	0.00

Correction of adjustment

losses in the line	% range	0.80	0.80	0.80
	u(Corr,$_{loss}$)	0.09	0.12	0.22
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	u(Corr,$_{cal}$)	0.19	0.26	0.48

Correction of Influence of Interferents

N_2O	% range			
	u(Corr,$_{N2O}$)	0.00	0.00	0.00
CO_2	% range			
	u(Corr,$_{CO2}$)	0.00	0.00	0.00
CH_4	% range			
	u(Corr,$_{CH4}$)	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
u(ΣCorrint) = $\max\left\lfloor S_{Int,p};S_{Int,n}\right\rfloor$	*u(ΣCorr $_{int}$)*	0.16	0.16	0.16

Correction of Influence Quantities

Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	u(Corr,$_{flow}$)	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	u(Corr,$_{press}$)	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	u(Corr,$_{temp}$)	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	u(Corr,$_{volt}$)	0.10	0.10	0.10

Oxygen reference concentration

Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!
Overall uncertainty of O_2 measurement	*U* ($O_{2,meas}$)	#REF!	#REF!	#REF!
	u(Corr,$_{O2}$)	N/A	N/A	N/A

Maximum standard uncertainty	u(Corr,$_{max}$)	0.19	0.26	0.48
5% of maximum standard uncertainty	u(Corr,$_{5\%}$)	0.01	0.01	0.02

Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
CH_4 range	0	10	0	50	mg/m^3
N_2O range	0	0	0	20	mg/m^3
CO_2 range	8	12	0	15	mg/m^3
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m^3

Influence Quantitiy Variations

	Minimum	Maximum	Value at cal	Performance	Units
Sensitivity to sample volume flow	55	65	60	5	l/h
Sensitivity to atmospheric pressure	99	100	99	1	kPa
Sensitivity to ambient temperature	278	313	288	10	K
Sensitivity to electrical voltage	187	250	230	5	V

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.42	0.47	0.65
Combined uncertainty	mg/m^3	0.68	0.75	1.04
Combined uncertainty at oxygen reference	mg/m^3	0.68	0.75	1.04

Expanded uncertainty expressed with a level of confidence of 95%, k=2

Overall uncertainty	ppm	0.8	0.9	1.3
Overall uncertainty	mg/m^3	1.4	1.5	2.1
Overall uncertainty relative to measured value	%	4.4	3.6	2.7
Overall uncertainty relative to range	%	9.1	10.0	13.8
Overall uncertainty relative to ELV	%	1.1	1.2	1.6

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2

Overall uncertainty	mg/m^3	N/A	N/A	N/A
Overall uncertainty relative to measured value	%	N/A	N/A	N/A
Overall uncertainty relative to range	%	N/A	N/A	N/A
Overall uncertainty relative to ELV	%	N/A	N/A	N/A

The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**Huntingdon**
Plant	**LEV 13**
Sampling Date	**15th January 2015**
Report Date	**26th February 2015**
Job Number	**EM02708**
Permit Number	**B22/11**

Report Prepared by:	***Print***	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***	EBuffam ……………………………………….	
	Print	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**

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REC Environmental Monitoring
10 Broad Lane
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Tel: 0845 676 9303
Company Registration No 03133832

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Monitoring Objectives

The monitoring was undertaken to check compliance with authorised emission limits.

All monitoring procedures were carried out to the MCERTS requirements under the REC Environmental Monitoring quality system to ISO 17025: 2005.

Monitoring was undertaken for the listed emissions from the following sampling positions:

Sampling Location	Emission
LEV 13	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

Emission	Method number	Method standard
Gas velocity and volume flow	TPM/01A	BS EN ISO 16911-1:2013
TOC	TPM/13	BS EN 12619 : 2013

Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Xaarjet Ltd.**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at Huntingdon		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
LEV 13		Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	Test 1	15/01/15	14:32	15:02	7.02	75	1.18	0.16	45.1
TOC	Test 2	15/01/15	15:02	15:32	5.84	75	1.18	0.16	37.5
TOC	Test 3	15/01/15	15:32	16:02	7.64	75	1.18	0.16	49.1

* at ref	Stack Gas Weight	0 °C	Wet Gas
Conditions	29.00 Kg/kmol	101.3 kpa	Oxygen None %

Where applicable	**Oxides of nitrogen results are expressed as nitrogen dioxide**		
	TOC results are expressed as total carbon		
Throughout Report:	*** Reference conditions (see above)**	**Nm³**	**273 K, 101.3 kPa**
	**** Analysis not required**	**# - UKAS accredited only**	
	ND Non detectable	**## - Not Accredited**	
	s - Subcontracted laboratory analysis	**N/A**	**Not applicable**

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a 95% confidence level. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

All tests included in this report are accredited under UKAS and MCERTS accreditation schemes unless otherwise stated. Opinions and interpretations expressed herein are outside the scope of MCERTS and UKAS accreditation.

Operating Information

The tables below shows details of the operating information on each sampling date for: **LEV 13**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
15/01/2015	Production and cleaning of inkjet cartridges	Continuous	N/A	N/A	N/A	Normal

There are no CEMs present on this process

Comments & Monitoring Deviations

A waste gas homogeneity test to BS EN 15259:2007 (MID) is not required:-
The homogeneity test is not applicable to non-combustion processes.

All monitoring was performed in accordance with the relevant procedures.

The velocity and temperature profile at the sampling location met the requirements of BS EN 13284-1: 2002.

When the results are expressed as non-detected the mass emissions are calculated from the detection limit and therefore they are worst case results.

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Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

Client	Xaarjet Ltd.
Site	Huntingdon
Plant	LEV 13
Sampling Date	15th January 2015
Report Date	26th February 2015
Job Number	EM02708
Permit Number	B22/11

Report Prepared by:	*Print*	Emily Buffam	
	MCERTS No.	MM04 502	Level 2 TE: 1,2,3,4
Report Approved by:	*Sign*	EBuffam ……………………………………….	
	Print	Emily Buffam	
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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013

Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.

Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Report authorised by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Team leader:	Chris Rhodes	MM02 117	-	30/09/2017	28/02/2018	28/02/2018	31/08/2018	31/12/2018
Technician:	Tom Clarkson	MM02 120	-	-	-	-	-	-

Equipment References

Equipment	Reference Number
FID	**VC12**
Heated Line	**HL24**
Data Logger	**DL14**
Stack Thermocouple	**PTTS138**
Barometer	**Met. Office**
Pitot	**PT138**

APPENDIX 2

Date	15/01/2015
Time	16:14
Pitot Cp	1.02

Barometric pressure	98.5	kPa
Duct static pressure	-0.24	kPa
Stack Area	0.283	m^2
Oxygen		%

Stack Diameter (circular)	0.60	m
		m
		m
Carbon dioxide		%

Traverse	Traverse	Depth	ΔP	T	Angle	velocity	Traverse	Depth	ΔP	T	Angle	velocity
Point	Line	cm	mmH$_2$O	^{o}C	^{o}	m/s	Line	cm	mmH$_2$O	^{o}C	^{o}	m/s
1	A	5.0					B	5.0				
2	A	5.0	1.9	24	<15	5.9	B	5.0				
3	A	7.1	2.2	24	<15	6.2	B	7.1				
4	A	10.6	2.5	24	<15	6.7	B	10.6				
5	A	15.0	3.2	24	<15	7.5	B	15.0				
6	A	21.4	3.4	24	<15	7.8	B	21.4				
7	A	38.6	3.4	24	<15	7.8	B	38.6				
8	A	45.0	3.8	24	<15	8.2	B	45.0				
9	A	49.4	5.7	24	<15	10.1	B	49.4				
10	A	52.9	1.3	24	<15	4.8	B	52.9				
11	A	55.0	2.0	24	<15	6.0	B	55.0				
12	A	55.0					B	55.0				

Average Pitot DP	2.83	mmH$_2$O
Average Temperature	297.2	K
Average Velocity	7.1	m/s
Average volumetric flow rate	2.00	m^3/s at stack conditions
Average volumetric flow rate	1.79	m^3/s (wet STP)
Average volumetric flow rate		m^3/s (dry STP)
Average volumetric flow rate		m^3/s (dry, STP, reference oxygen concentraion)

Sampling plane requirements Re: BS EN 13284-1:2001 5.2

a	Angel of gas flow less than 15^o with regard to duct axis	YES
b	No local negative flow	YES
c	Minimum pitot greater than 5Pa	YES
d	Ratio of highest to lowest local gas velocity less than 3:1	YES
	Minimum local gas velocity	4.8
	Maximum local gas velocity	10.1
	Ratio of highest to lowest local gas velocity	2.08

Preliminary Velocity Traverse Data

Date 15/01/2015

From 14:32 to 15:02 30 minute mean

Volatile organic compounds	vppm, wet	4.37	mg/m³*	7.02

From 15:02 to 15:32 30 minute mean

Volatile organic compounds	vppm, wet	3.63	mg/m³*	5.84

.

From 15:32 to 16:02 30 minute mean

Volatile organic compounds	vppm, wet	4.75	mg/m³*	7.64

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity *k* = 2
Nitrogen	%	99.999	VC174989	-	± 2
Volatile organic compounds	vppm	78.8	VCSMG4537	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	14:24	Final Time	16:06
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	79.04	0.00	77.79

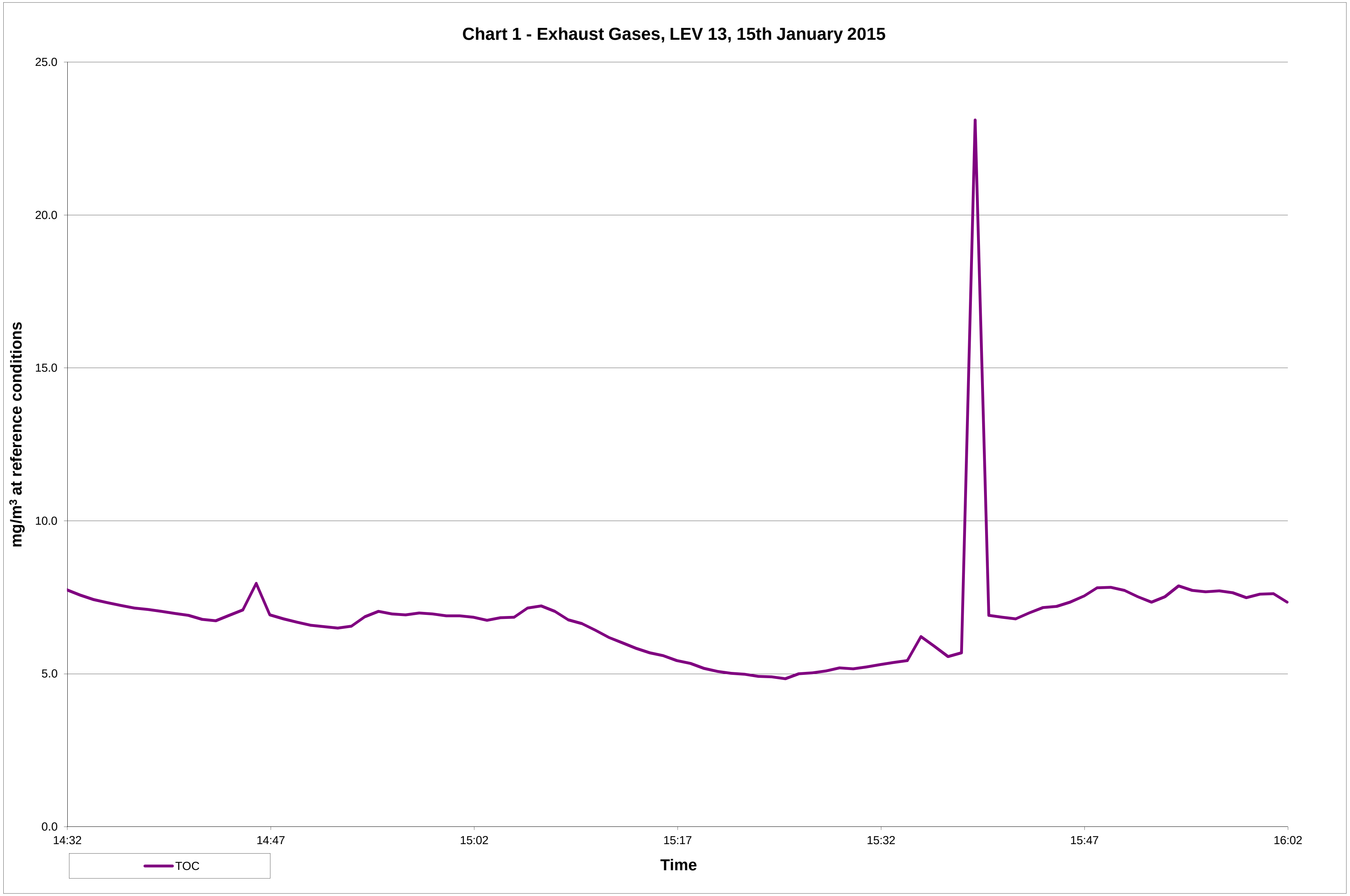
Chart 1 - Exhaust Gases, LEV 13, 15th January 2015
mg/m³ at reference conditions
25.0
20.0
15.0
10.0
5.0
0.0
14:32
14:47
15:02
15:17
15:32
15:47
16:02
Time
TOC

APPENDIX 3

Photograph Of The Sampling Location

LEV 13 – Room extract

General Calculations

Stack area:

$$Area\,of\;a\,circle = \frac{\pi . D^2}{4}$$

D = Diameter (m)
π = 3.142

Pressure conversion:

1mmH2O = 0.00980665 kPa
1mmH2O = 9.80665 Pa
1 mar = 0.1 kPa

Water vapour concentration:
From reference calculations (taken from BS EN 14790):

$$V_{WC(\%)} = \frac{\dfrac{m_{WC} . V_{mol(std)}}{M_W}}{\dfrac{m_{WC} . V_{mol(std)}}{M_W} + V_{m(std)}} \times 100$$

VWC (%) = Water vapour content on wet basis, in volume % (m^3 of water vapour in m^3 of wet gas)
Vm(std) = Dry gas volume measured, corrected to standard conditions (m^3)
mWC = Mass of water collected in the impingers (g)
Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)
Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)
From reference calculations (taken from BS EN 14790):

$$V_{m(std)} = y_d \times (V_2 - V_1) \times \frac{T_{std}}{T_m} \times \frac{p_m}{p_{std}}$$

Vm(std) = Dry gas meter volume at standard conditions (m^3)
yd = Gas meter calibration coefficient
(V2-V1) = Dry gas meter volume at actual conditions (m^3)
Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)
pm = Absolute pressure at the gas meter (kPa)
pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):
From reference calculations (taken from EA TGN M2):

$$IsokineticRatio(\%) = \frac{Velocity\ at\ the\ sampling\ nozzle}{Velocity\ of\ the\ stack\ gas} \times 100$$

Estimating Measurment Uncertainty
Uncertainty estimates are calculated using the general rule of uncertainty propagation. Guidance is taken from publications including UKAS document M3003 and ISO 20988:2007.

Flow Calculations

Velocity:
From reference calculations (taken from ISO 10780):

$$\bar{v} = KC\sqrt{\frac{T_s \, \Delta \bar{p}}{p_e \, M_s}}$$

$\bar{v} =$ Average velocity (m/s)
C = velocity calculation constant = 129
Ts = Average stack temperature (K)
Ms = Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol
K = Pitot calibration coefficient
Pe = Absolute gas pressure (kPa)
$\Delta \bar{p} =$ Average pitot tube pressure differencial (kPa)

Volume flow rate
From reference calculations (taken from ISO 10780):

$$q_{va} = \bar{v}A$$

qva = Average flow rate (m^3/s)
$\bar{v} =$ Average velocity (m/s)
A = Stack cross-sectional area (m^2)

Volume flow rate corrected for moisture
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(100 - H_a)}{(100 - H_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ha = Moisture at actual conditions (%volume)
Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(T_m \, p_a)}{(T_a \, p_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ta = Temperature at actual conditions (K)
Tm = Reference Temperatue (K)
pa = Absolute gas pressure at actual conditions (kPa)
pm = Reference pressure (kPa)

Volume flow rate corrected for oxygen
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(20.9 - O_{2,ref})}{(20.9 - O_{2,m})}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
O2,m = Actual oxygen concentration (%)
O2,ref = Reference oxygen concentration (%)

Concentration Calculations

Concentration:
From reference calculations (taken from BS EN 13284-1):

$$c = \frac{m}{V}$$

c = Concentration
m = Mass of substane
V = Volume sampled

Mass Emission

$$Mass\ emission = c \times q_m$$

c = Concentration
q = Volume flow rate

Concentration corrected for oxygen:
From reference calculations (taken from BS ISO 9096):

$$c_m = c_a \times \frac{20.9 - O_{2,ref}}{20.9 - O_{2,a}}$$

cm = Concentration at reference conditions
ca = Actual concentration
O2, ref = Reference oxygen (%)
O2, a= Actual Oxygen (%)

Concentration corrected for moisture:
From reference calculations (taken from BS ISO 9096):

Convert wet gas to dry gas

$$c_{dry} = c_{wet} \times \frac{100}{100 - H_a}$$

Convert dry gas to wet gas

$$c_{wet} = c_{dry} \times \frac{100 - H_a}{100}$$

cwet = Concentration wet gas
cdry = Concentration dry gas
Ha = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m^3
From reference calculations (taken from EA TGN M2):

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

When Converting TOC

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight\ of\ carbon\ in\ span\ gas(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

$$C_{ppm} = C_{reading} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{rep} + Corr_{adj} + \sum_{i=1}^{p} Corr_{\text{inf}} + Corr_{\text{int}}$$

Where:

$C_{,ppm}$	=	concentration in ppm	$Corr_{rep}$	=	correction of repeatability of measurement
$C_{NO,reading}$	=	concentration given by analyser	$Corr_{adj}$	=	correction of adjustment
$Corr_{fit}$	=	correction of lack of fit	$Corr_{inf}$	=	correction of influence quantities
$Corr_{0,dr}$	=	correction of zero drift	$Corr_{int}$	=	correction of interferents
$Corr_{s,dr}$	=	correction of span drift			

Calculation of partial uncertainties

u($Corr_{fit}$) = $\dfrac{\left(\dfrac{X_{fit,\max}}{100 \times range}\right)}{\sqrt{3}}$

Where:

$X_{fit,max}$ is the maximum allowable deviation from linearity

Expressed as % of the range and calculated by applying a rectangular probability distribution

u($Corr_{0,dr}$) = $\dfrac{X_{0,dr}}{\sqrt{3}}$ u($Corr_{s,dr}$) = $\dfrac{X_{s,dr}}{\sqrt{3}}$

u($Corr_{rep}$) = max ($S_{0,rep}$; S_{srep}) = S_{rep}

Where:

$S_{r,0}$	is the standard uncertainty at zero level
$S_{r,s}$	is the standard uncertainty at span level

u($Corr_{adj}$) = u($Corr_{loss}$) + u($Corr_{cal}$)

u($Corr_{loss}$) = $\dfrac{C_{j,loss}}{\sqrt{3}}$

u($Corr_{cal}$) = $\dfrac{U_{cal}}{2}$

Where:

u($Corr_{loss}$)	is the uncertainty due to losses in sample line
u($Corr_{cal}$)	is the uncertainty due to losses in sample line
$cj,_{loss}$	is the concentration of sample loss at span level
U_{cal}	is the expanded uncertainty of the calibration gas

u($Corr_{inf}$) = $c_j \sqrt{\dfrac{\left(x_{j,\max} - x_{j,adj}\right)^2 + \left(x_{j,\min} - x_{j,adj}\right) \times \left(x_{j,\max} - x_{j,adj}\right) + \left(x_{j,\min} - x_{j,adj}\right)^2}{3}}$

Where:

c_j	is the sensitivity coefficient of the influence quantity
$x_{j,min}$	is the minimum value of the influence quantity during monitoring
$x_{j,max}$	is the maximum value of the influence quantity during monitoring
$x_{j,adj}$	is the value of the influence quantity during adjustment

u($Corr_{int}$) = $\dfrac{c_j}{Int_{j,test}} \sqrt{\dfrac{Int_{j,\max}{}^2 + Int_{j,\min} \times Int_{j,\max} + Int_{j,\min}{}^2}{3}}$

and

u(Σ$Corr_{int}$) = $\max\left\lfloor S_{Int,p} ; S_{Int,n} \right\rfloor$

Where:

c_j	is the sensitivity coefficient of the interferent j
$Int_{j,test}$	is the concentration of the interferent j used to determine c_j
$Int_{j,min}$	is the minimum value of the interferent j quantity during monitoring
$Int_{j,max}$	is the maximum value of the interferent j quantity during monitoring
$Int_{j,adj}$	is the concentration of the interferent j in the cal gas used to adjust the analyser
$S_{int,p}$	is the sum of interferents with positive impact
$S_{int,n}$	is the sum of interferents with negative impact

Combined uncertainty

u(C, $_{ppm}$) =

$$\sqrt{u^2\left(corr_{fit}\right) + u^2\left(corr_{0,dr}\right) + u^2\left(corr_{s,dr}\right) + u^2\left(corr_{rep}\right) + u^2\left(corr_{s,vf}\right) + u^2\left(corr_{a,press}\right) + u^2\left(corr_{temp}\right) + u^2\left(corr_{volt}\right) + u^2\left(corr_{adj}\right) + S_{Int}{}^2}$$

Overall expanded uncertainty (k = 2) $U\left(C_m\right) = u\left(C_m\right) \times k$

Uncertainty of NOx measurements

u($C_{NOx,conv}$) = $\dfrac{C_{NOx} \times R \times \eta}{\sqrt{3}}$

Where:

C_{NOx}	is the concentration of NOx measured by the analyser
R	is the ratio of NO:Nox in the stack gas
η	is the NOx converter efficiency

Combined uncertainty NOx measurements

u($C_{NOx,stack}$) =

$$\sqrt{u^2\left(corr_{fit}\right) + u^2\left(corr_{0,dr}\right) + u^2\left(corr_{s,dr}\right) + u^2\left(corr_{rep}\right) + u^2\left(corr_{s,vf}\right) + u^2\left(corr_{a,press}\right) + u^2\left(corr_{temp}\right) + u^2\left(corr_{volt}\right) + u^2\left(corr_{adj}\right) + S_{Int}{}^2 + u^2\left(corr_{NOx,conv}\right)}$$

Uncertainty of mass concentration at oxygen reference concentration

u(C, $_{O2\,ref}$) =

$$\sqrt{u^2\left(corr_{fit}\right) + u^2\left(corr_{0,dr}\right) + u^2\left(corr_{s,dr}\right) + u^2\left(corr_{rep}\right) + u^2\left(corr_{s,vf}\right) + u^2\left(corr_{a,press}\right) + u^2\left(corr_{temp}\right) + u^2\left(corr_{volt}\right) + u^2\left(corr_{adj}\right) + S_{Int}{}^2 + \left(\frac{u^2\left(O_{2,meas,dry}\right)}{\left(21 - O_{2,meas,dry}\right)^2}\right)}$$

Where:

u(C,$O_{2,ref)}$	=	uncertainty associated with the mass concentration at O_2 ref. concentration	in	mg/m^3
C,$O_{2,ref}$	=	mass concentration at O_2 reference concentration	in	mg/m^3
$O_{2,meas}$	=	O_2 measured concentration	in	% volume
u(($O_{2,meas)dry)}$	=	uncertainty associated to the measured O_2 concentration	in	% (relative to $O_{2\ meas}$)

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon BS EN12619:2013

Analyser Type/Model	Sick Maihak	
Reference Oxygen %	0	(0 = No correction)

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	4.4	3.6	4.8
Measured concentration	mg/m^3	7.0	5.8	7.6
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A

Calibration gas	ppm	78.8	78.8	78.8
Calibration gas	mg/m^3	126.6	126.6	126.6
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0

Correction of Lack of Fit

Lack of fit	% range	2.0	2.0	2.0
	$u(Corr_{,fit})$	0.11	0.11	0.11

Corrections of Zero and Span Drift (*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))

Zero Drift	% range	0.00	0.00	0.00
	$u(Corr_{,0dr})$	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	$u(Corr_{,sdr})$	0.00	0.00	0.00

Correction of Repeatability of Measurement

Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	$u(Corr_{,rep})$	0.00	0.00	0.00

Correction of adjustment

losses in the line	% range	0.52	0.52	0.52
	$u(Corr_{,loss})$	0.01	0.01	0.01
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	$u(Corr_{,cal})$	0.04	0.04	0.05

Correction of Influence of Interferents

N_2O	% range			
	$u(Corr_{,N2O})$	0.00	0.00	0.00
CO_2	% range			
	$u(Corr_{,CO2})$	0.00	0.00	0.00
CH_4	% range			
	$u(Corr_{,CH4})$	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
u(ΣCorrint) = $\max\left[S_{Int,p};S_{Int,n}\right]$	*u(ΣCorr $_{int}$)*	0.16	0.16	0.16

Correction of Influence Quantities

Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	$u(Corr_{,flow})$	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	$u(Corr_{,press})$	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	$u(Corr_{,temp})$	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	$u(Corr_{,volt})$	0.10	0.10	0.10

Oxygen reference concentration

Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!
Overall uncertainty of O_2 measurement	$U(O_{2,meas})$	#REF!	#REF!	#REF!
	$u(Corr_{,O2})$	N/A	N/A	N/A

Maximum standard uncertainty	$u(Corr_{,max})$	0.11	0.11	0.11
5% of maximum standard uncertainty	$u(Corr_{,5\%})$	0.01	0.01	0.01

Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
CH_4 range	0	10	0	50	mg/m^3
N_2O range	0	0	0	20	mg/m^3
CO_2 range	8	12	0	15	mg/m^3
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m^3

Influence Quantitiy Variations

	Minimum	Maximum	Value at cal	Performance	Units
Sensitivity to sample volume flow	55	65	60	5	l/h
Sensitivity to atmospheric pressure	99	100	99	1	kPa
Sensitivity to ambient temperature	278	313	288	10	K
Sensitivity to electrical voltage	187	250	230	5	V

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.37	0.37	0.37
Combined uncertainty	mg/m^3	0.59	0.59	0.59
Combined uncertainty at oxygen reference	mg/m^3	0.59	0.59	0.59

Expanded uncertainty expressed with a level of confidence of 95%, k=2

Overall uncertainty	ppm	0.7	0.7	0.7
Overall uncertainty	mg/m^3	1.2	1.2	1.2
Overall uncertainty relative to measured value	%	16.8	20.2	15.5
Overall uncertainty relative to range	%	7.9	7.9	7.9
Overall uncertainty relative to ELV	%	0.9	0.9	0.9

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2

Overall uncertainty	mg/m^3	N/A	N/A	N/A
Overall uncertainty relative to measured value	%	N/A	N/A	N/A
Overall uncertainty relative to range	%	N/A	N/A	N/A
Overall uncertainty relative to ELV	%	N/A	N/A	N/A

The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**Huntingdon**
Plant	**LEV 14**
Sampling Date	**15th January 2015**
Report Date	**26th February 2015**
Job Number	**EM02708**
Permit Number	**B22/11**

Report Prepared by:	***Print***	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***	EBuffam ……………………………………….	
	Print	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**

1783

REC Environmental Monitoring
10 Broad Lane
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Company Registration No 03133832

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Monitoring Objectives

The monitoring was undertaken to check compliance with authorised emission limits.

All monitoring procedures were carried out to the MCERTS requirements under the REC Environmental Monitoring quality system to ISO 17025: 2005.

Monitoring was undertaken for the listed emissions from the following sampling positions:

Sampling Location	Emission
LEV 14	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

Emission	Method number	Method standard
Gas velocity and volume flow	TPM/01A	BS EN ISO 16911-1:2013
TOC	TPM/13	BS EN 12619 : 2013

Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Xaarjet Ltd.**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at Huntingdon LEV 14		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
		Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	Test 1	15/01/15	15:00	15:30	18.0	75	1.26	0.16	65.1
TOC	Test 2	15/01/15	15:30	16:00	13.0	75	1.22	0.16	47.1
TOC	Test 3	15/01/15	16:00	16:30	8.40	75	1.19	0.16	30.4

* at ref	Stack Gas Weight		0 °C	Wet Gas		
Conditions	29.00	Kg/kmol	101.3 kpa	Oxygen	None	%

Where applicable Oxides of nitrogen results are expressed as nitrogen dioxide
TOC results are expressed as total carbon

Throughout Report:
* Reference conditions (see above)
** Analysis not required
ND Non detectable
s - Subcontracted laboratory analysis

Nm³ 273 K, 101.3 kPa
- UKAS accredited only
- Not Accredited
N/A Not applicable

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a 95% confidence level. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Operating Information

The tables below shows details of the operating information on each sampling date for: **LEV 14**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
15/01/2015	Production and cleaning of inkjet cartridges	Continuous	N/A	N/A	N/A	Normal

There are no CEMs present on this process

Comments & Monitoring Deviations

A waste gas homogeneity test to BS EN 15259:2007 (MID) is not required:-
The homogeneity test is not applicable to non-combustion processes.

All monitoring was performed in accordance with the relevant procedures.

The velocity and temperature profile at the sampling location met the requirements of BS EN 13284-1: 2002.

When the results are expressed as non-detected the mass emissions are calculated from the detection limit and therefore they are worst case results.

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Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

Client	**Xaarjet Ltd.**
Site	**Huntingdon**
Plant	**LEV 14**
Sampling Date	**15th January 2015**
Report Date	**26th February 2015**
Job Number	**EM02708**
Permit Number	**B22/11**

Report Prepared by:	*Print*	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**
Report Approved by:	*Sign*	EBuffam ……………………………………….	
	Print	**Emily Buffam**	
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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013

Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.

Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Report authorised by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Team leader:	Chris Rhodes	MM02 117	-	30/09/2017	28/02/2018	28/02/2018	31/08/2018	31/12/2018
Technician:	Tom Clarkson	MM02 120	-	-	-	-	-	-

Equipment References

Equipment	Reference Number
FID	**VC09**
Heated Line	**HL24**
Data Logger	**DL06**
Stack Thermocouple	**PTTS138**
Barometer	**Met. Office**
Pitot	**PT138**

APPENDIX 2

Date	15/01/2015		Barometric pressure	98.5	kPa		Stack Diameter (circular)	0.45	m
Time	15:15		Duct static pressure	-0.04	kPa				m
Pitot Cp	1.02		Stack Area	0.159	m^2				m
			Oxygen		%		Carbon dioxide		%

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s
1	A	5.0					B	5.0				
2	A	5.0					B	5.0				
3	A	5.3	3.3	25	<15	7.6	B	5.3				
4	A	8.0	3.1	25	<15	7.4	B	8.0				
5	A	11.3	3.2	25	<15	7.5	B	11.3				
6	A	16.0	3.1	25	<15	7.4	B	16.0				
7	A	29.0	2.9	25	<15	7.1	B	29.0				
8	A	33.8	2.7	25	<15	6.9	B	33.8				
9	A	37.0	2.4	25	<15	6.6	B	37.0				
10	A	39.7	2.3	25	<15	6.4	B	39.7				
11	A	40.0					B	40.0				
12	A	40.0					B	40.0				

Average Pitot DP	2.85	mmH_2O
Average Temperature	298.2	K
Average Velocity	7.1	m/s
Average volumetric flow rate	1.13	m^3/s at stack conditions
Average volumetric flow rate	1.01	m^3/s (wet STP)
Average volumetric flow rate		m^3/s (dry STP)
Average volumetric flow rate		m^3/s (dry, STP, reference oxygen concentraion)

Sampling plane requirements Re: BS EN 13284-1:2001 5.2

a	Angel of gas flow less than 15^o with regard to duct axis		YES
b	No local negative flow		YES
c	Minimum pitot greater than 5Pa		YES
d	Ratio of highest to lowest local gas velocity less than 3:1		YES
	Minimum local gas velocity	6.4	
	Maximum local gas velocity	7.6	
	Ratio of highest to lowest local gas velocity	1.18	

Preliminary Velocity Traverse Data

Date 15/01/2015

From 15:00 to 15:30 30 minute mean

Volatile organic compounds	vppm, wet	11.19	mg/m³*	17.99

From 15:30 to 16:00 30 minute mean

Volatile organic compounds	vppm, wet	8.10	mg/m³*	13.01

.

From 16:00 to 16:30 30 minute mean

Volatile organic compounds	vppm, wet	5.23	mg/m³*	8.40

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity *k* = 2
Nitrogen	%	99.999	VC174989	-	± 2
Volatile organic compounds	vppm	78.8	VCSMG4537	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	14:33	Final Time	16:35
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	78.80	0.10	78.92

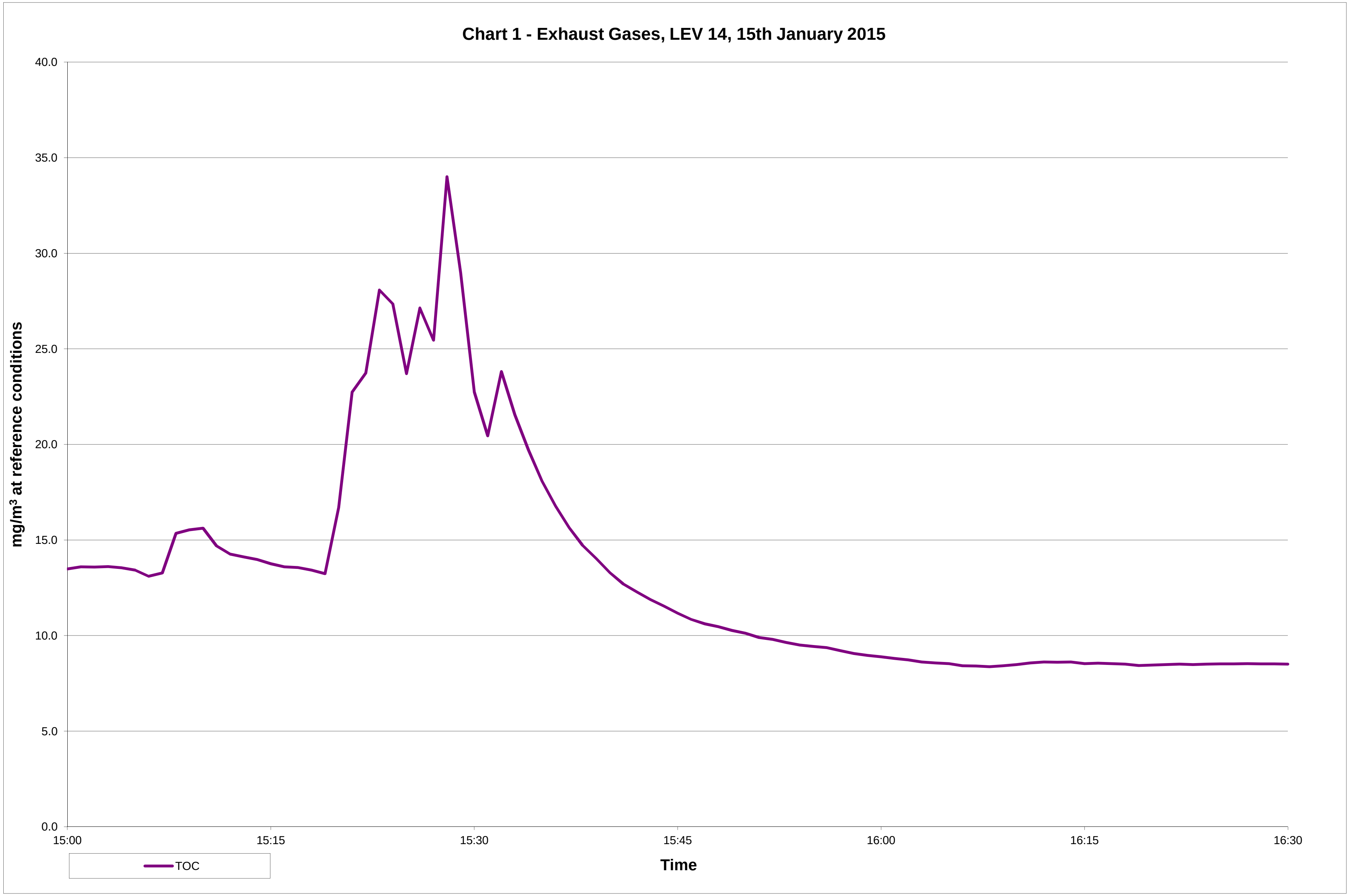
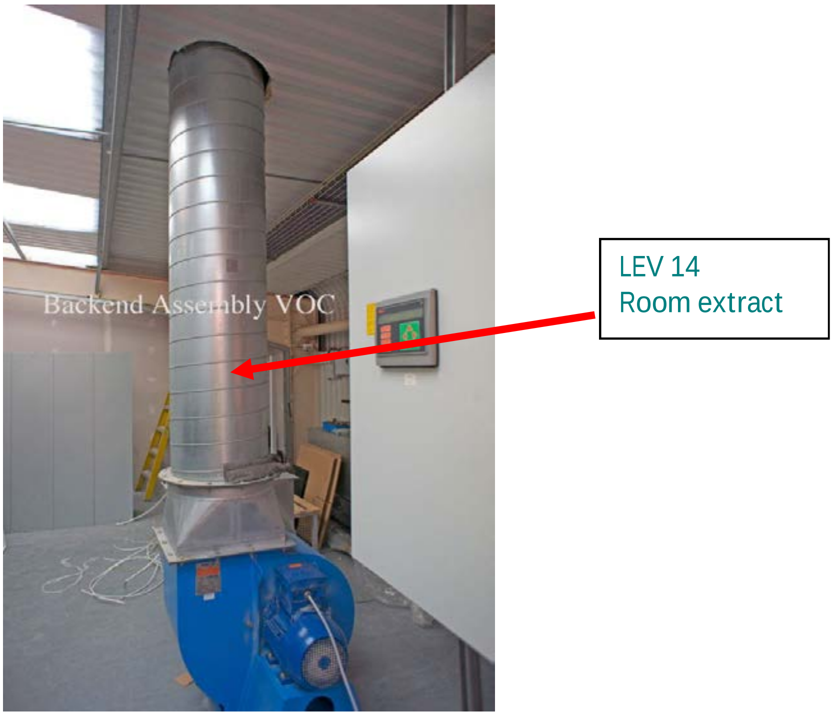


Chart 1 - Exhaust Gases, LEV 14, 15th January 2015
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
mg/m³ at reference conditions
15:00
15:15
15:30
15:45
16:00
16:15
16:30
Time
TOC

APPENDIX 3

Photograph Of The Sampling Location



General Calculations

Stack area:

$$Area\,of\,a\,circle = \frac{\pi.D^2}{4}$$

D = Diameter (m)
π = 3.142

Pressure conversion:

1mmH2O = 0.00980665 kPa
1mmH2O = 9.80665 Pa
1 mar = 0.1 kPa

Water vapour concentration:
From reference calculations (taken from BS EN 14790):

$$V_{WC(\%)} = \frac{\frac{m_{WC}.V_{mol(std)}}{M_W}}{\frac{m_{WC}.V_{mol(std)}}{M_W} + V_{m(std)}} \times 100$$

VWC (%) = Water vapour content on wet basis, in volume % (m^3 of water vapour in m^3 of wet gas)
Vm(std) = Dry gas volume measured, corrected to standard conditions (m^3)
mWC = Mass of water collected in the impingers (g)
Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)
Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)
From reference calculations (taken from BS EN 14790):

$$V_{m(std)} = y_d \times (V_2 - V_1) \times \frac{T_{std}}{T_m} \times \frac{p_m}{p_{std}}$$

Vm(std) = Dry gas meter volume at standard conditions (m^3)
yd = Gas meter calibration coefficient
(V2-V1) = Dry gas meter volume at actual conditions (m^3)
Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)
pm = Absolute pressure at the gas meter (kPa)
pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):
From reference calculations (taken from EA TGN M2):

$$IsokineticRatio(\%) = \frac{Velocity\ at\ the\ sampling\ nozzle}{Velocity\ of\ the\ stack\ gas} \times 100$$

Estimating Measurment Uncertainty
Uncertainty estimates are calculated using the general rule of uncertainty propagation. Guidance is taken from publications including UKAS document M3003 and ISO 20988:2007.

Flow Calculations

Velocity:
From reference calculations (taken from ISO 10780):

$$\bar{v} = KC\sqrt{\frac{T_s\,\Delta\bar{p}}{p_e\,M_s}}$$

$\bar{v} =$ Average velocity (m/s)
$C =$ velocity calculation constant = 129
$Ts =$ Average stack temperature (K)
$Ms =$ Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol
$K =$ Pitot calibration coefficient
$Pe =$ Absolute gas pressure (kPa)
$\Delta\bar{p} =$ Average pitot tube pressure differencial (kPa)

Volume flow rate
From reference calculations (taken from ISO 10780):

$$q_{va} = \bar{v}A$$

$qva =$ Average flow rate (m^3/s)
$\bar{v} =$ Average velocity (m/s)
$A =$ Stack cross-sectional area (m^2)

Volume flow rate corrected for moisture
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\,\frac{(100 - H_a)}{(100 - H_m)}$$

$qm =$ Corrected volume flowrate (m^3/s)
$qva =$ Volume flow rate at actual conditions (m^3/s)
$Ha =$ Moisture at actual conditions (%volume)
$Hm =$ Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\,\frac{(T_m\,p_a)}{(T_a\,p_m)}$$

$qm =$ Corrected volume flowrate (m^3/s)
$qva =$ Volume flow rate at actual conditions (m^3/s)
$Ta =$ Temperature at actual conditions (K)
$Tm =$ Reference Temperatue (K)
$pa =$ Absolute gas pressure at actual conditions (kPa)
$pm =$ Reference pressure (kPa)

Volume flow rate corrected for oxygen
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\,\frac{(20.9 - O_{2,ref})}{(20.9 - O_{2,m})}$$

$qm =$ Corrected volume flowrate (m^3/s)
$qva =$ Volume flow rate at actual conditions (m^3/s)
$O2,m =$ Actual oxygen concentration (%)
$O2,ref =$ Reference oxygen concentration (%)

Concentration Calculations

Concentration:
From reference calculations (taken from BS EN 13284-1):

$$c = \frac{m}{V}$$

c = Concentration
m = Mass of substane
V = Volume sampled

Mass Emission

$$Mass\ emission = c \times q_m$$

c = Concentration
q = Volume flow rate

Concentration corrected for oxygen:
From reference calculations (taken from BS ISO 9096):

$$c_m = c_a \times \frac{20.9 - O_{2,ref}}{20.9 - O_{2,a}}$$

cm = Concentration at reference conditions
ca = Actual concentration
O2, ref = Reference oxygen (%)
O2, a= Actual Oxygen (%)

Concentration corrected for moisture:
From reference calculations (taken from BS ISO 9096):

Convert wet gas to dry gas

$$c_{dry} = c_{wet} \times \frac{100}{100 - H_a}$$

Convert dry gas to wet gas

$$c_{wet} = c_{dry} \times \frac{100 - H_a}{100}$$

cwet = Concentration wet gas
cdry = Concentration dry gas
Ha = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m^3
From reference calculations (taken from EA TGN M2):

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

When Converting TOC

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight\ of\ carbon\ in\ span\ gas(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

$$C_{ppm} = C_{reading} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{rep} + Corr_{adj} + \sum_{i=1}^{p} Corr_{\inf} + Corr_{\mathrm{int}}$$

Where:

$C_{,ppm}$ = concentration in ppm
$C_{NO,reading}$ = concentration given by analyser
$Corr_{fit}$ = correction of lack of fit
$Corr_{0,dr}$ = correction of zero drift
$Corr_{s,dr}$ = correction of span drift
$Corr_{rep}$ = correction of repeatability of measurement
$Corr_{adj}$ = correction of adjustment
$Corr_{inf}$ = correction of influence quantities
$Corr_{int}$ = correction of interferents

Calculation of partial uncertainties

$$u(Corr_{fit}) = \frac{\left(\dfrac{X_{fit,\max}}{100 \times range}\right)}{\sqrt{3}}$$

Where:

$X_{fit,max}$ is the maximum allowable deviation from linearity

Expressed as % of the range and calculated by applying a rectangular probability distribution

$$u(Corr_{0,dr}) = \frac{X_{0,dr}}{\sqrt{3}} \qquad u(Corr_{s,dr}) = \frac{X_{s,dr}}{\sqrt{3}}$$

$$u(Corr_{rep}) = \max\,(S_{0,rep}\,;\,S_{srep}) = S_{rep}$$

Where:

$S_{r,0}$ is the standard uncertainty at zero level
$S_{r,s}$ is the standard uncertainty at span level

$$u(Corr_{adj}) = u(Corr_{loss}) + u(Corr_{cal})$$

$$u(Corr_{loss}) = \frac{C_{j,loss}}{\sqrt{3}}$$

$$u(Corr_{cal}) = \frac{U_{cal}}{2}$$

Where:

$u(Corr_{loss})$ is the uncertainty due to losses in sample line
$u(Corr_{cal})$ is the uncertainty due to losses in sample line
$cj_{,loss}$ is the concentration of sample loss at span level
U_{cal} is the expanded uncertainty of the calibration gas

$$u(Corr_{inf}) = c_j \sqrt{\frac{\left(x_{j,\max} - x_{j,adj}\right)^2 + \left(x_{j,\min} - x_{j,adj}\right) \times \left(x_{j,\max} - x_{j,adj}\right) + \left(x_{j,\min} - x_{j,adj}\right)^2}{3}}$$

Where:

c_j is the sensitivity coefficient of the influence quantity
$x_{j,min}$ is the minimum value of the influence quantity during monitoring
$x_{j,max}$ is the maximum value of the influence quantity during monitoring
$x_{j,adj}$ is the value of the influence quantity during adjustment

$$u(Corr_{int}) = \frac{c_j}{Int_{j,test}} \sqrt{\frac{Int_{j,\max}{}^2 + Int_{j,\min} \times Int_{j,\max} + Int_{j,\min}{}^2}{3}}$$

and

$$u(\Sigma Corr_{int}) = \max\left\lfloor S_{Int,p}\,;\,S_{Int,n}\right\rfloor$$

Where:

c_j is the sensitivity coefficient of the interferent j
$Int_{j,test}$ is the concentration of the interferent j used to determine c_j
$Int_{j,min}$ is the minimum value of the interferent j quantity during monitoring
$Int_{j,max}$ is the maximum value of the interferent j quantity during monitoring
$Int_{j,adj}$ is the concentration of the interferent j in the cal gas used to adjust the analyser
$S_{int,p}$ is the sum of interferents with positive impact
$S_{int,n}$ is the sum of interferents with negative impact

Combined uncertainty

$u(C,_{ppm})$ =

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + S_{Int}{}^2}$$

Overall expanded uncertainty (k = 2) $U(C_m) = u(C_m) \times k$

Uncertainty of NOx measurements

$$u(C_{NOx},_{conv}) = \frac{C_{NOx} \times R \times \eta}{\sqrt{3}}$$

Where:

C_{NOx} is the concentration of NOx measured by the analyser
R is the ratio of NO:Nox in the stack gas
η is the NOx converter efficiency

Combined uncertainty NOx measurements

$u(C_{NOx},_{stack})$ =

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + S_{Int}{}^2 + u^2(corr_{NOx,conv})}$$

Uncertainty of mass concentration at oxygen reference concentration

$u(C,_{O2\,ref})$ =

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + S_{Int}{}^2 + \left(\frac{u^2(O_{2,meas,dry})}{(21 - O_{2,meas,dry})^2}\right)}$$

Where:

$u(C,O_{2,ref})$ = uncertainty associated with the mass concentration at O_2 ref. concentration in mg/m^3
$C,O_{2,ref}$ = mass concentration at O_2 reference concentration in mg/m^3
$O_{2,meas}$ = O_2 measured concentration in % volume
$u((O_{2,meas})dry)$ = uncertainty associated to the measured O_2 concentration in % (relative to $O_{2\ meas}$)

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon BS EN12619:2013

Analyser Type/Model	Sick Maihak	
Reference Oxygen %	0	(0 = No correction)

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	11.2	8.1	5.2
Measured concentration	mg/m^3	18.0	13.0	8.4
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A

Calibration gas	ppm	78.8	78.8	78.8
Calibration gas	mg/m^3	126.6	126.6	126.6
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0

Correction of Lack of Fit

Lack of fit	% range	2.0	2.0	2.0
	u(Corr,$_{fit}$)	0.11	0.11	0.11

Corrections of Zero and Span Drift (*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))

Zero Drift	% range	0.00	0.00	0.00
	u(Corr,$_{0dr}$)	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	u(Corr,$_{sdr}$)	0.00	0.00	0.00

Correction of Repeatability of Measurement

Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	u(Corr,$_{rep}$)	0.00	0.00	0.00

Correction of adjustment

losses in the line	% range	1.28	1.28	1.28
	u(Corr,$_{loss}$)	0.08	0.06	0.04
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	u(Corr,$_{cal}$)	0.11	0.08	0.05

Correction of Influence of Interferents

N_2O	% range			
	u(Corr,$_{N2O}$)	0.00	0.00	0.00
CO_2	% range			
	u(Corr,$_{CO2}$)	0.00	0.00	0.00
CH_4	% range			
	u(Corr,$_{CH4}$)	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
u(ΣCorrint) = $\max\lfloor S_{Int,p};S_{Int,n}\rfloor$	*u(ΣCorr $_{int}$)*	0.16	0.16	0.16

Correction of Influence Quantities

Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	u(Corr,$_{flow}$)	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	u(Corr,$_{press}$)	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	u(Corr,$_{temp}$)	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	u(Corr,$_{volt}$)	0.10	0.10	0.10

Oxygen reference concentration

Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!
Overall uncertainty of O_2 measurement	*U* (O_{2},$_{meas}$)	#REF!	#REF!	#REF!
	u(Corr,$_{O2}$)	N/A	N/A	N/A

Maximum standard uncertainty	u(Corr,$_{max}$)	0.11	0.11	0.11
5% of maximum standard uncertainty	u(Corr,$_{5\%}$)	0.01	0.01	0.01

Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
CH_4 range	0	10	0	50	mg/m^3
N_2O range	0	0	0	20	mg/m^3
CO_2 range	8	12	0	15	mg/m^3
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m^3

Influence Quantitiy Variations

	Minimum	Maximum	Value at cal	Performance	Units
Sensitivity to sample volume flow	55	65	60	5	l/h
Sensitivity to atmospheric pressure	99	100	99	1	kPa
Sensitivity to ambient temperature	278	313	288	10	K
Sensitivity to electrical voltage	187	250	230	5	V

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.39	0.38	0.37
Combined uncertainty	mg/m^3	0.63	0.61	0.60
Combined uncertainty at oxygen reference	mg/m^3	0.63	0.61	0.60

Expanded uncertainty expressed with a level of confidence of 95%, k=2

Overall uncertainty	ppm	0.8	0.8	0.7
Overall uncertainty	mg/m^3	1.3	1.2	1.2
Overall uncertainty relative to measured value	%	7.0	9.3	14.2
Overall uncertainty relative to range	%	8.4	8.1	7.9
Overall uncertainty relative to ELV	%	1.0	1.0	0.9

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2

Overall uncertainty	mg/m^3	N/A	N/A	N/A
Overall uncertainty relative to measured value	%	N/A	N/A	N/A
Overall uncertainty relative to range	%	N/A	N/A	N/A
Overall uncertainty relative to ELV	%	N/A	N/A	N/A

The uncertainty evaluation has been carried out in accordance with UKAS requirements.

REC Environmental Monitoring

a division of Resource and Environmental Consultants Ltd

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

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**Huntingdon**
Plant	**LEV 17**
Sampling Date	**16th January 2015**
Report Date	**26th February 2015**
Job Number	**EM02708**
Permit Number	**B22/11**

Report Prepared by:	***Print***	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***	EBuffam ……………………………………….	
	Print	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**

REC Environmental Monitoring
10 Broad Lane
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MCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME ilac-MRA UKAS TESTING
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Monitoring Objectives

The monitoring was undertaken to check compliance with authorised emission limits.

All monitoring procedures were carried out to the MCERTS requirements under the REC Environmental Monitoring quality system to ISO 17025: 2005.

Monitoring was undertaken for the listed emissions from the following sampling positions:

Sampling Location	Emission
LEV 17	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

Emission	Method number	Method standard
Gas velocity and volume flow	TPM/01A	BS EN ISO 16911-1:2013
TOC	TPM/13	BS EN 12619 : 2013

Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Xaarjet Ltd.**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at Huntingdon		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
LEV 17		Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	Test 1	16/01/15	09:20	09:50	7.85	75	1.18	0.16	0.75
TOC	Test 2	16/01/15	09:50	10:20	6.92	75	1.18	0.16	0.66
TOC	Test 3	16/01/15	10:20	10:50	9.75	75	1.19	0.16	0.94

* at ref	Stack Gas Weight	0 °C	Wet Gas
Conditions	29.00 Kg/kmol	101.3 kpa	Oxygen None %

Where applicable Oxides of nitrogen results are expressed as nitrogen dioxide
TOC results are expressed as total carbon

Throughout Report:

* Reference conditions (see above)	Nm³	273 K, 101.3 kPa
** Analysis not required	# - UKAS accredited only	
ND Non detectable	## - Not Accredited	
s - Subcontracted laboratory analysis	N/A	Not applicable

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a 95% confidence level. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Operating Information

The tables below shows details of the operating information on each sampling date for: **LEV 17**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
16/01/2015	Production and cleaning of inkjet cartridges	Continuous	N/A	N/A	N/A	Normal

There are no CEMs present on this process

Comments & Monitoring Deviations

A waste gas homogeneity test to BS EN 15259:2007 (MID) is not required:-
The homogeneity test is not applicable to non-combustion processes.

All monitoring was performed in accordance with the relevant procedures.

The velocity and temperature profile at the sampling location met the requirements of BS EN 13284-1: 2002.

When the results are expressed as non-detected the mass emissions are calculated from the detection limit and therefore they are worst case results.

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Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

Client	**Xaarjet Ltd.**
Site	**Huntingdon**
Plant	**LEV 17**
Sampling Date	**16th January 2015**
Report Date	**26th February 2015**
Job Number	**EM02708**
Permit Number	**B22/11**

Report Prepared by:	*Print*	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**
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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013

Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.

Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Report authorised by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Team leader:	Chris Rhodes	MM02 117	-	30/09/2017	28/02/2018	28/02/2018	31/08/2018	31/12/2018
Technician:	Tom Clarkson	MM02 120	-	-	-	-	-	-

Equipment References

Equipment	Reference Number
FID	**VC12**
Heated Line	**HL24**
Data Logger	**DL06**
Stack Thermocouple	**PTTS138**
Barometer	**Met. Office**
Pitot	**PT138**

APPENDIX 2

Date	16/01/2015
Time	09:10
Pitot Cp	1.02

Barometric pressure	100.4	kPa
Duct static pressure	0.06	kPa
Stack Area	0.006	m^2
Oxygen		%

Stack Diameter (circular)	0.09	m
		m
		m
Carbon dioxide		%

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s
1	A	5.0					B	5.0				
2	A	5.0					B	5.0				
3	A	5.0					B	5.0				
4	A	5.0					B	5.0				
5	A	5.0					B	5.0				
6	A	5.0	1.2	16	<15	4.5	B	5.0				
7	A	4.0					B	4.0				
8	A	4.0					B	4.0				
9	A	4.0					B	4.0				
10	A	4.0					B	4.0				
11	A	4.0					B	4.0				
12	A	4.0					B	4.0				

Average Pitot DP	1.19	mmH_2O
Average Temperature	289.2	K
Average Velocity	4.5	m/s
Average volumetric flow rate	0.03	m^3/s at stack conditions
Average volumetric flow rate	0.03	m^3/s (wet STP)
Average volumetric flow rate		m^3/s (dry STP)
Average volumetric flow rate		m^3/s (dry, STP, reference oxygen concentraion)

Sampling plane requirements Re: BS EN 13284-1:2001 5.2

a	Angel of gas flow less than 15^o with regard to duct axis	YES
b	No local negative flow	YES
c	Minimum pitot greater than 5Pa	YES
d	Ratio of highest to lowest local gas velocity less than 3:1	YES

Minimum local gas velocity	4.5
Maximum local gas velocity	4.5
Ratio of highest to lowest local gas velocity	1.00

Preliminary Velocity Traverse Data

Date 16/01/2015

From 09:20 to 09:50 30 minute mean

Volatile organic compounds	vppm, wet	4.89	mg/m³*	7.85

From 09:50 to 10:20 30 minute mean

Volatile organic compounds	vppm, wet	4.30	mg/m³*	6.92

.

From 10:20 to 10:50 30 minute mean

Volatile organic compounds	vppm, wet	6.07	mg/m³*	9.75

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity *k* = 2
Nitrogen	%	99.999	VC174989	-	± 2
Volatile organic compounds	vppm	78.8	VCSMG4537	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	09:09	Final Time	12:40
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	78.56	0.08	78.68

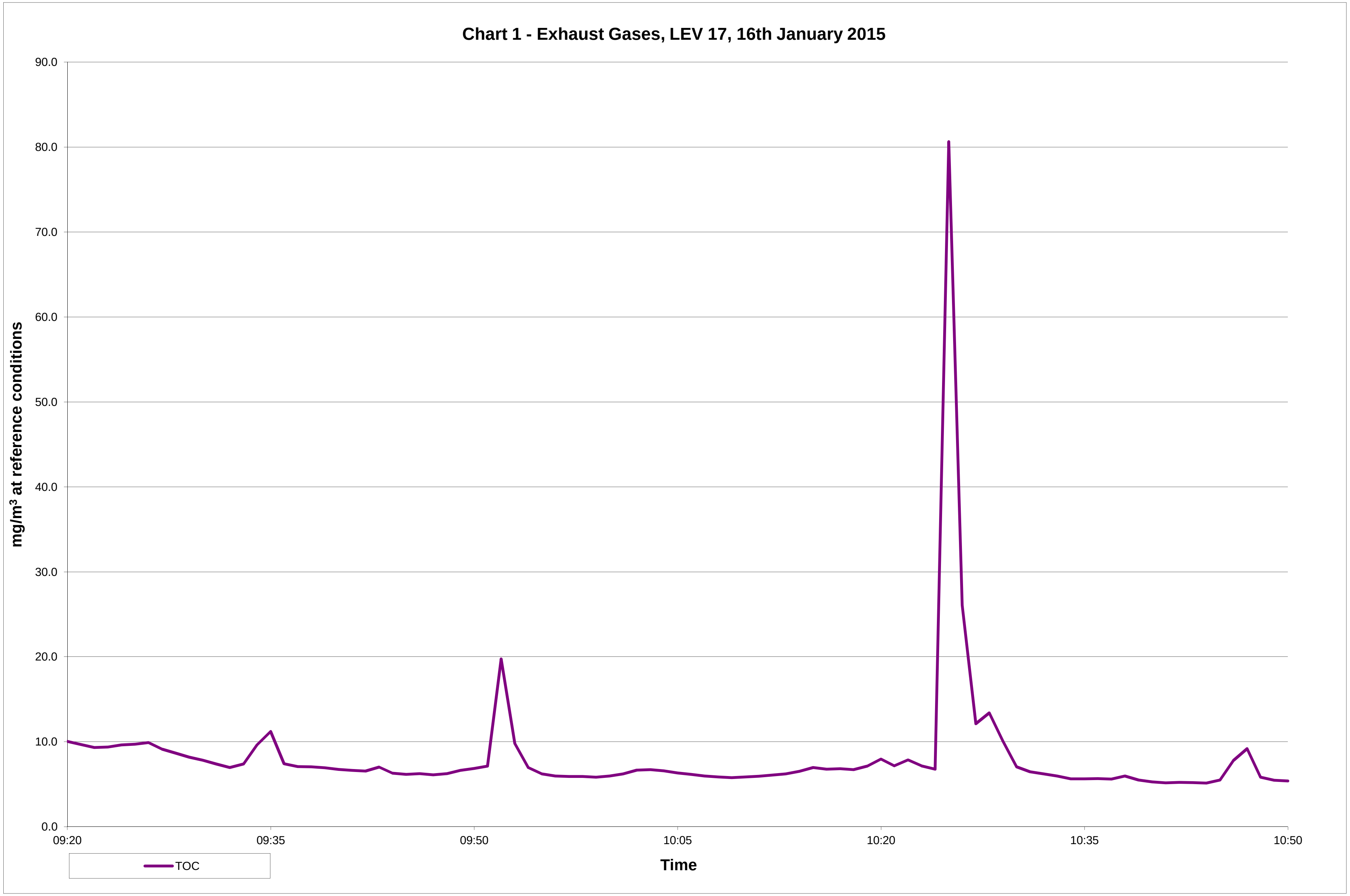
Chart 1 - Exhaust Gases, LEV 17, 16th January 2015
mg/m³ at reference conditions
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
09:20
09:35
09:50
10:05
10:20
10:35
10:50
Time
TOC

APPENDIX 3

General Calculations

Stack area:

$$Area\,of\;a\,circle = \frac{\pi.D^2}{4}$$

D =	Diameter (m)
π =	3.142

Pressure conversion:

1mmH2O = 0.00980665 kPa
1mmH2O = 9.80665 Pa
1 mar = 0.1 kPa

Water vapour concentration:
From reference calculations (taken from BS EN 14790):

$$V_{WC(\%)} = \frac{\frac{m_{WC}.V_{mol(std)}}{M_W}}{\frac{m_{WC}.V_{mol(std)}}{M_W} + V_{m(std)}} \times 100$$

VWC (%) =	Water vapour content on wet basis, in volume % (m^3 of water vapour in m^3 of wet gas)
Vm(std) =	Dry gas volume measured, corrected to standard conditions (m^3)
mWC =	Mass of water collected in the impingers (g)
Mw =	Molecular weight of water, 18.01534 rounded to 18 (g/mol)
Vmol(std) =	Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)
From reference calculations (taken from BS EN 14790):

$$V_{m(std)} = y_d \times (V_2 - V_1) \times \frac{T_{std}}{T_m} \times \frac{p_m}{p_{std}}$$

Vm(std) =	Dry gas meter volume at standard conditions (m^3)
yd =	Gas meter calibration coefficient
(V2-V1) =	Dry gas meter volume at actual conditions (m^3)
Tm =	Actual Temperature (K)
Tstd =	Standard temperature (273 K)
pm =	Absolute pressure at the gas meter (kPa)
pstd =	Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):
From reference calculations (taken from EA TGN M2):

$$IsokineticRatio(\%) = \frac{Velocity\ at\ the\ sampling\ nozzle}{Velocity\ of\ the\ stack\ gas} \times 100$$

Estimating Measurment Uncertainty
Uncertainty estimates are calculated using the general rule of uncertainty propagation. Guidance is taken from publications including UKAS document M3003 and ISO 20988:2007.

Flow Calculations

Velocity:
From reference calculations (taken from ISO 10780):

$$\bar{v} = KC\sqrt{\frac{T_s\,\Delta\bar{p}}{p_e\,M_s}}$$

$\bar{v} =$ Average velocity (m/s)
C = velocity calculation constant = 129
Ts = Average stack temperature (K)
Ms = Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol
K = Pitot calibration coefficient
Pe = Absolute gas pressure (kPa)
$\Delta\bar{p} =$ Average pitot tube pressure differencial (kPa)

Volume flow rate
From reference calculations (taken from ISO 10780):

$$q_{va} = \bar{v}A$$

qva = Average flow rate (m^3/s)
$\bar{v} =$ Average velocity (m/s)
A = Stack cross-sectional area (m^2)

Volume flow rate corrected for moisture
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(100 - H_a)}{(100 - H_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ha = Moisture at actual conditions (%volume)
Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(T_m\,p_a)}{(T_a\,p_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ta = Temperature at actual conditions (K)
Tm = Reference Temperatue (K)
pa = Absolute gas pressure at actual conditions (kPa)
pm = Reference pressure (kPa)

Volume flow rate corrected for oxygen
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\frac{(20.9 - O_{2,ref})}{(20.9 - O_{2,m})}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
O2,m = Actual oxygen concentration (%)
O2,ref = Reference oxygen concentration (%)

Concentration Calculations

Concentration:
From reference calculations (taken from BS EN 13284-1):

$$c = \frac{m}{V}$$

c = Concentration
m = Mass of substane
V = Volume sampled

Mass Emission

$$Mass\ emission = c \times q_m$$

c = Concentration
q = Volume flow rate

Concentration corrected for oxygen:
From reference calculations (taken from BS ISO 9096):

$$c_m = c_a \times \frac{20.9 - O_{2,ref}}{20.9 - O_{2,a}}$$

cm = Concentration at reference conditions
ca = Actual concentration
O2, ref = Reference oxygen (%)
O2, a= Actual Oxygen (%)

Concentration corrected for moisture:
From reference calculations (taken from BS ISO 9096):

Convert wet gas to dry gas

$$c_{dry} = c_{wet} \times \frac{100}{100 - H_a}$$

Convert dry gas to wet gas

$$c_{wet} = c_{dry} \times \frac{100 - H_a}{100}$$

cwet = Concentration wet gas
cdry = Concentration dry gas
Ha = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m^3
From reference calculations (taken from EA TGN M2):

$$Concentration(mg / m^3) = \frac{Concentration(ppm) \times molecular\ weight(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

When Converting TOC

$$Concentration(mg / m^3) = \frac{Concentration(ppm) \times molecular\ weight of\ carbon in\ span gas(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

$$C_{ppm} = C_{reading} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{rep} + Corr_{adj} + \sum_{i=1}^{p} Corr_{\mathrm{inf}} + Corr_{\mathrm{int}}$$

Where:

$C_{,ppm}$ = concentration in ppm
$C_{NO,reading}$ = concentration given by analyser
$Corr_{fit}$ = correction of lack of fit
$Corr_{0,dr}$ = correction of zero drift
$Corr_{s,dr}$ = correction of span drift
$Corr_{rep}$ = correction of repeatability of measurement
$Corr_{adj}$ = correction of adjustment
$Corr_{inf}$ = correction of influence quantities
$Corr_{int}$ = correction of interferents

Calculation of partial uncertainties

$u(Corr_{fit})$ = $\dfrac{\left(\dfrac{X_{fit,\max}}{100\times range}\right)}{\sqrt{3}}$

Where:
$X_{fit,max}$ is the maximum allowable deviation from linearity

Expressed as % of the range and calculated by applying a rectangular probability distribution

$u(Corr_{0,dr})$ = $\dfrac{X_{0,dr}}{\sqrt{3}}$ $u(Corr_{s,dr})$ = $\dfrac{X_{s,dr}}{\sqrt{3}}$

$u(Corr_{rep})$ = max ($S_{0,rep}$; S_{srep}) = S_{rep}

Where:
$S_{r,0}$ is the standard uncertainty at zero level
$S_{r,s}$ is the standard uncertainty at span level

$u(Corr_{adj})$ = $u(Corr_{loss})$ + $u(Corr_{cal})$

$u(Corr_{loss})$ = $\dfrac{C_{j,loss}}{\sqrt{3}}$

$u(Corr_{cal})$ = $\dfrac{U_{cal}}{2}$

Where:
$u(Corr_{loss})$ is the uncertainty due to losses in sample line
$u(Corr_{cal})$ is the uncertainty due to losses in sample line
$cj_{,loss}$ is the concentration of sample loss at span level
U_{cal} is the expanded uncertainty of the calibration gas

$u(Corr_{inf})$ = $c_j\sqrt{\dfrac{\left(x_{j,\max}-x_{j,adj}\right)^2+\left(x_{j,\min}-x_{j,adj}\right)\times\left(x_{j,\max}-x_{j,adj}\right)+\left(x_{j,\min}-x_{j,adj}\right)^2}{3}}$

Where:
c_j is the sensitivity coefficient of the influence quantity
$x_{j,min}$ is the minimum value of the influence quantity during monitoring
$x_{j,max}$ is the maximum value of the influence quantity during monitoring
$x_{j,adj}$ is the value of the influence quantity during adjustment

$u(Corr_{int})$ = $\dfrac{c_j}{Int_{j,test}}\sqrt{\dfrac{Int_{j,\max}{}^2+Int_{j,\min}\times Int_{j,\max}+Int_{j,\min}{}^2}{3}}$

and

$u(\Sigma Corr_{int})$ = $\max\left\lfloor S_{Int,p}\,;S_{Int,n}\right\rfloor$

Where:
c_j is the sensitivity coefficient of the interferent j
$Int_{j,test}$ is the concentration of the interferent j used to determine c_j
$Int_{j,min}$ is the minimum value of the interferent j quantity during monitoring
$Int_{j,max}$ is the maximum value of the interferent j quantity during monitoring
$Int_{j,adj}$ is the concentration of the interferent j in the cal gas used to adjust the analyser
$S_{int,p}$ is the sum of interferents with positive impact
$S_{int,n}$ is the sum of interferents with negative impact

Combined uncertainty

$u(C,_{ppm})$ =

$$\sqrt{u^2\left(corr_{fit}\right)+u^2\left(corr_{0,dr}\right)+u^2\left(corr_{s,dr}\right)+u^2\left(corr_{rep}\right)+u^2\left(corr_{s,vf}\right)+u^2\left(corr_{a,press}\right)+u^2\left(corr_{temp}\right)+u^2\left(corr_{volt}\right)+u^2\left(corr_{adj}\right)+S_{Int}{}^2}$$

Overall expanded uncertainty (k = 2) $U\left(C_m\right)=u\left(C_m\right)\times k$

Uncertainty of NOx measurements

$u(C_{NOx,conv})$ = $\dfrac{C_{NOx}\times R\times\eta}{\sqrt{3}}$

Where:
C_{NOx} is the concentration of NOx measured by the analyser
R is the ratio of NO:Nox in the stack gas
η is the NOx converter efficiency

Combined uncertainty NOx measurements

$u(C_{NOx,stack})$ =

$$\sqrt{u^2\left(corr_{fit}\right)+u^2\left(corr_{0,dr}\right)+u^2\left(corr_{s,dr}\right)+u^2\left(corr_{rep}\right)+u^2\left(corr_{s,vf}\right)+u^2\left(corr_{a,press}\right)+u^2\left(corr_{temp}\right)+u^2\left(corr_{volt}\right)+u^2\left(corr_{adj}\right)+S_{Int}{}^2+u^2\left(corr_{NOx,conv}\right)}$$

Uncertainty of mass concentration at oxygen reference concentration

$u(C,_{O2\,ref})$ =

$$\sqrt{u^2\left(corr_{fit}\right)+u^2\left(corr_{0,dr}\right)+u^2\left(corr_{s,dr}\right)+u^2\left(corr_{rep}\right)+u^2\left(corr_{s,vf}\right)+u^2\left(corr_{a,press}\right)+u^2\left(corr_{temp}\right)+u^2\left(corr_{volt}\right)+u^2\left(corr_{adj}\right)+S_{Int}{}^2+\left(\frac{u^2\left(O_{2,meas,dry}\right)}{\left(21-O_{2,meas,dry}\right)^2}\right)}$$

Where:
$u(C,O_{2,ref})$ = uncertainty associated with the mass concentration at O_2 ref. concentration in mg/m^3
$C,O_{2,ref}$ = mass concentration at O_2 reference concentration in mg/m^3
$O_{2,meas}$ = O_2 measured concentration in % volume
$u((O_{2,meas})dry)$ = uncertainty associated to the measured O_2 concentration in % (relative to $O_{2\,meas}$)

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon BS EN12619:2013

Analyser Type/Model	Sick Maihak	
Reference Oxygen %	0	(0 = No correction)

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	4.9	4.3	6.1
Measured concentration	mg/m^3	7.9	6.9	9.8
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A

Calibration gas	ppm	78.8	78.8	78.8
Calibration gas	mg/m^3	126.6	126.6	126.6
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0

Correction of Lack of Fit

Lack of fit	% range	2.0	2.0	2.0
	$u(Corr_{,fit})$	0.11	0.11	0.11

Corrections of Zero and Span Drift (*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))

Zero Drift	% range	0.00	0.00	0.00
	$u(Corr_{,0dr})$	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	$u(Corr_{,sdr})$	0.00	0.00	0.00

Correction of Repeatability of Measurement

Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	$u(Corr_{,rep})$	0.00	0.00	0.00

Correction of adjustment

losses in the line	% range	0.18	0.18	0.18
	$u(Corr_{,loss})$	0.01	0.00	0.01
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	$u(Corr_{,cal})$	0.05	0.04	0.06

Correction of Influence of Interferents

N_2O	% range			
	$u(Corr_{,N2O})$	0.00	0.00	0.00
CO_2	% range			
	$u(Corr_{,CO2})$	0.00	0.00	0.00
CH_4	% range			
	$u(Corr_{,CH4})$	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
u(ΣCorrint) = $\max\left[S_{Int,p};S_{Int,n}\right]$	*u(ΣCorr $_{int}$)*	0.16	0.16	0.16

Correction of Influence Quantities

Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	$u(Corr_{,flow})$	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	$u(Corr_{,press})$	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	$u(Corr_{,temp})$	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	$u(Corr_{,volt})$	0.10	0.10	0.10

Oxygen reference concentration

Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!
Overall uncertainty of O_2 measurement	$U(O_{2,meas})$	#REF!	#REF!	#REF!
	$u(Corr_{,O2})$	N/A	N/A	N/A

Maximum standard uncertainty	$u(Corr_{,max})$	0.11	0.11	0.11
5% of maximum standard uncertainty	$u(Corr_{,5\%})$	0.01	0.01	0.01

Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
CH_4 range	0	10	0	50	mg/m^3
N_2O range	0	0	0	20	mg/m^3
CO_2 range	8	12	0	15	mg/m^3
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m^3

Influence Quantitiy Variations

	Minimum	Maximum	Value at cal	Performance	Units
Sensitivity to sample volume flow	55	65	60	5	l/h
Sensitivity to atmospheric pressure	99	100	99	1	kPa
Sensitivity to ambient temperature	278	313	288	10	K
Sensitivity to electrical voltage	187	250	230	5	V

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.37	0.37	0.37
Combined uncertainty	mg/m^3	0.59	0.59	0.59
Combined uncertainty at oxygen reference	mg/m^3	0.59	0.59	0.59

Expanded uncertainty expressed with a level of confidence of 95%, k=2

Overall uncertainty	ppm	0.7	0.7	0.7
Overall uncertainty	mg/m^3	1.2	1.2	1.2
Overall uncertainty relative to measured value	%	15.1	17.1	12.2
Overall uncertainty relative to range	%	7.9	7.9	7.9
Overall uncertainty relative to ELV	%	0.9	0.9	0.9

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2

Overall uncertainty	mg/m^3	N/A	N/A	N/A
Overall uncertainty relative to measured value	%	N/A	N/A	N/A
Overall uncertainty relative to range	%	N/A	N/A	N/A
Overall uncertainty relative to ELV	%	N/A	N/A	N/A

The uncertainty evaluation has been carried out in accordance with UKAS requirements.

REC Environmental Monitoring

a division of Resource and Environmental Consultants Ltd

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

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**Huntingdon**
Plant	**LEV 19**
Sampling Date	**16th January 2015**
Report Date	**26th February 2015**
Job Number	**EM02708**
Permit Number	**B22/11**

Report Prepared by:	***Print***	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***	EBuffam ……………………………………….	
	Print	**Emily Buffam**	
	MCERTS No.	**MM04 502**	**Level 2 TE: 1,2,3,4**

MCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

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Monitoring Objectives

The monitoring was undertaken to check compliance with authorised emission limits.

All monitoring procedures were carried out to the MCERTS requirements under the REC Environmental Monitoring quality system to ISO 17025: 2005.

Monitoring was undertaken for the listed emissions from the following sampling positions:

Sampling Location	Emission
LEV 19	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

Emission	Method number	Method standard
Gas velocity and volume flow	TPM/01A	BS EN ISO 16911-1:2013
TOC	TPM/13	BS EN 12619 : 2013

Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Xaarjet Ltd.**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at Huntingdon LEV 19		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
		Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	Test 1	16/01/15	11:00	11:30	3.69	75	1.17	0.16	6.80
TOC	Test 2	16/01/15	11:30	12:00	2.67	75	1.17	0.16	4.91
TOC	Test 3	16/01/15	12:00	12:42	4.19	75	1.18	0.16	7.72

* at ref	Stack Gas Weight	0 °C	Wet Gas
Conditions	29.00 Kg/kmol	101.3 kpa	Oxygen None %

Where applicable Oxides of nitrogen results are expressed as nitrogen dioxide
TOC results are expressed as total carbon

Throughout Report:	*	Reference conditions (see above)	Nm³	273 K, 101.3 kPa
	**	Analysis not required	# - UKAS accredited only	
	ND	Non detectable	## - Not Accredited	
	s - Subcontracted laboratory analysis		N/A	Not applicable

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a 95% confidence level. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Operating Information

The tables below shows details of the operating information on each sampling date for: **LEV 19**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
16/01/2015	**Production and cleaning of inkjet cartridges**	**Continuous**	**N/A**	**N/A**	**N/A**	**Normal**

There are no CEMs present on this process

Comments & Monitoring Deviations

A waste gas homogeneity test to BS EN 15259:2007 (MID) is not required:-
The homogeneity test is not applicable to non-combustion processes.

All monitoring was performed in accordance with the relevant procedures.

The velocity and temperature profile at the sampling location met the requirements of BS EN 13284-1: 2002.

When the results are expressed as non-detected the mass emissions are calculated from the detection limit and therefore they are worst case results.

The power tripped between 12:08 and 12:17, data from within this period was removed

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Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

Client	Xaarjet Ltd.
Site	Huntingdon
Plant	LEV 19
Sampling Date	16th January 2015
Report Date	26th February 2015
Job Number	EM02708
Permit Number	B22/11

Report Prepared by:	*Print*	Emily Buffam	
	MCERTS No.	MM04 502	Level 2 TE: 1,2,3,4
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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013

Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.

Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Report authorised by:	Emily Buffam	MM04 502	-	30/06/2016	30/06/2016	31/08/2016	31/08/2016	31/08/2016
Team leader:	Chris Rhodes	MM02 117	-	30/09/2017	28/02/2018	28/02/2018	31/08/2018	31/12/2018
Technician:	Tom Clarkson	MM02 120	-	-	-	-	-	-

Equipment References

Equipment	Reference Number
FID	**VC12**
Heated Line	**HL24**
Data Logger	**DL06**
Stack Thermocouple	**PTTS138**
Barometer	**Met. Office**
Pitot	**PT138**

APPENDIX 2

Date	16/01/2015
Time	09:10
Pitot Cp	1.02

Barometric pressure	100.4	kPa
Duct static pressure	0.08	kPa
Stack Area	0.096	m^2
Oxygen		%

Stack Diameter (circular)	0.35	m
		m
		m
Carbon dioxide		**%**

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T ^oC	Angle ^{o}	velocity m/s
1	A	5.0					B	5.0				
2	A	5.0					B	5.0				
3	A	5.0	2.1	19	<15	6.0	B	5.0				
4	A	6.2	2.2	19	<15	6.2	B	6.2				
5	A	8.8	1.9	19	<15	5.7	B	8.8				
6	A	12.5	1.8	19	<15	5.6	B	12.5				
7	A	22.5	2.0	19	<15	5.9	B	22.5				
8	A	26.3	1.9	19	<15	5.7	B	26.3				
9	A	28.8	1.7	19	<15	5.4	B	28.8				
10	A	30.0	1.6	19	<15	5.3	B	30.0				
11	A	30.0					B	30.0				
12	A	30.0					B	30.0				

Average Pitot DP	1.93	mmH_2O
Average Temperature	292.2	K
Average Velocity	5.7	m/s
Average volumetric flow rate	0.55	m^3/s at stack conditions
Average volumetric flow rate	0.51	m^3/s (wet STP)
Average volumetric flow rate		m^3/s (dry STP)
Average volumetric flow rate		m^3/s (dry, STP, reference oxygen concentraion)

Sampling plane requirements Re: BS EN 13284-1:2001 5.2

a	Angel of gas flow less than 15^o with regard to duct axis	YES
b	No local negative flow	YES
c	Minimum pitot greater than 5Pa	YES
d	Ratio of highest to lowest local gas velocity less than 3:1	YES
	Minimum local gas velocity	5.3
	Maximum local gas velocity	6.2
	Ratio of highest to lowest local gas velocity	1.17

Date 16/01/2015

From 11:00 to 11:30 30 minute mean

Volatile organic compounds	vppm, wet	2.30	mg/m^3*	3.69

From 11:30 to 12:00 30 minute mean

Volatile organic compounds	vppm, wet	1.66	mg/m^3*	2.67

.

From 12:00 to 12:42 30 minute mean

Volatile organic compounds	vppm, wet	2.61	mg/m^3*	4.19

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m^3*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity *k* = 2
Nitrogen	%	99.999	VC174989	-	± 2
Volatile organic compounds	vppm	78.8	VCSMG4537	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	09:09	Final Time	12:40
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	78.56	0.08	78.68

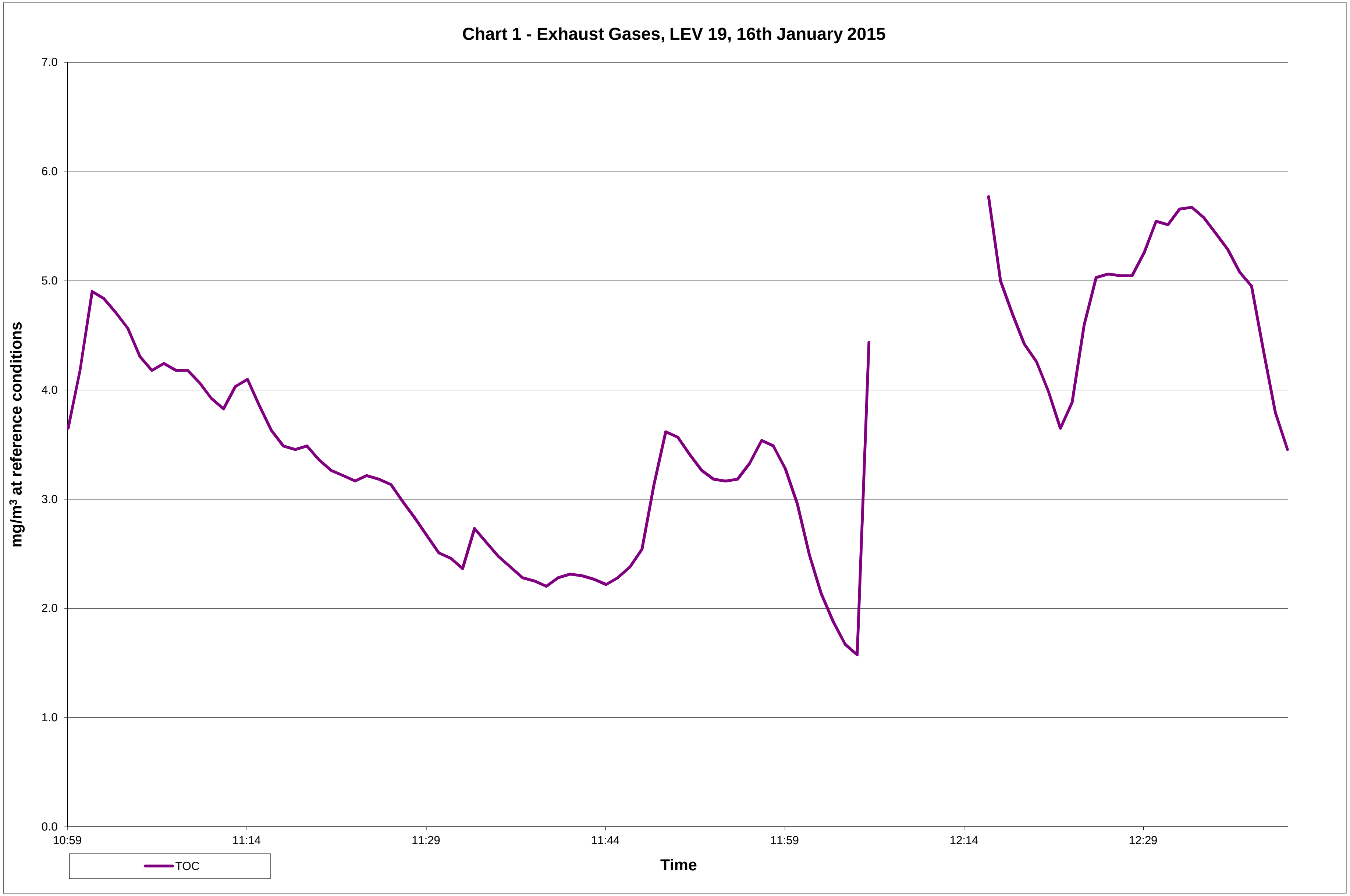
Chart 1 - Exhaust Gases, LEV 19, 16th January 2015
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
mg/m³ at reference conditions
10:59
11:14
11:29
11:44
11:59
12:14
12:29
Time
TOC

APPENDIX 3

General Calculations

Stack area:

$$Area\,of\;a\,circle = \frac{\pi.D^2}{4}$$

D = Diameter (m)
π = 3.142

Pressure conversion:

1mmH2O = 0.00980665 kPa
1mmH2O = 9.80665 Pa
1 mar = 0.1 kPa

Water vapour concentration:
From reference calculations (taken from BS EN 14790):

$$V_{WC(\%)} = \frac{\dfrac{m_{WC}.V_{mol(std)}}{M_W}}{\dfrac{m_{WC}.V_{mol(std)}}{M_W} + V_{m(std)}} \times 100$$

VWC (%) = Water vapour content on wet basis, in volume % (m^3 of water vapour in m^3 of wet gas)
Vm(std) = Dry gas volume measured, corrected to standard conditions (m^3)
mWC = Mass of water collected in the impingers (g)
Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)
Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)
From reference calculations (taken from BS EN 14790):

$$V_{m(std)} = y_d \times (V_2 - V_1) \times \frac{T_{std}}{T_m} \times \frac{p_m}{p_{std}}$$

Vm(std) = Dry gas meter volume at standard conditions (m^3)
yd = Gas meter calibration coefficient
(V2-V1) = Dry gas meter volume at actual conditions (m^3)
Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)
pm = Absolute pressure at the gas meter (kPa)
pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):
From reference calculations (taken from EA TGN M2):

$$IsokineticRatio(\%) = \frac{Velocity\ at\ the\ sampling\ nozzle}{Velocity\ of\ \ the\ stack\ gas} \times 100$$

Estimating Measurment Uncertainty
Uncertainty estimates are calculated using the general rule of uncertainty propagation. Guidance is taken from publications including UKAS document M3003 and ISO 20988:2007.

Flow Calculations

Velocity:
From reference calculations (taken from ISO 10780):

$$\bar{v} = KC\sqrt{\frac{T_s \, \Delta\bar{p}}{p_e \, M_s}}$$

$\bar{v} =$ Average velocity (m/s)
C = velocity calculation constant = 129
Ts = Average stack temperature (K)
Ms = Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol
K = Pitot calibration coefficient
Pe = Absolute gas pressure (kPa)
$\Delta\bar{p} =$ Average pitot tube pressure differencial (kPa)

Volume flow rate
From reference calculations (taken from ISO 10780):

$$q_{va} = \bar{v}A$$

qva = Average flow rate (m^3/s)
$\bar{v} =$ Average velocity (m/s)
A = Stack cross-sectional area (m^2)

Volume flow rate corrected for moisture
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\,\frac{(100 - H_a)}{(100 - H_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ha = Moisture at actual conditions (%volume)
Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\,\frac{(T_m \, p_a)}{(T_a \, p_m)}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
Ta = Temperature at actual conditions (K)
Tm = Reference Temperatue (K)
pa = Absolute gas pressure at actual conditions (kPa)
pm = Reference pressure (kPa)

Volume flow rate corrected for oxygen
From reference calculations (taken from BS ISO 9096):

$$q_m = q_{va}\,\frac{(20.9 - O_{2,ref})}{(20.9 - O_{2,m})}$$

qm = Corrected volume flowrate (m^3/s)
qva = Volume flow rate at actual conditions (m^3/s)
O2,m = Actual oxygen concentration (%)
O2,ref = Reference oxygen concentration (%)

Concentration Calculations

Concentration:
From reference calculations (taken from BS EN 13284-1):

$$c = \frac{m}{V}$$

c = Concentration
m = Mass of substane
V = Volume sampled

Mass Emission

$$Mass\ emission = c \times q_m$$

c = Concentration
q = Volume flow rate

Concentration corrected for oxygen:
From reference calculations (taken from BS ISO 9096):

$$c_m = c_a \times \frac{20.9 - O_{2,ref}}{20.9 - O_{2,a}}$$

cm = Concentration at reference conditions
ca = Actual concentration
O2, ref = Reference oxygen (%)
O2, a= Actual Oxygen (%)

Concentration corrected for moisture:
From reference calculations (taken from BS ISO 9096):

Convert wet gas to dry gas

$$c_{dry} = c_{wet} \times \frac{100}{100 - H_a}$$

Convert dry gas to wet gas

$$c_{wet} = c_{dry} \times \frac{100 - H_a}{100}$$

cwet = Concentration wet gas
cdry = Concentration dry gas
Ha = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m^3
From reference calculations (taken from EA TGN M2):

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

When Converting TOC

$$Concentration(mg/m^3) = \frac{Concentration(ppm) \times molecular\ weight\ of\ carbon\ in\ span\ gas(g)}{molar\ volume(l)\ at\ a\ given\ temperature}$$

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

$$C_{ppm} = C_{reading} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{rep} + Corr_{adj} + \sum_{i=1}^{p} Corr_{\mathrm{inf}} + Corr_{\mathrm{int}}$$

Where:

$C_{,ppm}$ = concentration in ppm
$C_{NO,reading}$ = concentration given by analyser
$Corr_{fit}$ = correction of lack of fit
$Corr_{0,dr}$ = correction of zero drift
$Corr_{s,dr}$ = correction of span drift
$Corr_{rep}$ = correction of repeatability of measurement
$Corr_{adj}$ = correction of adjustment
$Corr_{inf}$ = correction of influence quantities
$Corr_{int}$ = correction of interferents

Calculation of partial uncertainties

u(Corr$_{fit}$) = $$\frac{\left(\dfrac{X_{fit,\max}}{100 \times range}\right)}{\sqrt{3}}$$

Where:

$X_{fit,max}$	is the maximum allowable deviation from linearity

Expressed as % of the range and calculated by applying a rectangular probability distribution

u(Corr$_{0,dr}$) = $\dfrac{X_{0,dr}}{\sqrt{3}}$ u(Corr$_{s,dr}$) = $\dfrac{X_{s,dr}}{\sqrt{3}}$

u(Corr$_{rep}$) = max (S$_{0,rep}$; S$_{srep}$) = S$_{rep}$

Where:

$S_{r,0}$	is the standard uncertainty at zero level
$S_{r,s}$	is the standard uncertainty at span level

u(Corr$_{adj}$) = u(Corr$_{loss}$) + u(Corr$_{cal}$)

u(Corr$_{loss}$) = $\dfrac{C_{j,loss}}{\sqrt{3}}$

u(Corr$_{cal}$) = $\dfrac{U_{cal}}{2}$

Where:

u(Corr$_{loss}$)	is the uncertainty due to losses in sample line
u(Corr$_{cal}$)	is the uncertainty due to losses in sample line
cj,$_{loss}$	is the concentration of sample loss at span level
U$_{cal}$	is the expanded uncertainty of the calibration gas

u(Corr $_{inf}$) = $$c_j \sqrt{\frac{\left(x_{j,\max} - x_{j,adj}\right)^2 + \left(x_{j,\min} - x_{j,adj}\right) \times \left(x_{j,\max} - x_{j,adj}\right) + \left(x_{j,\min} - x_{j,adj}\right)^2}{3}}$$

Where:

c_j	is the sensitivity coefficient of the influence quantity
$x_{j,min}$	is the minimum value of the influence quantity during monitoring
$x_{j,max}$	is the maximum value of the influence quantity during monitoring
$x_{j,adj}$	is the value of the influence quantity during adjustment

u(Corr $_{int}$) = $$\frac{c_j}{Int_{j,test}} \sqrt{\frac{{Int_{j,\max}}^2 + Int_{j,\min} \times Int_{j,\max} + {Int_{j,\min}}^2}{3}}$$

and

u(ΣCorr $_{int}$) = $\max\left\lfloor S_{Int,p} ; S_{Int,n} \right\rfloor$

Where:

c_j	is the sensitivity coefficient of the interferent j
Int$_{j,test}$	is the concentration of the interferent j used to determine c$_j$
Int$_{j,min}$	is the minimum value of the interferent j quantity during monitoring
Int$_{j,max}$	is the maximum value of the interferent j quantity during monitoring
Int$_{j,adj}$	is the concentration of the interferent j in the cal gas used to adjust the analyser
$S_{int,p}$	is the sum of interferents with positive impact
$S_{int,n}$	is the sum of interferents with negative impact

Combined uncertainty

u(C, $_{ppm}$) =

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + {S_{Int}}^2}$$

Overall expanded uncertainty (k = 2) $U(C_m) = u(C_m) \times k$

Uncertainty of NOx measurements

u(C $_{NOx , conv}$) = $\dfrac{C_{NOx} \times R \times \eta}{\sqrt{3}}$

Where:

C$_{NOx}$	is the concentration of NOx measured by the analyser
R	is the ratio of NO:Nox in the stack gas
η	is the NOx converter efficiency

Combined uncertainty NOx measurements

u(C $_{NOx , stack}$) =

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + {S_{Int}}^2 + u^2(corr_{NOx,conv})}$$

Uncertainty of mass concentration at oxygen reference concentration

u(C, $_{O2\ ref}$) =

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + {S_{Int}}^2 + \left(\frac{u^2(O_{2,meas,dry})}{(21 - O_{2,meas,dry})^2}\right)}$$

Where:

u(C,O$_{2,ref)}$ = uncertainty associated with the mass concentration at O$_2$ ref. concentration in mg/m^3
C,O$_{2,ref}$ = mass concentration at O$_2$ reference concentration in mg/m^3
O$_{2,meas}$ = O$_2$ measured concentration in % volume
u((O$_{2,meas)dry)}$ = uncertainty associated to the measured O$_2$ concentration in % (relative to O$_{2\ meas}$)

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon BS EN12619:2013

Analyser Type/Model	Sick Maihak	
Reference Oxygen %	0	(0 = No correction)

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	2.3	1.7	2.6
Measured concentration	mg/m^3	3.7	2.7	4.2
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A

Calibration gas	ppm	78.8	78.8	78.8
Calibration gas	mg/m^3	126.6	126.6	126.6
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0

Correction of Lack of Fit

Lack of fit	% range	2.0	2.0	2.0
	$u(Corr_{,fit})$	0.11	0.11	0.11

Corrections of Zero and Span Drift (*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))

Zero Drift	% range	0.00	0.00	0.00
	$u(Corr_{,0dr})$	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	$u(Corr_{,sdr})$	0.00	0.00	0.00

Correction of Repeatability of Measurement

Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	$u(Corr_{,rep})$	0.00	0.00	0.00

Correction of adjustment

losses in the line	% range	0.18	0.18	0.18
	$u(Corr_{,loss})$	0.00	0.00	0.00
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	$u(Corr_{,cal})$	0.02	0.02	0.03

Correction of Influence of Interferents

N_2O	% range			
	$u(Corr_{,N2O})$	0.00	0.00	0.00
CO_2	% range			
	$u(Corr_{,CO2})$	0.00	0.00	0.00
CH_4	% range			
	$u(Corr_{,CH4})$	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
$u(\Sigma Corrint) = \max\lfloor S_{Int,p};S_{Int,n}\rfloor$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16

Correction of Influence Quantities

Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	$u(Corr_{,flow})$	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	$u(Corr_{,press})$	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	$u(Corr_{,temp})$	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	$u(Corr_{,volt})$	0.10	0.10	0.10

Oxygen reference concentration

Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!
Overall uncertainty of O_2 measurement	$U(O_{2,meas})$	#REF!	#REF!	#REF!
	$u(Corr_{,O2})$	N/A	N/A	N/A

Maximum standard uncertainty	$u(Corr_{,max})$	0.11	0.11	0.11
5% of maximum standard uncertainty	$u(Corr_{,5\%})$	0.01	0.01	0.01

Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
CH_4 range	0	10	0	50	mg/m^3
N_2O range	0	0	0	20	mg/m^3
CO_2 range	8	12	0	15	mg/m^3
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m^3

Influence Quantitiy Variations

	Minimum	Maximum	Value at cal	Performance	Units
Sensitivity to sample volume flow	55	65	60	5	l/h
Sensitivity to atmospheric pressure	99	100	99	1	kPa
Sensitivity to ambient temperature	278	313	288	10	K
Sensitivity to electrical voltage	187	250	230	5	V

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.37	0.37	0.37
Combined uncertainty	mg/m^3	0.59	0.59	0.59
Combined uncertainty at oxygen reference	mg/m^3	0.59	0.59	0.59

Expanded uncertainty expressed with a level of confidence of 95%, k=2

Overall uncertainty	ppm	0.7	0.7	0.7
Overall uncertainty	mg/m^3	1.2	1.2	1.2
Overall uncertainty relative to measured value	%	31.8	44.0	28.1
Overall uncertainty relative to range	%	7.8	7.8	7.8
Overall uncertainty relative to ELV	%	0.9	0.9	0.9

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2

Overall uncertainty	mg/m^3	N/A	N/A	N/A
Overall uncertainty relative to measured value	%	N/A	N/A	N/A
Overall uncertainty relative to range	%	N/A	N/A	N/A
Overall uncertainty relative to ELV	%	N/A	N/A	N/A

The uncertainty evaluation has been carried out in accordance with UKAS requirements.