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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 1
Sampling Date	15th January 2015
Report Date	26th February 2015
Job Number	EM02708
Permit Number	B22/11

Report	Prepared	by:	Print
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**Report Approved by:** 

MCERTS No.

Sign

Print

Emily Buffam

MM04 502

Level 2 TE: 1,2,3,4

Emily Buffam

MCERTS No.

MM04 502

Level 2 TE: 1,2,3,4

REC Environmental Monitoring 10 Broad Lane Moldgreen Huddersfield HD5 9BX

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 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
тос	TPM/13	BS EN 12619 : 2013

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# 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.

Emis	Emission at		Sampling		Emission	Authorised	Uncertainty	Detection	Mass
Hunt	Huntingdon		Time		Result	Limit	+/-	Limit	Emission
LI	EV 1	Date	Start	End	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	g/h
тос	Test 1	15/01/15	11:30	12:00	53.0	75	1.70	0.16	154.8
тос	Test 2	15/01/15	12:00	12:30	50.8	75	1.67	0.16	148.5
тос	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	Oxid TOC	es of nitrogen results are expressed as nitrogen dioxide results are expressed as total carbon			
Throughout Report:	*	Reference conditions (see above)	Nr	m³	273 K, 101.3 kPa
	**	Analysis not required	#	- UK	AS accredited only
	ND	Non detectable	##	# - N	ot Accredited
	s - Si	ubcontracted 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.





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## **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.

Client	Xaarjet Ltd.
Site	Huntingdon
Plant	LEV 1
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Report Approved by:	Sign	EBiffam	
	Print	Emily Buffam	
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# **APPENDIX 1**

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# **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.

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# Sampling Project Personnel Competency And Expiry Dates

Report prepared by:	Emily Buffam	MCERTS No MM04 502	Level 1 -	Level 2 30/06/2016	TE1 30/06/2016	TE2 31/08/2016	TE3 31/08/2016	TE4 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

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# **APPENDIX 2**

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		_			_	
Date	15/01/2015		Barometric pressure	98.5	kPa	Stack Diameter
Time	10:30		Duct static pressure	-0.08	kPa	
Pitot Cp	1.02		Stack Area	0.126	m²	
		-	Oxygen		%	Carbon dioxide

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

Traverse	Traverse	Depth	ΔΡ	Т	Angle	velocity	Traverse	Depth	ΔP	Т	Angle	velocity
Point	Line	cm	mmH <sub>2</sub> O	°C	0	m/s	Line	cm	mmH <sub>2</sub> O	°C	0	m/s
1	А	5.0					В	5.0				
2	А	5.0					В	5.0				
3	А	5.0	5.5	21	<15	9.8	В	5.0				
4	А	7.1	3.5	21	<15	7.9	В	7.1				
5	А	10.0	2.9	21	<15	7.1	В	10.0				
6	А	14.2	3.4	21	<15	7.7	В	14.2				
7	А	25.8	3.0	21	<15	7.2	В	25.8				
8	А	30.0	1.9	21	<15	5.8	В	30.0				
9	А	32.9	2.0	21	<15	6.0	В	32.9				
10	А	35.0	1.9	21	<15	5.8	В	35.0				
11	А	35.0					В	35.0				
12	А	35.0					В	35.0				

Average Pitot DP	2.93	mmH₂O
Average Temperature	294.2	к
Average Velocity	7.2	m/s
Average volumetric flow rate	0.90	m <sup>3</sup> /s at stack conditions
Average volumetric flow rate	0.81	m³/s (wet STP)
Average volumetric flow rate		m³/s (dry STP)
Average volumetric flow rate		m <sup>3</sup> /s (dry, STP, reference oxygen concentraion)

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

а	Angel of gas flow less than 15° with regard to duct axis			
b	No local negative flow			
с	Minimum pitot greater than 5Pa			
d	Ratio of highest to lowest local gas velocity less than 3:1			
	Minimum local gas velocity			
	Maximum local gas velocity 9.8			
	Ratio of highest to lowest local gas velocity 1.70			

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Date	15/01/2015						
From	11:30	to	12:00	30 minute mean			
Volatile orga	nic compounds		vppm, wet	32.97	mg/m <sup>3*</sup>	52	.99
From	12:00	to	12:30	30 minute mean			
Volatile orga	nic compounds		vppm, wet	31.64	mg/m³*	50	.84
From	12:30	to	13:00	30 minute mean			
Volatile orga	nic compounds		vppm, wet	25.98	mg/m³*	41	.75
Sampling De	etection Limits			_			
Volatile orga	nic compounds		vppm	0.10	mg/m³*	0.	16
Reference G	as Details						
Species			Units	Value	Cylinder	Analyser	Uncertainity
					Reference	Range	<i>k</i> = 2
Nitrogen			%	99.999	VC174989	-	± 2

Zero And Span Gas Details

Volatile organic compounds

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

vppm

78.8

VCSMG4537

100

± 2

Xaarjet Ltd., Huntingdon, Permit Number: B22/11, R/15-5960, v1 Visit 1 of 2015

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# **APPENDIX 3**

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# Photograph Of The Sampling Location

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# **General Calculations**

Stack area:

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

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):

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

VWC (%) =Water vapour content on wet basis, in volume % (m³ of water vapour in m³ of wet gas)Vm(std) =Dry gas volume measured, corrected to standard conditions (m³)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) = yd =	Dry gas meter volume at standard conditions (m <sup>3</sup> ) Gas meter calibration coefficient
(V2-V1) =	Dry gas meter volume at actual conditions (m <sup>3</sup> )
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.

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# **Flow Calculations**

### Velocity:

From reference calculations (taken from ISO 10780):

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

Average velocity (m/s)

v = C =velocity calculation constant = 129

Ts = Average stack temperature (K)

Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol Ms =

K= Pitot calibration coefficient

Pe = Absolute gas pressure (kPa)

 $\Delta p = \Delta p$  = Average pitot tube pressure differencial (kPa)

#### Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m<sup>3</sup>/s)

Average velocity (m/s) v =

Stack cross-sectional area (m<sup>2</sup>) A =

#### 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<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/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):

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

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/s)

Ta = Temperature at actual conditions (K)

Tm =Reference Temperatue (K)

Absolute gas pressure at actual conditions (kPa) pa =

Reference pressure (kPa) pm =

#### Volume flow rate corrected for oxygen

From reference calculations (taken from BS ISO 9096):

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

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

O2, ref = Reference oxygen concentration (%)

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## **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 conditionsca =Actual concentrationO2, 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 gascdry =Concentration dry gasHa =Water vapour content (%vol)

**Conversion of parts per million (ppm) to mg/m<sup>3</sup>** 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

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

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### Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

#### Model equation

Model equation			p
$C_{ppm} = C_{readi}$	$_{ng} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{s,dr}$	$Corr_{rep} + Corr_{adj} + $	$\sum Cor_{inf} + Cor_{int}$
Where:			i=l
C ,ppm	<ul> <li>concentration in ppm</li> </ul>		Corr <sub>rep</sub> = correction of repeatability of measurement
C <sub>NO,reading</sub>	<ul> <li>concentration given by analyse</li> </ul>	r	Corr <sub>adj</sub> = correction of adjustment
Corr <sub>fit</sub>	<ul> <li>correction of lack of fit</li> </ul>		<i>Corr</i> <sub>inf</sub> = correction of influence quantities
Corr <sub>0,dr</sub>	<ul> <li>correction of zero drift</li> </ul>		Corr <sub>int</sub> = correction of interferents
Corr <sub>s,dr</sub>	= correction of span drift		
Calculation of	partial uncertainties		
···(Com.)	· · · · · · · · · · · · · · · · · · ·	14/1	
u(Con <sub>fit</sub> )	$=$ $\left( \underbrace{X_{fit,max}}_{} \right)$	where:	to the mention of the second test for the second test
	$(100 \times range)$	X <sub>fit,max</sub>	is the maximum allowable deviation from linearity
	$\overline{\sqrt{3}}$		
Expressed as %	6 of the range and calculated by applying a	rectangular probabilit	y distribution
	X	~~~	V
u(Con <sub>0,dr</sub> )	$=$ $\frac{X_{0,dr}}{\sqrt{2}}$ $U(C)$	off <sub>s,dr</sub> ) =	$\frac{X_{s,dr}}{\overline{\Box}}$
	$\sqrt{3}$		$\sqrt{3}$
u(Corr)	= max (Some : Some)	= Sran	
a(conrep)	(Co,rep ; Csrep)	Where:	
		S <sub>r.0</sub>	is the standard uncertainty at zero level
		S	is the standard uncertainty at span level
		-1,5	
u(Corr <sub>adi</sub> )	= u(Corr <sub>loss</sub> ) + u(Corr <sub>cal</sub> )	Where:	
	C	u(Corr <sub>loss</sub> )	is the uncertainty due to losses in sample line
u(Corr <sub>loss</sub> )	= C <sub>j,loss</sub>	u(Corr <sub>col</sub> )	is the uncertainty due to losses in sample line
( 1000)	$\sqrt{3}$	Ci.lose	is the concentration of sample loss at span level
u(Corr <sub>ad</sub> )	= U <sub>cal</sub>	U	is the expanded uncertainty of the calibration gas
( Cal	2	Cal	
	$(x - x)^2 + (x - x)^2$	$-r$ ) $\times$ (r	$(-r)^{+}$
u(Corr <sub>inf</sub> )	$= C_{j} \sqrt{\frac{(x_{j,\max} - x_{j,adj}) + (x_{j,i})}{(x_{j,\max} - x_{j,adj})}}$	$\min - x_{j,adj} / (x_{j,\max})$	$-x_{j,adj}$ $+ (x_{j,\min} - x_{j,adj})$
	S V	3	
		where:	
		C <sub>j</sub>	is the sensitivity coefficient of the influence quantity
		<b>X</b> <sub>j,min</sub>	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
	2	V Int 1 Int	2
u(Corr <sub>int</sub> )	$= \frac{C_j}{1} \frac{III_{j,\max} + III_{j,\min}}{1}$	$\times Im_{j,\max} + Im_{j,\min}$	1
	$Int_{j,test}$	3	
and		Where:	
		c <sub>j</sub>	is the sensitivity coefficient of the interferent j
$u(\Sigma Corr_{int})$	$= \max[S_{Int,p}; S_{Int,n}]$	Int <sub>j,test</sub>	is the concentration of the interferent j used to determine c <sub>j</sub>
		Int <sub>j,min</sub>	is the minimum value of the interferent j quantity during monitoring
		Int <sub>j,max</sub>	is the maximum value of the interferent j quantity during monitoring
		Int <sub>j,adj</sub>	is the concentration of the interferent j in the cal gas used to adjust the analyse
		S int,p	is the sum of interferents with positive impact
		S int,n	is the sum of interferents with negative impact
Combined unc	ertainty		
	_		
u(C, <sub>ppm</sub> )	=		
$\sqrt{u^2(corr_{fit})}$	$+u^2(corr_{0,dr})+u^2(corr_{s,dr})+u^2(corr)$	$r_{rep}$ )+ $u^2(corr_{s,vf})$ +	$u^{2}(corr_{a, press}) + u^{2}(corr_{temp}) + u^{2}(corr_{volt}) + u^{2}(corr_{adj}) + S_{Int}^{2}$
	led upgertainty $(k-2)$ $U(C)$	(c)	
overall expand	$U(C_m) = U(C_m)$	$u(C_m) \times \kappa$	
Uncertainty of	NOx measurements	\// L =	
	$C_{NOr} \times R \times \eta$	where:	is the concentration of NOV measured by the available
u(C <sub>NOx</sub> , <sub>conv</sub> )	$=$ $\frac{1}{\sqrt{2}}$		is the ratio of NO:Nox in the stock and
	<b>N</b> 5	η	is the NOx converter efficiency
Combined unc	ertainty NOx measurements	·	···· · · · · · · · · · · · · · · · · ·
u(C <sub>NOx</sub> , stack)	=		
$u^2(a a m)$	$u^{2}(aam) + u^{2}(aam) + u^{2}(aam)$	$(1 + u^2)$	$(2) + u^2 (2) $
$\sqrt{u} (corr_{fit})^+$	$u (corr_{0,dr}) + u (corr_{s,dr}) + u (corr_{rep})$	$+u (corr_{s,vf})+u (corr_{s,vf})$	$2OPT_{a,press}$ + $u$ ( $COPT_{temp}$ ) + $u$ ( $COPT_{volt}$ ) + $u$ ( $COPT_{adj}$ ) + $S_{Int}$ + $u$ ( $COPT_{NOX,conv}$ )
Uncertainty of	mass concentration at oxygen reference	concentration	
u(C, <sub>02 ref</sub> )	=		
		-( ) (	$(u^2(0))$
$u^2(corr_{fit})+u$	$^{2}(corr_{0,dr})+u^{2}(corr_{s,dr})+u^{2}(corr_{rep})+$	$u^2(corr_{s,vf}) + u^2(corr_{s,vf})$	$r_{a,press}$ + $u^{2}(corr_{temp})$ + $u^{2}(corr_{volt})$ + $u^{2}(corr_{adj})$ + $S_{Int}^{2}$ + $\left \frac{u^{2}(C_{2,meas,dry})}{(21 - O_{2})^{2}}\right ^{2}$
Where <sup>.</sup>			(-2,meas,dry)
u(C,O <sub>2 raf</sub> )	<ul> <li>uncertainty associated with the</li> </ul>	mass concentration a	at O <sub>2</sub> ref. concentration in mg/m <sup>3</sup>
C,O <sub>2 ref</sub>	<ul> <li>mass concentration at O<sub>2</sub> refer</li> </ul>	ence concentration	in mg/m <sup>3</sup>
O2 mar-	= 0 <sub>2</sub> measured concentration		in % volume
∠,medS	- <u>_</u>		

uncertainty associated to the measured  $\mathrm{O}_{\mathrm{2}}$  concentration

=

u((O<sub>2,meas)dry)</sub>

- in % volume
- % (relative to  $O_{2 \text{ meas}}$ ) in

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# **APPENDIX 4**

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

Analyser Type/Model	Sick	Maihak	1		
Reference Oxygen %		0	( 0 = No corre	ction)	
		<b>T</b> 14	<b>T</b> 10	<b>T</b> 10	
Limit value	ma/m <sup>3</sup>	1 est 1 75	1est 2 75	1 est 3 75	
Limit value	ppm	46.7	46.7	46.7	
Measured concentration	ppm	33.0	31.6	26.0	
Measured concentration	mg/m <sup>3</sup>	53.0	50.8	41.8	
Concentration at $O_2$ ref. concentration	mg/m <sup>3</sup>	N/A	N/A	N/A	
Calibration gas	ppm	78.8	78.8	78.8	
Calibration gas	mg/m <sup>3</sup>	126.6	126.6	126.6	
Analyser range	ppm	9.3	9.3	9.3	
Analyser range	mg/m <sup>3</sup>	15.0	15.0	15.0	
Correction of Lack of Fit					
Lack of fit	% range	2.0	2.0	2.0	
	u(Corr, <sub>fit</sub> )	0.11	0.11	0.11	
Corrections of Zero and Span Drift	(*All drift is c	alculated for	the residual is	assumed to be	e < 5% u(max) )
	% range	0.00	0.00	0.00	
Span Drift	% range	0.00	0.00	0.00	
	u(Corr, <sub>sdr</sub> )	0.00	0.00	0.00	
Correction of Repeatability of Measurement	0/	0.0	0.0	0.0	
Repeatability SD at span level	% range	0.0	0.0	0.0	
(Not reported)	u(con,rep)	0.00	0.00	0.00	
Correction of adjustment					
losses in the line	% range	1.04	1.04	1.04	
	u(Corr, <sub>loss</sub> )	0.20	0.19	0.16	
Uncertainty of calibration gas	% range	2.0	2.0	2.0	
	u(Con, <sub>cal</sub> )	0.33	0.32	0.26	
Correction of Influence of Interferents					
N <sub>2</sub> O	% range				
	u(Corr, <sub>N2O</sub> )	0.00	0.00	0.00	
CO <sub>2</sub>	% range	0.00		0.00	
	u(Corr, <sub>CO2</sub> )	0.00	0.00	0.00	
0114	u(Corr.cus)	0.00	0.00	0.00	
Total of interferent influences	% range	2.50	2.50	2.50	
$u(\Sigma Corrint) = \max[S_{Int,p}; S_{Int,n}]$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16	
Correction of Influence Quantities	0/ 100.00	1.60	1.60	1.60	
Sensitivity to sample volume now	u(Corr.	0.09	0.09	0.09	
Sensitivity to atmospheric pressure	% range	0.00	0.00	0.00	
(Not reported)	u(Corr,press)	0.00	0.00	0.00	
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40	
Osmaitisitus ta ale atria duratta na	u(Corr, <sub>temp</sub> )	-0.28	-0.28	-0.28	
Sensitivity to electrical voltage	% range	0.50	0.50	0.50	
(Not reported)	u(con,voit)	0.10	0.10	0.10	
Oxygen reference concentration					
Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!	
Overall uncertainty of O <sub>2</sub> measurement	U(O <sub>2</sub> ,meas)	#REF!	#REF!	#REF!	
	u(Corr, <sub>02</sub> )	N/A	N/A	N/A	
Maximum standard uncertainty	u(Corr)	0.33	0.32	0.26	
5% of maximum standard uncertainty	u(Corr,5%)	0.02	0.02	0.01	
	.0,07				
				<b>D</b> (	
Interrerent Concentration Variations	Minimum	Maximum 10	Value at cal	Performance	Units
	0	0	0	20	mg/m <sup>°</sup>
CO <sub>2</sub> range	8	12	0	15	mg/m <sup>3</sup>
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m <sup>3</sup>
Influence Quantitiy Variations	Minimum	Movimum	Value et eal	Porformanco	Unito
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	К
Sensitivity to electrical voltage	187	250	230	5	V
Moonurement uncortainty		Toot 4	Toot 2	Tort 2	
Combined uncertainty	nnm	0.53	0.52	0 47	
Combined uncertainty	ma/m <sup>3</sup>	0.85	0.83	0.76	
Combined uncertainty at oxygen reference	mg/m <sup>3</sup>	0.85	0.83	0.76	
Expanded uncertainty expressed with a level of confide	ence of 95%, k	=2	4.0	0.0	
Overall uncertainty	ppm	1.1	1.0	0.9	
Overall uncertainty relative to measured value	mg/m	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 <sup>3</sup>	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.

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

Report	Prepared	by:	Print
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**Report Approved by:** 

MCERTS No.

Sign

Print

**Emily Buffam** 

MM04 502

Level 2 TE: 1,2,3,4

**Emily Buffam** 

MM04 502

MCERTS No.

Level 2 TE: 1,2,3,4

**REC Environmental Monitoring** 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303



Company Registration No 03133832



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Page 21 Uncertainty Estimates:- TOC

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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
тос	TPM/13	BS EN 12619 : 2013

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# 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.

Emis	sion at	Sampling		Emission	Authorised	Uncertainty	Detection	Mass	
Hunt	ingdon	Time		Result	Limit	+/-	Limit	Emission	
LI	EV 2	Date	Start	End	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	g/h
тос	Test 1	15/01/15	11:30	12:00	11.9	75	1.23	0.16	16.8
тос	Test 2	15/01/15	12:00	13:03	7.34	75	1.19	0.16	10.4
тос	Test 3	15/01/15	13:03	13:33	5.54	75	1.18	0.16	7.85

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

Where applicable	VIE Oxides of nitrogen results are expressed as nitrogen dioxide TOC results are expressed as total carbon				
Throughout Report:	*	Reference conditions (see above)		Nm <sup>3</sup>	273 K, 101.3 kPa
	**	Analysis not required		# - UI	KAS accredited only
	ND	Non detectable		## - N	ot 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.





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## **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	EBiffam	
	Print	Emily Buffam	
	MCERTS No.	MM04 502	Level 2 TE: 1,2,3,4



REC Environmental Monitoring 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832



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# **APPENDIX 1**

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# **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.

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# Sampling Project Personnel Competency And Expiry Dates

Report prepared by:	Emily Buffam	MCERTS No MM04 502	Level 1 -	Level 2 30/06/2016	TE1 30/06/2016	TE2 31/08/2016	TE3 31/08/2016	TE4 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			

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# **APPENDIX 2**

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				_	
Date	15/01/2015	Barometric pressure	98.5	kPa	Stack Diamet
Time	10:00	Duct static pressure	-0.14	kPa	
Pitot Cp	1.02	Stack Area	0.073	m²	
		Oxygen		%	Carbon dioxid

1	Stack Diameter (circular)	0.305	m
a			m
			m
	Carbon dioxide		%

Traverse	Traverse	Depth	ΔΡ	Т	Angle	velocity	Traverse	Depth	ΔP	Т	Angle	velocity
Point	Line	cm	mmH <sub>2</sub> O	°C	0	m/s	Line	cm	mmH <sub>2</sub> O	°C	0	m/s
1	А	5.0					В	5.0				
2	A	5.0					В	5.0				
3	А	5.0	3.7	22	<15	8.0	В	5.0				
4	А	5.4	3.5	22	<15	7.9	В	5.4				
5	А	7.6	2.1	22	<15	6.0	В	7.6				
6	A	10.9	1.8	22	<15	5.6	В	10.9				
7	А	19.6	2.2	22	<15	6.2	В	19.6				
8	А	22.9	1.6	22	<15	5.2	В	22.9				
9	А	25.1	1.3	22	<15	4.8	В	25.1				
10	А	25.5	1.0	22	<15	4.2	В	25.5				
11	A	25.5					В	25.5				
12	А	25.5					В	25.5				

Average Pitot DP	2.04	mmH₂O
Average Temperature	295.2	к
Average Velocity	6.0	m/s
Average volumetric flow rate	0.44	m <sup>3</sup> /s at stack conditions
Average volumetric flow rate	0.39	m³/s (wet STP)
Average volumetric flow rate		m³/s (dry STP)
Average volumetric flow rate		m <sup>3</sup> /s (dry, STP, reference oxygen concentraion)

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

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

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Date	15/01/2015							
From	11:30	to	12:00	30 minute mean				
Volatile orga	nic compounds		vppm, wet	7.41	mg/m³*	11	.90	
From	12.00	to	13.03	30 minute mean				
Volatile orga	nic compounds	10	vppm, wet	4.57	mg/m³*	7.	34	
					Ŭ			
From	13:03	to	13:33	30 minute mean				
Volatile organic compounds			vppm, wet	3.45	mg/m³*	5.54		
Sampling De	tection Limits			-				
Volatile organic compounds			vppm	0.10	mg/m <sup>3*</sup>	0.16		
Reference G	as Details							
Species			Units	Value	Cylinder Reference	Analyser Range	Uncertainity $k = 2$	
Nitrogen			%	99,999	VC174989	-	± 2	

Zero And Span Gas Details

Volatile organic compounds

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

78.8

VCSMG4537

100

± 2

vppm

Xaarjet Ltd., Huntingdon, Permit Number: B22/11, R/15-5961, v1 Visit 1 of 2015

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# **APPENDIX 3**

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# Photograph Of The Sampling Location
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### **General Calculations**

Stack area:

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

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):

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

VWC (%) =Water vapour content on wet basis, in volume % (m³ of water vapour in m³ of wet gas)Vm(std) =Dry gas volume measured, corrected to standard conditions (m³)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) = yd =	Dry gas meter volume at standard conditions (m <sup>3</sup> ) Gas meter calibration coefficient
(V2-V1) =	Dry gas meter volume at actual conditions (m <sup>3</sup> )
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.

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### **Flow Calculations**

### Velocity:

From reference calculations (taken from ISO 10780):

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

Average velocity (m/s)

v = C =velocity calculation constant = 129

Ts = Average stack temperature (K)

Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol Ms =

K= Pitot calibration coefficient

Pe = Absolute gas pressure (kPa)

 $\Delta p = \Delta p$  = Average pitot tube pressure differencial (kPa)

### Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m<sup>3</sup>/s)

Average velocity (m/s) v =

Stack cross-sectional area (m<sup>2</sup>) A =

### Volume flow rate corrected for moisture

From reference calculations (taken from BS ISO 9096):

$$q_{m} = q_{va} \frac{\left(100 - H_{a}\right)}{(100 - H_{m})}$$

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/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):

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

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/s)

Ta = Temperature at actual conditions (K)

Tm =Reference Temperatue (K)

Absolute gas pressure at actual conditions (kPa) pa =

Reference pressure (kPa) pm =

### Volume flow rate corrected for oxygen

From reference calculations (taken from BS ISO 9096):

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

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

O2, ref = Reference oxygen concentration (%)

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### **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 conditionsca =Actual concentrationO2, 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 gascdry =Concentration dry gasHa =Water vapour content (%vol)

**Conversion of parts per million (ppm) to mg/m<sup>3</sup>** 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

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

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#### Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

#### Model iatio

wodel equation			
$C_{ppm} = C_{readin}$	$_{g} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{s,dr}$	$orr_{rep} + Corr_{adj} +$	$\sum_{i=1}^{p} Corr_{inf} + Corr_{int}$
Where:			<i>i</i> =1
C_ppm	<ul> <li>concentration in ppm</li> </ul>		Corr <sub>rep</sub> = correction of repeatability of measurement
C <sub>NO,reading</sub>	= concentration given by analyser		Corr <sub>adj</sub> = correction of adjustment
Corr <sub>fit</sub>	<ul> <li>correction of lack of fit</li> </ul>		<i>Corr<sub>inf</sub></i> = correction of influence quantities
Corr <sub>0,dr</sub>	<ul> <li>correction of zero drift</li> </ul>		Corr <sub>int</sub> = correction of interferents
Corr <sub>s,dr</sub>	= correction of span drift		
Calculation of p	partial uncertainties		
u(Corr <sub>fit</sub> )	$= \left( X_{fit,max} \right)$	Where:	
	$\left(\frac{100 \times range}{100 \times range}\right)$	X <sub>fit,max</sub>	is the maximum allowable deviation from linearity
	$\sqrt{3}$		
Expressed as %	of the range and calculated by applying a r	ectangular probabili	ty distribution
u(Corr <sub>0,dr</sub> )	= $X_{0,dr}$ u(Co	rr <sub>s,dr</sub> ) =	$X_{s,dr}$
	$\sqrt{3}$		$\sqrt{3}$
u(Corr <sub>rep</sub> )	= max (S <sub>0,rep</sub> ; S <sub>srep</sub> )	= S <sub>rep</sub>	
		Where:	to the standard concerns to the standard
		S <sub>r,0</sub>	is the standard uncertainty at zero level
		S <sub>r,s</sub>	is the standard uncertainty at span level
u(Corr <sub>adj</sub> )	= u(Corr <sub>loss</sub> ) + u(Corr <sub>cal</sub> )	Where:	
	$C_{i lass}$	u(Corr <sub>loss</sub> )	is the uncertainty due to losses in sample line
u(Corr <sub>loss</sub> )	$=$ $\frac{-\sqrt{3}}{\sqrt{3}}$	u(Corr <sub>cal</sub> )	is the uncertainty due to losses in sample line
	– <i>U</i> .	CJ, <sub>loss</sub>	is the concentration of sample loss at span level
u(con <sub>cal</sub> )	$\frac{-\frac{1}{2}}{2}$	Ocal	
u(Corr )	$(x_{i,\max} - x_{i,adi})^2 + (x_{i,\max})^2$	$(x_{i,max}) \times (x_{i,max})$	$(-x_{i,adi}) + (x_{i,min} - x_{i,adi})^2$
u(Corr inf)	$= c_j \sqrt{\frac{c_j}{c_j}}$	3	
		Where:	
		cj	is the sensitivity coefficient of the influence quantity
		X <sub>j,min</sub>	is the minimum value of the influence quantity during monitoring
		×j,max	is the value of the influence quantity during adjustment
		^j,adj	
(2)	$c_i = \left[ Int_{i,max}^2 + Int_{i,min} \right]$	$\times Int_{i,max} + Int_{i,mi}$	2 n
u(Corr <sub>int</sub> )	$= \frac{1}{Int_{int}} \sqrt{\frac{1}{1}}$	3	<u> </u>
and	j,test	Where:	
		c <sub>j</sub>	is the sensitivity coefficient of the interferent j
$u(\Sigma Corr_{int})$	$= \max \left[ S_{Int,p}; S_{Int,n} \right]$	Int <sub>j,test</sub>	is the concentration of the interferent $\boldsymbol{j}$ used to determine $\boldsymbol{c}_{\boldsymbol{j}}$
		Int <sub>j,min</sub>	is the minimum value of the interferent j quantity during monitoring
		Int <sub>j,max</sub>	is the maximum value of the interferent j quantity during monitoring
		Int <sub>j,adj</sub>	is the concentration of the interferent j in the cal gas used to adjust the analyse
		S int,p	is the sum of interferents with positive impact
Combined unce	ertainty	S int,n	is the sum of interferents with negative impact
u(C)	_		
u(0, ppm)	-		
$\sqrt{u^2(corr_{fit})}$	$+ u^{2}(corr_{0,dr}) + u^{2}(corr_{s,dr}) + u^{2}(corr_{r})$	$_{ep}$ )+ $u^{2}(corr_{s,vf})$ +	$u^{2}(corr_{a,press}) + u^{2}(corr_{temp}) + u^{2}(corr_{volt}) + u^{2}(corr_{adj}) + S_{Int}^{2}$
Overall expande	ed uncertainty (k = 2) $U(C_m) = t$	$u(C_m) \times k$	
Uncertainty of N	NOx measurements		
	$C_{NC} \times R \times n$	Where:	is the concentration of NO.
u(C <sub>NOx</sub> , <sub>conv</sub> )	$=$ $\frac{\sqrt{3}}{\sqrt{3}}$	R C <sub>NOx</sub>	is the ratio of NO:Nox in the stack gas
<b>.</b>		η	is the NOx converter efficiency
Combined unce	ertainty NOx measurements		
$u(C_{NOx}, _{stack})$	=		
$\sqrt{u^2(corr_{fit})+u}$	$u^2(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{rep})$	$+u^2(corr_{s,vf})+u^2($	$(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + S_{Int}^2 + u^2(corr_{NOX,conv})$
Uncertainty of r	nass concentration at oxygen reference	concentration	
u(C, <sub>O2 ref</sub> )	=		
$u^2(corr_{fit})+u^2$	$(corr_{0,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2$	$u^2(corr_{s,vf}) + u^2(co$	$rr_{a, press}$ + $u^{2}(corr_{temp})$ + $u^{2}(corr_{volt})$ + $u^{2}(corr_{adj})$ + $S_{lat}^{2}$ + $\left(\frac{u^{2}(O_{2,meas,dry})}{(21-O_{2,meas,dry})^{2}}\right)^{2}$
Where:			( <sup>2</sup> ,meas,dry)
u(C,O <sub>2,ref)</sub>	= uncertainty associated with the	mass concentration	at O <sub>2</sub> ref. concentration in mg/m <sup>3</sup>
C,O <sub>2,ref</sub>	= mass concentration at O <sub>2</sub> refere	nce concentration	in mg/m <sup>3</sup>

- O2 measured concentration  $O_{2,\text{meas}}$ =
- uncertainty associated to the measured O2 concentration u((O<sub>2,meas)dry)</sub> =
- in % volume
- % (relative to  $O_{2 \text{ meas}}$ ) in

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## **APPENDIX 4**

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

Analyser Type/Model	Sick	Maihak	1		
Reference Oxygen %		0	( 0 = No corre	ction)	
			-		
		Test 1	Test 2	Test 3	
Limit value	mg/m <sup>3</sup>	75	75	75	
Measured concentration	ppm	40.7	46.7	40.7	
Measured concentration	mg/m <sup>3</sup>	11.9	7.3	5.4	
Concentration at O <sub>2</sub> ref. concentration	mg/m <sup>3</sup>	N/A	N/A	0.0 N/A	
	iiiq/iii				
Calibration gas	ppm	78.8	78.8	78.8	
Calibration gas	mg/m <sup>3</sup>	126.6	126.6	126.6	
Analyser range	ppm	9.3	9.3	9.3	
Analyser range	mg/m <sup>3</sup>	15.0	15.0	15.0	
Operation of Look of Et					
Correction of Lack of Fit	0/ 100 00	2.0	2.0	2.0	
EACK OF III	U(Corr	0.11	0.11	0.11	
	u(con,ttt)	0.11	0.11	0.11	
Corrections of Zero and Span Drift	(*All drift is c	alculated for .:	the residual is	assumed to be	a < 5% u(max)
Zero Drift	% range	0.00	0.00	0.00	, ,
	u(Corr, <sub>0dr</sub> )	0.00	0.00	0.00	
Span Drift	% range	0.00	0.00	0.00	
	u(Corr, <sub>sdr</sub> )	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, <sub>rep</sub> )	0.00	0.00	0.00	
Correction of adjustment					
losses in the line	% range	1 07	1 07	1 07	
	u(Corr)	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 <sub>2</sub> O	% range				
	u(Corr, <sub>N2O</sub> )	0.00	0.00	0.00	
CO <sub>2</sub>	% range				
	u(Corr, <sub>CO2</sub> )	0.00	0.00	0.00	
CH <sub>4</sub>	% range	0.00	0.00	0.00	
Tatal of interferent influences	u(Corr, <sub>CH4</sub> )	0.00	0.00	0.00	
$u(\Sigma Corrint) = \max[S_1 : S_2]$	% range	2.50	2.50	2.50	
$u[2 \text{ contract}] = \dots [\gamma_{\text{fat},p}, \gamma_{\text{fat},n}]$	u(20011 int)	0.10	0.10	0.10	
Correction of Influence Quantities					
Sensitivity to sample volume flow	% range	1.60	1.60	1.60	
	u(Corr, <sub>flow</sub> )	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, <sub>temp</sub> )	-0.28	-0.28	-0.28	
Sensitivity to electrical voltage	% range	0.50	0.50	0.50	
(Not reported)	u(Corr, <sub>volt</sub> )	0.10	0.10	0.10	
Oxygen reference concentration	0/	"DIV//01	#DIV//01	#DIV//01	
Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!	
Overall uncertainty of O <sub>2</sub> measurement	U(Corr)	#REF!	#REF!	#REF!	
	u(0011,02)	IN/A	IN/A	19/74	
Maximum standard uncertainty	u(Corr)	0.11	0.11	0.11	
5% of maximum standard uncertainty	u(Corr.sec)	0.01	0.01	0.01	
· · · · · · · · · · · · · · · · · · ·					
Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
CH <sub>4</sub> range	0	10	0	50	mg/m <sup>3</sup>
N <sub>2</sub> O range	0	0	0	20	ma/m <sup>3</sup>
CO <sub>2</sub> range	8	12	0	15	mg/m <sup>3</sup>
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Охуден епест	U	20	U	2	mg/m°
Influence Quantitiv 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	К
Sensitivity to electrical voltage	187	250	230	5	V
Measurement uncertainty	<u> </u>	Test 1	Test 2	Test 3	
Combined uncertainty	ppm	0.38	0.37	0.37	
Combined uncertainty	mg/m <sup>3</sup>	0.61	0.60	0.59	
Combined uncertainty at oxygen reference	mg/m <sup>3</sup>	0.61	0.60	0.59	
<b>_</b>					
Expanded uncertainty expressed with a level of confide	ence of 95%, k	=2	o <del>-</del>	· · - ·	
Overall uncertainty	ppm	0.8	0.7	0.7	
Overall uncertainty	mg/m	1.2	1.2	1.2	
Overall uncertainty relative to range	%	10.3	10.2	∠1.4 7 0	
Overall uncertainty relative to FLV	/0 %	1.0	0.0	0.9	
anoonanny rolanto to LEV	70		0.0	0.0	

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2								
Overall uncertainty	mg/m <sup>3</sup>	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.

0.4	Here Corrections
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
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**Report Approved by:** 

MCERTS No.

MCERTS No.

Sign

Print

Emily Buffam

MM04 502

Level 2 TE: 1,2,3,4

EBuffam

Emily Buffam

MM04 502

Level 2 TE: 1,2,3,4

REC Environmental Monitoring 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832



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- Page 3 Special Monitoring Requirements
- Page 3 Summary Of Methods
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- Page 5 Operating Information
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Page 21 Uncertainty Estimates:- TOC

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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
тос	TPM/13	BS EN 12619 : 2013

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### 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.

Emis	sion at	Sampling		Emission	Authorised	Uncertainty	Detection	Mass	
Hunt	Huntingdon Time		Result	Limit	+/-	Limit	Emission		
LE	EV 9	Date	Start	End	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	g/h
тос	Test 1	16/01/15	09:50	10:20	31.2	75	1.36	0.16	68.7
тос	Test 2	16/01/15	10:20	10:50	42.1	75	1.49	0.16	92.6
тос	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	0 °C Wet Gas			
Conditions	29.00 Kg/kmol	101.3 kpa	Oxygen	None	%	

Where applicable	oplicable         Oxides of nitrogen results are expressed as nitrogen dioxide           TOC results are expressed as total carbon				
Throughout Report:	*	Reference conditions (see above)	Nm <sup>3</sup>	273 K, 101.3 kPa	
	**	Analysis not required	# - Uł	AS accredited only	
	ND	Non detectable	## - N	ot Accredited	
	s - Su	bcontracted 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.





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### **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	EBiffam	
	Print	Emily Buffam	
	MCERTS No.	MM04 502	Level 2 TE: 1,2,3,4



REC Environmental Monitoring 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832



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# **APPENDIX 1**

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### **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.

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### Sampling Project Personnel Competency And Expiry Dates

Report prepared by:	Emily Buffam	MCERTS No MM04 502	Level 1 -	Level 2 30/06/2016	TE1 30/06/2016	TE2 31/08/2016	TE3 31/08/2016	TE4 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

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## **APPENDIX 2**

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		_			_	
Date	16/01/2015		Barometric pressure	100.4	kPa	Stack Diameter (c
Time	09:00	Ī	Duct static pressure	0.97	kPa	
Pitot Cp	1.02	Ī	Stack Area	0.071	m²	
-		-	Oxygen		%	Carbon dioxide

Pa	Stack Diameter (circular)	0.30	m
Pa			m
n <sup>2</sup>			m
D	Carbon dioxide		%

Traverse	Traverse	Depth	ΔΡ	Т	Angle	velocity	Traverse	Depth	ΔP	Т	Angle	velocity
Point	Line	cm	mmH <sub>2</sub> O	°C	0	m/s	Line	cm	mmH <sub>2</sub> O	°C	0	m/s
1	А	5.0					В	5.0				
2	А	5.0					В	5.0				
3	А	5.0					В	5.0				
4	А	5.3	2.7	20	<15	6.7	В	5.3				
5	А	7.5	3.7	20	<15	7.9	В	7.5				
6	А	10.7	4.9	20	<15	9.1	В	10.7				
7	А	19.3	6.0	20	<15	10.1	В	19.3				
8	А	22.5	6.3	20	<15	10.3	В	22.5				
9	А	24.7	7.8	20	<15	11.5	В	24.7				
10	A	25.0					В	25.0				
11	A	25.0					В	25.0				
12	А	25.0					В	25.0				

Average Pitot DP	5.08	mmH <sub>2</sub> O
Average Temperature	293.2	к
Average Velocity	9.3	m/s
Average volumetric flow rate	0.66	m <sup>3</sup> /s at stack conditions
Average volumetric flow rate	0.61	m³/s (wet STP)
Average volumetric flow rate		m³/s (dry STP)
Average volumetric flow rate		m <sup>3</sup> /s (dry, STP, reference oxygen concentraion)

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

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

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Date	16/01/2015						
From	09:50	to	10:20	30 minute mean	I		
Volatile orgai	nic compounds		vppm, wet	19.43	mg/m <sup>3*</sup>	31	.23
From	10:20	to	10:50	30 minute mean	I		
Volatile organ	nic compounds		vppm, wet	26.19	mg/m <sup>3*</sup>	42	.09
From	11.35	to	12.05	30 minute mean			
Volatile orga	nic compounds	10	vppm wet	48 30	ma/m <sup>3*</sup>	77	63
Volatile organ				40.00	mg/m		
Sampling De	tection Limits						
Volatile orga	nic compounds		vppm	0.10	mg/m³*	0.	16
Reference G	as Details						
Species			Units	Value	Cylinder Reference	Analyser Range	Uncertainity $k = 2$
Nitrogen			%	99 999	VC174989		+ 2

Zero And Span Gas Details

Volatile organic compounds

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

78.8

VCSMG4537

100

± 2

vppm

Xaarjet Ltd., Huntingdon, Permit Number: B22/11, R/15-5962, v1 Visit 1 of 2015

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## **APPENDIX 3**

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# Photograph Of The Sampling Location

LEV 9

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### **General Calculations**

Stack area:

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

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):

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

VWC (%) =Water vapour content on wet basis, in volume % (m³ of water vapour in m³ of wet gas)Vm(std) =Dry gas volume measured, corrected to standard conditions (m³)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) = yd =	Dry gas meter volume at standard conditions (m <sup>3</sup> ) Gas meter calibration coefficient
(V2-V1) =	Dry gas meter volume at actual conditions (m <sup>3</sup> )
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.

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### **Flow Calculations**

### Velocity:

From reference calculations (taken from ISO 10780):

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

Average velocity (m/s)

v = C =velocity calculation constant = 129

Ts = Average stack temperature (K)

Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol Ms =

K= Pitot calibration coefficient

Pe = Absolute gas pressure (kPa)

 $\Delta p = \Delta p$  = Average pitot tube pressure differencial (kPa)

### Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m<sup>3</sup>/s)

Average velocity (m/s) v =

Stack cross-sectional area (m<sup>2</sup>) A =

### 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<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/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):

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

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/s)

Ta = Temperature at actual conditions (K)

Tm =Reference Temperatue (K)

Absolute gas pressure at actual conditions (kPa) pa =

Reference pressure (kPa) pm =

### Volume flow rate corrected for oxygen

From reference calculations (taken from BS ISO 9096):

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

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

O2, ref = Reference oxygen concentration (%)

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### **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 conditionsca =Actual concentrationO2, 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 gascdry =Concentration dry gasHa =Water vapour content (%vol)

**Conversion of parts per million (ppm) to mg/m<sup>3</sup>** 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

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

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### Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

### Model equation

Model equation			p
$C_{ppm} = C_{readi}$	$_{ng} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{s,dr}$	$Corr_{rep} + Corr_{adj} + $	$\sum Cor_{inf} + Cor_{int}$
Where:			i=l
C ,ppm	<ul> <li>concentration in ppm</li> </ul>		Corr <sub>rep</sub> = correction of repeatability of measurement
C <sub>NO,reading</sub>	<ul> <li>concentration given by analyse</li> </ul>	r	Corr <sub>adj</sub> = correction of adjustment
Corr <sub>fit</sub>	<ul> <li>correction of lack of fit</li> </ul>		<i>Corr</i> <sub>inf</sub> = correction of influence quantities
Corr <sub>0,dr</sub>	<ul> <li>correction of zero drift</li> </ul>		Corr <sub>int</sub> = correction of interferents
Corr <sub>s,dr</sub>	= correction of span drift		
Calculation of	partial uncertainties		
···(Com.)	· · · · · · · · · · · · · · · · · · ·	14/1	
u(Con <sub>fit</sub> )	$=$ $\left( \underbrace{X_{fit,max}}_{} \right)$	where:	to the mention of the second test for the second test
	$(100 \times range)$	X <sub>fit,max</sub>	is the maximum allowable deviation from linearity
	$\overline{\sqrt{3}}$		
Expressed as %	6 of the range and calculated by applying a	rectangular probabilit	y distribution
	X	~~~	V
u(Con <sub>0,dr</sub> )	$=$ $\frac{X_{0,dr}}{\sqrt{2}}$ $U(C)$	off <sub>s,dr</sub> ) =	$\frac{X_{s,dr}}{\overline{\Box}}$
	$\sqrt{3}$		$\sqrt{3}$
u(Corr)	= max (Some : Some)	= Sran	
a(conrep)	(Co,rep ; Csrep)	Where:	
		S <sub>r.0</sub>	is the standard uncertainty at zero level
		S	is the standard uncertainty at span level
		-1,5	
u(Corr <sub>adi</sub> )	= u(Corr <sub>loss</sub> ) + u(Corr <sub>cal</sub> )	Where:	
	C	u(Corr <sub>loss</sub> )	is the uncertainty due to losses in sample line
u(Corr <sub>loss</sub> )	= C <sub>j,loss</sub>	u(Corr <sub>col</sub> )	is the uncertainty due to losses in sample line
( 1000)	$\sqrt{3}$	Ci.lose	is the concentration of sample loss at span level
u(Corr <sub>ad</sub> )	= U <sub>cal</sub>	U	is the expanded uncertainty of the calibration gas
( Cal	2	Cal	
	$(x - x)^2 + (x - x)^2$	$-r$ ) $\times$ (r	$(-r)^{+}$
u(Corr <sub>inf</sub> )	$= C_{j} \sqrt{\frac{(x_{j,\max} - x_{j,adj}) + (x_{j,i})}{(x_{j,\max} - x_{j,adj})}}$	$\min - x_{j,adj} / (x_{j,\max})$	$-x_{j,adj}$ $+ (x_{j,\min} - x_{j,adj})$
	S V	3	
		where:	
		C <sub>j</sub>	is the sensitivity coefficient of the influence quantity
		<b>X</b> <sub>j,min</sub>	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
	2	V Int 1 Int	2
u(Corr <sub>int</sub> )	$= \frac{C_j}{1} \frac{III_{j,\max} + III_{j,\min}}{1}$	$\times Im_{j,\max} + Im_{j,\min}$	1
	$Int_{j,test}$	3	
and		Where:	
		cj	is the sensitivity coefficient of the interferent j
$u(\Sigma Corr_{int})$	$= \max[S_{Int,p}; S_{Int,n}]$	Int <sub>j,test</sub>	is the concentration of the interferent j used to determine c <sub>j</sub>
		Int <sub>j,min</sub>	is the minimum value of the interferent j quantity during monitoring
		Int <sub>j,max</sub>	is the maximum value of the interferent j quantity during monitoring
		Int <sub>j,adj</sub>	is the concentration of the interferent j in the cal gas used to adjust the analyse
		S int,p	is the sum of interferents with positive impact
		S int,n	is the sum of interferents with negative impact
Combined unc	ertainty		
	_		
u(C, <sub>ppm</sub> )	=		
$\sqrt{u^2(corr_{fit})}$	$+u^2(corr_{0,dr})+u^2(corr_{s,dr})+u^2(corr)$	$r_{rep}$ )+ $u^2(corr_{s,vf})$ +	$u^{2}(corr_{a, press}) + u^{2}(corr_{temp}) + u^{2}(corr_{volt}) + u^{2}(corr_{adj}) + S_{Int}^{2}$
	led upgertainty $(k-2)$ $U(C)$	(c)	
overall expand	$U(C_m) = U(C_m)$	$u(C_m) \times \kappa$	
Uncertainty of	NOx measurements	\// L =	
	$C_{NOr} \times R \times \eta$	where:	is the concentration of NOV measured by the available
u(C <sub>NOx</sub> , <sub>conv</sub> )	$=$ $\frac{1}{\sqrt{2}}$		is the ratio of NO:Nox in the stock and
	<b>N</b> 5	η	is the NOx converter efficiency
Combined unc	ertainty NOx measurements	·	···· · · · · · · · · · · · · · · · · ·
u(C <sub>NOx</sub> , stack)	=		
$u^2(a a m)$	$u^{2}(aam) + u^{2}(aam) + u^{2}(aam)$	$(1 + u^2)$	$(2) + u^2 (2) $
$\sqrt{u} (corr_{fit})^+$	$u (corr_{0,dr}) + u (corr_{s,dr}) + u (corr_{rep})$	$+u (corr_{s,vf})+u (corr_{s,vf})$	$2OPT_{a,press}$ + $u$ ( $COPT_{temp}$ ) + $u$ ( $COPT_{volt}$ ) + $u$ ( $COPT_{adj}$ ) + $S_{Int}$ + $u$ ( $COPT_{NOX,conv}$ )
Uncertainty of	mass concentration at oxygen reference	concentration	
u(C, <sub>02 ref</sub> )	=		
		-( ) (	$(u^2(0))$
$u^2(corr_{fit})+u$	$^{2}(corr_{0,dr})+u^{2}(corr_{s,dr})+u^{2}(corr_{rep})+$	$u^2(corr_{s,vf}) + u^2(corr_{s,vf})$	$r_{a,press}$ + $u^{2}(corr_{temp})$ + $u^{2}(corr_{volt})$ + $u^{2}(corr_{adj})$ + $S_{Int}^{2}$ + $\left \frac{u^{2}(C_{2,meas,dry})}{(21 - O_{2})^{2}}\right ^{2}$
Where <sup>.</sup>			(-2,meas,dry)
u(C,O <sub>2 raf</sub> )	<ul> <li>uncertainty associated with the</li> </ul>	mass concentration a	at O <sub>2</sub> ref. concentration in mg/m <sup>3</sup>
C,O <sub>2 ref</sub>	<ul> <li>mass concentration at O<sub>2</sub> refer</li> </ul>	ence concentration	in mg/m <sup>3</sup>
O2 mar-	= 0 <sub>2</sub> measured concentration		in % volume
∠,medS	- <u>_</u>		

uncertainty associated to the measured  $\mathrm{O}_{\mathrm{2}}$  concentration

=

u((O<sub>2,meas)dry)</sub>

- in % volume % (relative to  $O_{2 \text{ meas}}$ )
- in

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## **APPENDIX 4**

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

Analyser Type/Model	Sick Maihak				
Reference Oxygen %		0	( 0 = No corre	ction)	
		Test 1	Test 2	Test 3	
Limit value	mg/m <sup>3</sup>	75	75	75	
Limit value	ppm	46.7	46.7	46.7	
Measured concentration	ppm	19.4	26.2	48.3	
Concentration at O <sub>2</sub> ref. concentration	mg/m <sup>3</sup>	N/A	42.1 N/A	N/A	
Calibration gas	ppm	78.8	78.8	78.8	
Calibration gas	mg/m <sup>3</sup>	93	126.6	126.6	
Analyser range	ma/m <sup>3</sup>	15.0	15.0	15.0	
Correction of Lack of Fit	0/ 100000	2.0	2.0	2.0	
Lack of fit	% range	2.0	2.0	2.0	
	u(constt)	0.11	0.111	0.111	
Corrections of Zero and Span Drift	(*All drift is c	alculated for .	. the residual is	assumed to be	e < 5% u(max) )
Zero Drift	% range	0.00	0.00	0.00	
Span Drift	% range	0.00	0.00	0.00	
opun bint	u(Corr, <sub>sdr</sub> )	0.00	0.00	0.00	
Correction of Repeatability of Measurement	0(	0.0	0.0	0.0	
Repeatability SD at span level	% range	0.0	0.0	0.0	
(Not reported)	u(consrep)	0.00	0.00	0.00	
Correction of adjustment					
losses in the line	% range	0.80	0.80	0.80	
Lincertainty of calibration das	u(Corr, <sub>loss</sub> )	0.09	0.12	0.22	
Chiertainty of calibration gas	u(Corr,cal)	0.19	0.26	0.48	
			•		
Correction of Influence of Interferents			1	1	
N <sub>2</sub> O	% range	0.00	0.00	0.00	
CO <sub>2</sub>	% range	0.00	0.00	0.00	
	u(Corr, <sub>CO2</sub> )	0.00	0.00	0.00	
CH <sub>4</sub>	% range		0.00	0.00	
Total of interferent influences	u(Corr, <sub>CH4</sub> ) % range	2.50	2.50	2.50	
$u(\Sigma Corrint) = \max[S_{lnt,p}; S_{lnt,n}]$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16	
Correction of Influence Quantities		4.00	1 4 00	4.00	
Sensitivity to sample volume flow	% range	1.60	1.60	1.60	
Sensitivity to atmospheric pressure	% range	0.03	0.03	0.03	
(Not reported)	u(Corr,press)	0.00	0.00	0.00	
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40	
Sopoitivity to electrical voltage	u(Corr, <sub>temp</sub> )	-0.28	-0.28	-0.28	
(Not reported)	u(Corr,volt)	0.30	0.10	0.10	
()	1010				
Oxygen reference concentration		1			
Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!	
Overall uncertainty of O <sub>2</sub> measurement	u(Corr.co)	#REF! N/A	#REF! N/A	#REF! N/A	
	1 (11 102)				
Maximum standard uncertainty	u(Corr, <sub>max</sub> )	0.19	0.26	0.48	
5% of maximum standard uncertainty	u(Corr, <sub>5%</sub> )	0.01	0.01	0.02	
Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
CH <sub>4</sub> range	0	10	0	50	mg/m <sup>3</sup>
N <sub>2</sub> O range	0	0	0	20	mg/m <sup>3</sup>
Oxygen effect variations	o Minimum	Maximum	Value at cal	Performance	mg/m <sup>-</sup> Units
Oxygen effect	0	20	0	2	mg/m <sup>3</sup>
Influence Quantitiy Variations	Minimum	Maximum	Value et ect	Performance	Unite
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	к
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 <sup>3</sup>	0.68	0.75	1.04	
Combined uncertainty at oxygen reference	mg/m <sup>3</sup>	0.68	0.75	1.04	
Expanded uncertainty expressed with a level of confide	ence of 95% 4	(=2			
Overall uncertainty	ppm	0.8	0.9	1.3	
Overall uncertainty	mg/m <sup>3</sup>	1.4	1.5	2.1	
Overall uncertainty relative to measured value	%	4.4	3.6	2.7	
Overall uncertainty relative to FLV	%	9.1	1.2	1.6	

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2						
Overall uncertainty	mg/m <sup>3</sup>	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.

Sito	Huntingdon
She	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
--------	----------	-----	-------

**Report Approved by:** 

MCERTS No.

Sign

Print

**Emily Buffam** 

MM04 502

Level 2 TE: 1,2,3,4

**Emily Buffam** 

MM04 502

MCERTS No.

Level 2 TE: 1,2,3,4

**REC Environmental Monitoring** 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832





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- Page 3 Summary Of Methods
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Page 21 Uncertainty Estimates:- TOC

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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
тос	TPM/13	BS EN 12619 : 2013

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### 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.

Emis	sion at	Sampling			Emission	Authorised	Uncertainty	Detection	Mass
Hunti	ingdon	Time		Result	Limit	+/-	Limit	Emission	
LE	V 13	Date	Start	End	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	g/h
тос	Test 1	15/01/15	14:32	15:02	7.02	75	1.18	0.16	45.1
тос	Test 2	15/01/15	15:02	15:32	5.84	75	1.18	0.16	37.5
тос	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	Oxide TOC	Oxides of nitrogen results are expressed as nitrogen dioxide TOC results are expressed as total carbon			
Throughout Report:	*	Reference conditions (see above)		Nm <sup>3</sup>	273 K, 101.3 kPa
	**	Analysis not required		# - UI	KAS accredited only
	ND	Non detectable		## - N	ot Accredited
s - Subcontracted laboratory analys		ibcontracted 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.





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### **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	EBiffam	
	Print	Emily Buffam	
	MCERTS No.	MM04 502	Level 2 TE: 1,2,3,4



REC Environmental Monitoring 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832



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# **APPENDIX 1**

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### **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.

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### Sampling Project Personnel Competency And Expiry Dates

Report prepared by:	Emily Buffam	MCERTS No MM04 502	Level 1 -	Level 2 30/06/2016	TE1 30/06/2016	TE2 31/08/2016	TE3 31/08/2016	TE4 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				
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# **APPENDIX 2**

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				_	
Date	15/01/2015	Barometric pressure	98.5	kPa	Stack Diamet
Time	16:14	Duct static pressure	-0.24	kPa	
Pitot Cp	1.02	Stack Area	0.283	m²	
		Oxygen		%	Carbon dioxid

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

Traverse	Traverse	Depth	ΔΡ	Т	Angle	velocity	Traverse	Depth	ΔΡ	Т	Angle	velocity
Point	Line	cm	mmH <sub>2</sub> O	°C	0	m/s	Line	cm	mmH <sub>2</sub> O	°C	0	m/s
1	А	5.0					В	5.0				
2	A	5.0	1.9	24	<15	5.9	В	5.0				
3	A	7.1	2.2	24	<15	6.2	В	7.1				
4	А	10.6	2.5	24	<15	6.7	В	10.6				
5	А	15.0	3.2	24	<15	7.5	В	15.0				
6	A	21.4	3.4	24	<15	7.8	В	21.4				
7	A	38.6	3.4	24	<15	7.8	В	38.6				
8	А	45.0	3.8	24	<15	8.2	В	45.0				
9	А	49.4	5.7	24	<15	10.1	В	49.4				
10	A	52.9	1.3	24	<15	4.8	В	52.9				
11	A	55.0	2.0	24	<15	6.0	В	55.0				
12	А	55.0					В	55.0				

Average Pitot DP	2.83	mmH <sub>2</sub> O
Average Temperature	297.2	к
Average Velocity	7.1	m/s
Average volumetric flow rate	2.00	m <sup>3</sup> /s at stack conditions
Average volumetric flow rate	1.79	m³/s (wet STP)
Average volumetric flow rate		m³/s (dry STP)
Average volumetric flow rate		m <sup>3</sup> /s (dry, STP, reference oxygen concentraion)

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

а	Angel of gas flow less than 15° with regard to duct axis			
b	No local negative flow			
с	Minimum pitot greater than 5Pa			
d	Ratio of highest to lowest local gas velocity less than 3:1			
	Minimum local gas velocity			
	Maximum local gas velocity	10.1		
	Ratio of highest to lowest local gas velocity 2.08			

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Date	15/01/2015						
From	14:32	to	15:02	30 minute mean	I		
Volatile orga	nic compounds		vppm, wet	4.37	mg/m³*	7.	02
From	15:02	to	15:32	30 minute mean	L		
Volatile orga	nic compounds		vppm, wet	3.63	mg/m³*	5.	84
From	15:32	to	16:02	30 minute mean	I		
Volatile orga	nic compounds		vppm, wet	4.75	mg/m³*	7.	64
Sampling De	tection Limits						
Volatile orga	nic compounds		vppm	0.10	mg/m³*	0.	16
Reference G	as Details						
Species			Units	Value	Cylinder Reference	Analyser Range	Uncertainity $k = 2$
Nitrogen			%	99.999	VC174989	-	± 2
Volatile orga	nic 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

Xaarjet Ltd., Huntingdon, Permit Number: B22/11, R/15-5963, v1 Visit 1 of 2015

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# **APPENDIX 3**

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# Photograph Of The Sampling Location

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### **General Calculations**

Stack area:

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

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):

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

VWC (%) =Water vapour content on wet basis, in volume % (m³ of water vapour in m³ of wet gas)Vm(std) =Dry gas volume measured, corrected to standard conditions (m³)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) = yd =	Dry gas meter volume at standard conditions (m <sup>3</sup> ) Gas meter calibration coefficient
(V2-V1) =	Dry gas meter volume at actual conditions (m <sup>3</sup> )
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.

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### **Flow Calculations**

### Velocity:

From reference calculations (taken from ISO 10780):

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

Average velocity (m/s)

v = C =velocity calculation constant = 129

Ts = Average stack temperature (K)

Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol Ms =

K= Pitot calibration coefficient

Pe = Absolute gas pressure (kPa)

 $\Delta p = \Delta p$  = Average pitot tube pressure differencial (kPa)

### Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m<sup>3</sup>/s)

Average velocity (m/s) v =

Stack cross-sectional area (m<sup>2</sup>) A =

### Volume flow rate corrected for moisture

From reference calculations (taken from BS ISO 9096):

$$q_{m} = q_{va} \frac{\left(100 - H_{a}\right)}{(100 - H_{m})}$$

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/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):

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

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/s)

Ta = Temperature at actual conditions (K)

Tm =Reference Temperatue (K)

Absolute gas pressure at actual conditions (kPa) pa =

Reference pressure (kPa) pm =

### Volume flow rate corrected for oxygen

From reference calculations (taken from BS ISO 9096):

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

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

O2, ref = Reference oxygen concentration (%)

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### **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 conditionsca =Actual concentrationO2, 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 gascdry =Concentration dry gasHa =Water vapour content (%vol)

**Conversion of parts per million (ppm) to mg/m<sup>3</sup>** 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

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

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### Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

#### Model equation

Model equation			p
$C_{ppm} = C_{readi}$	$_{ng} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{s,dr}$	$Corr_{rep} + Corr_{adj} + $	$\sum Cor_{inf} + Cor_{int}$
Where:			i=l
C ,ppm	<ul> <li>concentration in ppm</li> </ul>		Corr <sub>rep</sub> = correction of repeatability of measurement
C <sub>NO,reading</sub>	<ul> <li>concentration given by analyse</li> </ul>	r	Corr <sub>adj</sub> = correction of adjustment
Corr <sub>fit</sub>	<ul> <li>correction of lack of fit</li> </ul>		<i>Corr</i> <sub>inf</sub> = correction of influence quantities
Corr <sub>0,dr</sub>	<ul> <li>correction of zero drift</li> </ul>		Corr <sub>int</sub> = correction of interferents
Corr <sub>s,dr</sub>	= correction of span drift		
Calculation of	partial uncertainties		
	· · · · · · · · · · · · · · · · · · ·	14/1	
u(Con <sub>fit</sub> )	$=$ $\left( \underbrace{X_{fit,max}}_{} \right)$	where:	to the mention of the second test for the second test
	$(100 \times range)$	X <sub>fit,max</sub>	is the maximum allowable deviation from linearity
	$\overline{\sqrt{3}}$		
Expressed as %	6 of the range and calculated by applying a	rectangular probabilit	y distribution
	X	~~~ )	V
u(Con <sub>0,dr</sub> )	$=$ $\frac{X_{0,dr}}{\sqrt{2}}$ $U(C)$	off <sub>s,dr</sub> ) =	$\frac{X_{s,dr}}{\overline{\Box}}$
	$\sqrt{3}$		$\sqrt{3}$
u(Corr)	= max (Some : Some)	= Sran	
a(conrep)	(Co,rep ; Csrep)	Where:	
		S <sub>r.0</sub>	is the standard uncertainty at zero level
		S	is the standard uncertainty at span level
		-1,5	
u(Corr <sub>adi</sub> )	= u(Corr <sub>loss</sub> ) + u(Corr <sub>cal</sub> )	Where:	
	C	u(Corr <sub>loss</sub> )	is the uncertainty due to losses in sample line
u(Corr <sub>loss</sub> )	= C <sub>j,loss</sub>	u(Corr <sub>col</sub> )	is the uncertainty due to losses in sample line
( 1000)	$\sqrt{3}$	Ci.lose	is the concentration of sample loss at span level
u(Corr <sub>eal</sub> )	= U <sub>cal</sub>	U	is the expanded uncertainty of the calibration gas
( Cal	2	Cal	
	$(x - x)^2 + (x - x)^2$	$-r$ ) $\times$ (r	$(-r)^{+}$
u(Corr <sub>inf</sub> )	$= C_{j} \sqrt{\frac{(x_{j,\max} - x_{j,adj}) + (x_{j,i})}{(x_{j,\max} - x_{j,adj})}}$	$\min - x_{j,adj} / (x_{j,\max})$	$-x_{j,adj}$ $+ (x_{j,\min} - x_{j,adj})$
	S V	3	
		where:	
		C <sub>j</sub>	is the sensitivity coefficient of the influence quantity
		<b>X</b> <sub>j,min</sub>	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
	2	V Int 1 Int	2
u(Corr <sub>int</sub> )	$= \frac{C_j}{1} \frac{III_{j,\max} + III_{j,\min}}{1}$	$\times Im_{j,\max} + Im_{j,\min}$	1
	$Int_{j,test}$	3	
and		Where:	
		c <sub>j</sub>	is the sensitivity coefficient of the interferent j
$u(\Sigma Corr_{int})$	$= \max[S_{Int,p}; S_{Int,n}]$	Int <sub>j,test</sub>	is the concentration of the interferent j used to determine c <sub>j</sub>
		Int <sub>j,min</sub>	is the minimum value of the interferent j quantity during monitoring
		Int <sub>j,max</sub>	is the maximum value of the interferent j quantity during monitoring
		Int <sub>j,adj</sub>	is the concentration of the interferent j in the cal gas used to adjust the analyse
		S int,p	is the sum of interferents with positive impact
		S int,n	is the sum of interferents with negative impact
Combined unc	ertainty		
	_		
u(C, <sub>ppm</sub> )	=		
$\sqrt{u^2(corr_{fit})}$	$+u^2(corr_{0,dr})+u^2(corr_{s,dr})+u^2(corr)$	$r_{rep}$ )+ $u^2(corr_{s,vf})$ +	$u^{2}(corr_{a, press}) + u^{2}(corr_{temp}) + u^{2}(corr_{volt}) + u^{2}(corr_{adj}) + S_{Int}^{2}$
	led upgertainty $(k-2)$ $U(C)$	(c)	
overall expand	$U(C_m) = U(C_m)$	$u(C_m) \times \kappa$	
Uncertainty of	NOx measurements	\// L =	
	$C_{NOr} \times R \times \eta$	where:	is the concentration of NOV measured by the available
u(C <sub>NOx</sub> , <sub>conv</sub> )	$=$ $\frac{1}{\sqrt{2}}$		is the ratio of NO:Nox in the stock and
	<b>N</b> 5	η	is the NOx converter efficiency
Combined unc	ertainty NOx measurements	·	···· · · · · · · · · · · · · · · · · ·
u(C <sub>NOx</sub> , stack)	=		
$u^2(a a m)$	$u^{2}(aam) + u^{2}(aam) + u^{2}(aam)$	$(1 + u^2)$	$(2) + u^2 (2) $
$\sqrt{u} (corr_{fit})^+$	$u (corr_{0,dr}) + u (corr_{s,dr}) + u (corr_{rep})$	$+u (corr_{s,vf})+u (corr_{s,vf})$	$2OPT_{a,press}$ + $u$ ( $COPT_{temp}$ ) + $u$ ( $COPT_{volt}$ ) + $u$ ( $COPT_{adj}$ ) + $S_{Int}$ + $u$ ( $COPT_{NOX,conv}$ )
Uncertainty of	mass concentration at oxygen reference	concentration	
u(C, <sub>02 ref</sub> )	=		
		-( ) (	$(u^2(0))$
$u^2(corr_{fit})+u$	$^{2}(corr_{0,dr})+u^{2}(corr_{s,dr})+u^{2}(corr_{rep})+$	$u^2(corr_{s,vf}) + u^2(corr_{s,vf})$	$r_{a,press}$ + $u^{2}(corr_{temp})$ + $u^{2}(corr_{volt})$ + $u^{2}(corr_{adj})$ + $S_{Int}^{2}$ + $\left \frac{u^{2}(C_{2,meas,dry})}{(21 - O_{2})^{2}}\right ^{2}$
Where <sup>.</sup>			(-2,meas,dry)
u(C,O <sub>2 raf</sub> )	<ul> <li>uncertainty associated with the</li> </ul>	mass concentration a	at O <sub>2</sub> ref. concentration in mg/m <sup>3</sup>
C,O <sub>2 ref</sub>	<ul> <li>mass concentration at O<sub>2</sub> refer</li> </ul>	ence concentration	in mg/m <sup>3</sup>
O2 mar-	= 0 <sub>2</sub> measured concentration		in % volume
∠,medS	- <u>_</u>		

uncertainty associated to the measured  $\mathrm{O}_{\mathrm{2}}$  concentration

=

u((O<sub>2,meas)dry)</sub>

- in % volume
- % (relative to  $O_{2 \text{ meas}}$ ) in

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# **APPENDIX 4**

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

Analyser Type/Model	Sick	Maihak	1		
Reference Oxygen %		0	( 0 = No corre	ction)	
		Test 1	Test 2	Test 3	
Limit value	ma/m <sup>3</sup>	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 <sup>3</sup>	7.0 N/A	5.8 N/A	7.6 N/A	
Concentration at O2 lef. Concentration	mq/m-	IN/A	IN/A	IN/A	
Calibration gas	ppm	78.8	78.8	78.8	
Calibration gas	mg/m <sup>3</sup>	126.6	126.6	126.6	
Analyser range	ppm	9.3	9.3	9.3	
Analyser range	mg/m <sup>3</sup>	15.0	15.0	15.0	
Correction of Lack of Fit					
Lack of fit	% range	2.0	2.0	2.0	
	u(Corr, <sub>fit</sub> )	0.11	0.11	0.11	
0 " (7 10 5"					
Zero Drift	(^All drift is c % range	alculated for	the residual is	assumed to be	e < 5% u(max) )
	u(Corr, <sub>0dr</sub> )	0.00	0.00	0.00	
Span Drift	% range	0.00	0.00	0.00	
	u(Corr, <sub>sdr</sub> )	0.00	0.00	0.00	
Correction of Repeatability of Measurement	% rongo	0.0	0.0	0.0	
(Not reported)	u(Corr)	0.0	0.00	0.00	
(nor reported)	+(++)ep/	0.00	0.00	0.00	
Correction of adjustment					
losses in the line	% range	0.52	0.52	0.52	
	u(Corr, <sub>loss</sub> )	0.01	0.01	0.01	
Uncertainty of calibration gas	% range	2.0	2.0	2.0	
	u(con <sub>scal</sub> )	0.04	0.04	0.05	
Correction of Influence of Interferents					
N <sub>2</sub> O	% range				
	u(Corr, <sub>N2O</sub> )	0.00	0.00	0.00	
CO <sub>2</sub>	% range	0.00	0.00	0.00	
СН.	% range	0.00	0.00	0.00	
	u(Corr, <sub>CH4</sub> )	0.00	0.00	0.00	
Total of interferent influences	% range	2.50	2.50	2.50	
$u(\Sigma Corrint) = \max[S_{Int,p}; S_{Int,n}]$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16	
Correction of Influence Quantities					
Sensitivity to sample volume flow	% range	1.60	1.60	1.60	
Sensitivity to sample volume now	u(Corr,fice)	0.09	0.09	0.09	
Sensitivity to atmospheric pressure	% range				
(Not reported)	u(Corr, <sub>press</sub> )	0.00	0.00	0.00	
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40	
Constituity to electrical valtage	u(Corr, <sub>temp</sub> )	-0.28	-0.28	-0.28	
(Not reported)	u(Corr)	0.50	0.50	0.50	
(not reported)	+(++++)voit/	0.10	0.10	0.10	
Oxygen reference concentration					
Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!	
Overall uncertainty of O <sub>2</sub> measurement	U(O <sub>2</sub> ,meas)	#REF!	#REF!	#REF!	
	u(COI1, <sub>02</sub> )	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 Opportunition () (	M	Maria	Malua 1	Destan	11-2
Interferent Concentration Variations	Minimum	Maximum	Value at cal	Performance	Units
N <sub>2</sub> O range	0	0	0	20	mg/m <sup>3</sup>
CO <sub>2</sub> range	8	12	0	15	ma/m <sup>3</sup>
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m <sup>3</sup>
Influence Quantities Verifications					
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	К
Sensitivity to electrical voltage	187	250	230	5	V
Measurement uncertainty		Toot 4	Toot 2	Toot 2	
Combined uncertainty	nnm	0.37	0.37	0.37	
Combined uncertainty	ma/m <sup>3</sup>	0.59	0.59	0.59	
Combined uncertainty at oxygen reference	mg/m <sup>3</sup>	0.59	0.59	0.59	
Expanded uncertainty expressed with a level of confide	ence of 95%, k	=2			
Overall uncertainty	ppm	0.7	0.7	0.7	
Overall uncertainty	mg/m°	16.8	1.Z 20.2	1.2	
Overall uncertainty relative to measured value	%	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 <sup>3</sup>	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.

Huntingdon
LEV 14
15th January 2015
26th February 2015
EM02708
B22/11

Report	Prepared	by:	Print
--------	----------	-----	-------

**Report Approved by:** 

MCERTS No.

Sign

Print

**Emily Buffam** 

MM04 502

Level 2 TE: 1,2,3,4

**Emily Buffam** 

MM04 502

MCERTS No.

Level 2 TE: 1,2,3,4

**REC Environmental Monitoring** 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832





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Page 21 Uncertainty Estimates:- TOC

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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		
тос	TPM/13	BS EN 12619 : 2013		

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### 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.

Emis	sion at	Sampling			Emission	Authorised	Uncertainty	Detection	Mass
Hunti	ingdon	Time		Result	Limit	+/-	Limit	Emission	
LE	V 14	Date	Start	End	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	g/h
тос	Test 1	15/01/15	15:00	15:30	18.0	75	1.26	0.16	65.1
тос	Test 2	15/01/15	15:30	16:00	13.0	75	1.22	0.16	47.1
тос	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	ole Oxides of nitrogen results are expressed as nitrogen dioxide TOC results are expressed as total carbon					
Throughout Report:	*	Reference conditions (see above)		Nm <sup>3</sup>	273 K, 101.3 kPa	
	**	Analysis not required		# - UI	KAS accredited only	
	ND	Non detectable		## - N	ot 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.





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### **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	EBiffam	
	Print	Emily Buffam	
	MCERTS No.	MM04 502	Level 2 TE: 1,2,3,4



REC Environmental Monitoring 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832



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# **APPENDIX 1**

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### **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.

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# Sampling Project Personnel Competency And Expiry Dates

Report prepared by:	Emily Buffam	MCERTS No MM04 502	Level 1 -	Level 2 30/06/2016	TE1 30/06/2016	TE2 31/08/2016	TE3 31/08/2016	TE4 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				

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# **APPENDIX 2**

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					_	
Date	15/01/2015	Ва	rometric pressure	98.5	kPa	Stack Diameter
Time	15:15	Du	ct static pressure	-0.04	kPa	
Pitot Cp	1.02	Sta	ick Area	0.159	m²	
		Ox	ygen		%	Carbon dioxide

Stack Diameter (circular)	0.45	m
		m
		m
Carbon dioxide		%

Traverse	Traverse	Depth	ΔΡ	Т	Angle	velocity	Traverse	Depth	ΔP	Т	Angle	velocity
Point	Line	cm	mmH <sub>2</sub> O	°C	0	m/s	Line	cm	mmH <sub>2</sub> O	°C	0	m/s
1	А	5.0					В	5.0				
2	А	5.0					В	5.0				
3	А	5.3	3.3	25	<15	7.6	В	5.3				
4	А	8.0	3.1	25	<15	7.4	В	8.0				
5	А	11.3	3.2	25	<15	7.5	В	11.3				
6	А	16.0	3.1	25	<15	7.4	В	16.0				
7	А	29.0	2.9	25	<15	7.1	В	29.0				
8	А	33.8	2.7	25	<15	6.9	В	33.8				
9	А	37.0	2.4	25	<15	6.6	В	37.0				
10	А	39.7	2.3	25	<15	6.4	В	39.7				
11	А	40.0					В	40.0				
12	А	40.0					В	40.0				

Average Pitot DP	2.85	mmH₂O
Average Temperature	298.2	к
Average Velocity	7.1	m/s
Average volumetric flow rate	1.13	m <sup>3</sup> /s at stack conditions
Average volumetric flow rate	1.01	m <sup>3</sup> /s (wet STP)
Average volumetric flow rate		m³/s (dry STP)
Average volumetric flow rate		m <sup>3</sup> /s (dry, STP, reference oxygen concentraion)

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

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

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Date	15/01/2015						
From	15:00	to	15:30	30 minute mean			
Volatile orga	nic compounds		vppm, wet	11.19	mg/m³*	17	.99
From	15:30	to	16:00	30 minute mean			
Volatile orgai	nic compounds		vppm, wet	8.10	mg/m³*	13	.01
From	16:00	to	16:30	30 minute mean			
Volatile orga	nic compounds		vppm, wet	5.23	mg/m³*	8.	40
Sampling Do	toption Limita						
Volatile organ	nic compounds		maav	0.10	ma/m³*	0.	16
Reference G	as Details						
Species			Units	Value	Cylinder Reference	Analyser Range	Uncertainity $k = 2$
Nitrogen			%	99.999	VC174989	-	± 2

Zero And Span Gas Details

Volatile organic compounds

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

vppm

78.8

VCSMG4537

100

±2

Xaarjet Ltd., Huntingdon, Permit Number: B22/11, R/15-5964, v1 Visit 1 of 2015

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# **APPENDIX 3**

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# Photograph Of The Sampling Location

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### **General Calculations**

Stack area:

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

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):

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

VWC (%) =Water vapour content on wet basis, in volume % (m³ of water vapour in m³ of wet gas)Vm(std) =Dry gas volume measured, corrected to standard conditions (m³)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) = yd =	Dry gas meter volume at standard conditions (m <sup>3</sup> ) Gas meter calibration coefficient
(V2-V1) =	Dry gas meter volume at actual conditions (m <sup>3</sup> )
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.

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### **Flow Calculations**

### Velocity:

From reference calculations (taken from ISO 10780):

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

Average velocity (m/s)

v = C =velocity calculation constant = 129

Ts = Average stack temperature (K)

Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol Ms =

K= Pitot calibration coefficient

Pe = Absolute gas pressure (kPa)

 $\Delta p = \Delta p$  = Average pitot tube pressure differencial (kPa)

### Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m<sup>3</sup>/s)

Average velocity (m/s) v =

Stack cross-sectional area (m<sup>2</sup>) A =

### Volume flow rate corrected for moisture

From reference calculations (taken from BS ISO 9096):

$$q_{m} = q_{va} \frac{\left(100 - H_{a}\right)}{(100 - H_{m})}$$

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/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):

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

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/s)

Ta = Temperature at actual conditions (K)

Tm =Reference Temperatue (K)

Absolute gas pressure at actual conditions (kPa) pa =

Reference pressure (kPa) pm =

### Volume flow rate corrected for oxygen

From reference calculations (taken from BS ISO 9096):

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

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

O2, ref = Reference oxygen concentration (%)

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### **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 conditionsca =Actual concentrationO2, 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 gascdry =Concentration dry gasHa =Water vapour content (%vol)

**Conversion of parts per million (ppm) to mg/m<sup>3</sup>** 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

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

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### Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

#### Model equation

Model equation			p
$C_{ppm} = C_{readi}$	$_{ng} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{s,dr}$	$Corr_{rep} + Corr_{adj} + $	$\sum Cor_{inf} + Cor_{int}$
Where:			i=l
C ,ppm	<ul> <li>concentration in ppm</li> </ul>		Corr <sub>rep</sub> = correction of repeatability of measurement
C <sub>NO,reading</sub>	<ul> <li>concentration given by analyse</li> </ul>	r	Corr <sub>adj</sub> = correction of adjustment
Corr <sub>fit</sub>	<ul> <li>correction of lack of fit</li> </ul>		<i>Corr</i> <sub>inf</sub> = correction of influence quantities
Corr <sub>0,dr</sub>	<ul> <li>correction of zero drift</li> </ul>		Corr <sub>int</sub> = correction of interferents
Corr <sub>s,dr</sub>	= correction of span drift		
Calculation of	partial uncertainties		
···(Com.)	· · · · · · · · · · · · · · · · · · ·	14/1	
u(Con <sub>fit</sub> )	$=$ $\left( \underbrace{X_{fit,max}}_{} \right)$	where:	to the mention of the state of the form the south of
	$(100 \times range)$	X <sub>fit,max</sub>	is the maximum allowable deviation from linearity
	$\overline{\sqrt{3}}$		
Expressed as %	6 of the range and calculated by applying a	rectangular probabilit	y distribution
	X	~~~	V
u(Con <sub>0,dr</sub> )	$=$ $\frac{X_{0,dr}}{\sqrt{2}}$ $U(C)$	off <sub>s,dr</sub> ) =	$\frac{X_{s,dr}}{\overline{\Box}}$
	$\sqrt{3}$		$\sqrt{3}$
u(Corr)	= max (Some : Some)	= Sran	
a(conrep)	(Co,rep ; Csrep)	Where:	
		S <sub>r.0</sub>	is the standard uncertainty at zero level
		S	is the standard uncertainty at span level
		-1,5	
u(Corr <sub>adi</sub> )	= u(Corr <sub>loss</sub> ) + u(Corr <sub>cal</sub> )	Where:	
	C	u(Corr <sub>loss</sub> )	is the uncertainty due to losses in sample line
u(Corr <sub>loss</sub> )	= C <sub>j,loss</sub>	u(Corr <sub>col</sub> )	is the uncertainty due to losses in sample line
( 1000)	$\sqrt{3}$	Ci.lose	is the concentration of sample loss at span level
u(Corr <sub>ad</sub> )	= U <sub>cal</sub>	U	is the expanded uncertainty of the calibration gas
( Cal	2	Cal	
	$(x - x)^2 + (x - x)^2$	$-r$ ) $\times$ (r	$(-r)^{+}$
u(Corr <sub>inf</sub> )	$= C_{j} \sqrt{\frac{(x_{j,\max} - x_{j,adj}) + (x_{j,i})}{(x_{j,\max} - x_{j,adj})}}$	$\min - x_{j,adj} / (x_{j,\max})$	$-x_{j,adj}$ $+ (x_{j,\min} - x_{j,adj})$
	S V	3	
		where:	
		C <sub>j</sub>	is the sensitivity coefficient of the influence quantity
		<b>X</b> <sub>j,min</sub>	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
	2	V Int 1 Int	2
u(Corr <sub>int</sub> )	$= \frac{C_j}{1} \frac{III_{j,\max} + III_{j,\min}}{1}$	$\times Im_{j,\max} + Im_{j,\min}$	1
	$Int_{j,test}$	3	
and		Where:	
		cj	is the sensitivity coefficient of the interferent j
$u(\Sigma Corr_{int})$	$= \max[S_{Int,p}; S_{Int,n}]$	Int <sub>j,test</sub>	is the concentration of the interferent j used to determine c <sub>j</sub>
		Int <sub>j,min</sub>	is the minimum value of the interferent j quantity during monitoring
		Int <sub>j,max</sub>	is the maximum value of the interferent j quantity during monitoring
		Int <sub>j,adj</sub>	is the concentration of the interferent j in the cal gas used to adjust the analyse
		S int,p	is the sum of interferents with positive impact
		S int,n	is the sum of interferents with negative impact
Combined unc	ertainty		
	_		
u(C, <sub>ppm</sub> )	=		
$\sqrt{u^2(corr_{fit})}$	$+u^2(corr_{0,dr})+u^2(corr_{s,dr})+u^2(corr)$	$r_{rep}$ )+ $u^2(corr_{s,vf})$ +	$u^{2}(corr_{a, press}) + u^{2}(corr_{temp}) + u^{2}(corr_{volt}) + u^{2}(corr_{adj}) + S_{Int}^{2}$
	led upgertainty $(k-2)$ $U(C)$	(c)	
overall expand	$U(C_m) = U(C_m)$	$u(C_m) \times \kappa$	
Uncertainty of	NOx measurements	\// L =	
	$C_{NOr} \times R \times \eta$	where:	is the concentration of NOV measured by the available
u(C <sub>NOx</sub> , <sub>conv</sub> )	$=$ $\frac{1}{\sqrt{2}}$		is the ratio of NO:Nox in the stock and
	<b>N</b> 5	η	is the NOx converter efficiency
Combined unc	ertainty NOx measurements	·	···· · · · · · · · · · · · · · · · · ·
u(C <sub>NOx</sub> , stack)	=		
$u^2(a a m)$	$u^{2}(aam) + u^{2}(aam) + u^{2}(aam)$	$(1 + u^2)$	$(2) + u^2 (2) $
$\sqrt{u} (corr_{fit})^+$	$u (corr_{0,dr}) + u (corr_{s,dr}) + u (corr_{rep})$	$+u (corr_{s,vf})+u (corr_{s,vf})$	$2OPT_{a,press}$ + $u$ ( $COPT_{temp}$ ) + $u$ ( $COPT_{volt}$ ) + $u$ ( $COPT_{adj}$ ) + $S_{Int}$ + $u$ ( $COPT_{NOX,conv}$ )
Uncertainty of	mass concentration at oxygen reference	concentration	
u(C, <sub>02 ref</sub> )	=		
		-( ) (	$(u^2(0))$
$u^2(corr_{fit})+u$	$^{2}(corr_{0,dr})+u^{2}(corr_{s,dr})+u^{2}(corr_{rep})+$	$u^2(corr_{s,vf}) + u^2(corr_{s,vf})$	$r_{a,press}$ + $u^{2}(corr_{temp})$ + $u^{2}(corr_{volt})$ + $u^{2}(corr_{adj})$ + $S_{Int}^{2}$ + $\left \frac{u^{2}(C_{2,meas,dry})}{(21 - O_{2})^{2}}\right ^{2}$
Where <sup>.</sup>			(-2,meas,dry)
u(C,O <sub>2 raf</sub> )	<ul> <li>uncertainty associated with the</li> </ul>	mass concentration a	at O <sub>2</sub> ref. concentration in mg/m <sup>3</sup>
C,O <sub>2 ref</sub>	<ul> <li>mass concentration at O<sub>2</sub> refer</li> </ul>	ence concentration	in mg/m <sup>3</sup>
O2 mar-	= 0 <sub>2</sub> measured concentration		in % volume
∠,medS	- <u>_</u>		

uncertainty associated to the measured  $\mathrm{O}_{\mathrm{2}}$  concentration

=

u((O<sub>2,meas)dry)</sub>

- in % volume
- % (relative to  $O_{2 \text{ meas}}$ ) in

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# **APPENDIX 4**

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

Analyser Type/Model	Sick	Maihak	]		
Reference Oxygen %		0	( 0 = No corre	ction)	
		Test 1	Test 2	Test 3	
Limit value	ma/m <sup>3</sup>	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 <sup>3</sup>	18.0 N/A	13.0 N/A	8.4 N/A	
Concentration at O <sub>2</sub> fer. concentration	mq/m-	IN/A	IN/A	IN/A	
Calibration gas	ppm	78.8	78.8	78.8	
Calibration gas	mg/m <sup>3</sup>	126.6	126.6	126.6	
Analyser range	ppm	9.3	9.3	9.3	
Analyser range	mg/m <sup>3</sup>	15.0	15.0	15.0	
Correction of Lack of Fit					
Lack of fit	% range	2.0	2.0	2.0	
	u(Corr, <sub>fit</sub> )	0.11	0.11	0.11	
Corrections of Zoro and Span Drift	(* A II		44		<b>50</b> ((
Zero Drift	(^All drift is c % range	alculated for .:.	the residual is	assumed to be	e < 5% u(max) )
	u(Corr, <sub>0dr</sub> )	0.00	0.00	0.00	
Span Drift	% range	0.00	0.00	0.00	
	u(Corr, <sub>sdr</sub> )	0.00	0.00	0.00	
Correction of Repeatability of Measurement	% range	0.0	0.0	0.0	
(Not reported)	u(Corr)	0.0	0.00	0.00	
()	- (- · /idp/				
Correction of adjustment					
losses in the line	% range	1.28	1.28	1.28	
Lipportainty of calibration acc	u(Corr, <sub>loss</sub> )	0.08	0.06	0.04	
Uncertainty of calibration gas	% range	2.0	2.0	2.0	
	u(contical)	0.11	0.00	0.00	
Correction of Influence of Interferents					
N <sub>2</sub> O	% range				
20	u(Corr, <sub>N2O</sub> )	0.00	0.00	0.00	
	% range	0.00	0.00	0.00	
CH,	% range	0.00	0.00	0.00	
- 4	u(Corr, <sub>CH4</sub> )	0.00	0.00	0.00	
Total of interferent influences	% range	2.50	2.50	2.50	
$u(\Sigma Corrint) = \max[S_{Int,p}; S_{Int,n}]$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16	
Correction of Influence Quantities					
Sensitivity to sample volume flow	% range	1.60	1.60	1.60	
	u(Corr, <sub>flow</sub> )	0.09	0.09	0.09	
Sensitivity to atmospheric pressure	% range				
(Not reported)	u(Corr, <sub>press</sub> )	0.00	0.00	0.00	
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40	
Sensitivity to electrical voltage	u(Corr, <sub>temp</sub> ) % range	-0.28	-0.28	-0.28	
(Not reported)	u(Corr,volt)	0.10	0.10	0.10	
<u></u>					
Oxygen reference concentration				-	
Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!	
Overall uncertainty of O <sub>2</sub> measurement	U(Corr	#REF!	#REF!	#REF!	
	u(COI1, <sub>02</sub> )	IN/A	IN/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 of oct	Performance	Unito
	0	10	0	50	ma/m <sup>3</sup>
N <sub>2</sub> O range	0	0	0	20	mg/m <sup>3</sup>
CO <sub>2</sub> range	8	12	0	15	mg/m <sup>3</sup>
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m <sup>3</sup>
Influence Quantitiv 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 <sup>3</sup>	0.63	0.61	0.60	
Combined uncertainty at oxygen reference	mg/m <sup>3</sup>	0.63	0.61	0.60	
Evenended uppertainty surgery and the test of the					
Expanded uncertainty expressed with a level of confide	ence of 95%, k	-2	0.8	07	
Overall uncertainty	ma/m <sup>3</sup>	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 <sup>3</sup>	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 17
Sampling Date	16th January 2015
Report Date	26th February 2015
Job Number	EM02708
Permit Number	B22/11

Report P	repared	by:	Print
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**Report Approved by:** 

MCERTS No.

Sign

Print

**Emily Buffam** 

MM04 502

Level 2 TE: 1,2,3,4

**Emily Buffam** 

MM04 502

MCERTS No.

Level 2 TE: 1,2,3,4

**REC Environmental Monitoring** 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303



Company Registration No 03133832



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- Page 3 Summary Of Methods
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- Page 5 Operating Information
- Page 5 Comments On Monitoring Procedures

### Page 6 Part 2: Supporting Information

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- Page 18 Uncertainty Estimate Calculations Instrumental Techniques

### Page 19 Appendix 4

Page 20 Uncertainty Estimates:- TOC

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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
тос	TPM/13	BS EN 12619 : 2013
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# 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.

Emis	Emission at Sampling			Emission	Authorised	Uncertainty	Detection	Mass	
Huntingdon Time				Result	Limit	+/-	Limit	Emission	
LEV 17		Date	Start	End	mg/m <sup>3</sup> *	mg/m <sup>3</sup> * mg/m <sup>3</sup> *		mg/m <sup>3</sup> *	g/h
тос	Test 1	16/01/15	09:20	09:50	7.85	75	1.18	0.16	0.75
тос	Test 2	16/01/15	09:50	10:20	6.92	75	1.18	0.16	0.66
тос	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	Oxide TOC I	Oxides of nitrogen results are expressed as nitrogen dioxide TOC results are expressed as total carbon			
Throughout Report:	*	Reference conditions (see above)	Nm <sup>3</sup>	273 K, 101.3 kPa	
	**	Analysis not required	# - UI	AS accredited only	
	ND	Non detectable	## - N	ot Accredited	
	s - Su	bcontracted 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.





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



REC Environmental Monitoring 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832



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# **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.

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## Sampling Project Personnel Competency And Expiry Dates

Report prepared by:	Emily Buffam	MCERTS No MM04 502	Level 1 -	Level 2 30/06/2016	TE1 30/06/2016	TE2 31/08/2016	TE3 31/08/2016	TE4 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

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		_			_	
Date	16/01/2015		Barometric pressure	100.4	kPa	Stack Diameter
Time	09:10		Duct static pressure	0.06	kPa	
Pitot Cp	1.02		Stack Area	0.006	m²	
		-	Oxygen		%	Carbon dioxide

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

Traverse	Traverse	Depth	ΔΡ	Т	Angle	velocity	Traverse	Depth	ΔP	Т	Angle	velocity
Point	Line	cm	mmH <sub>2</sub> O	°C	0	m/s	Line	cm	mmH <sub>2</sub> O	°C	0	m/s
1	А	5.0					В	5.0				
2	A	5.0					В	5.0				
3	A	5.0					В	5.0				
4	А	5.0					В	5.0				
5	А	5.0					В	5.0				
6	A	5.0	1.2	16	<15	4.5	В	5.0				
7	A	4.0					В	4.0				
8	А	4.0					В	4.0				
9	А	4.0					В	4.0				
10	A	4.0					В	4.0				
11	A	4.0					В	4.0				
12	А	4.0					В	4.0				

Average Pitot DP	1.19	mmH₂O
Average Temperature	289.2	к
Average Velocity	4.5	m/s
Average volumetric flow rate	0.03	m <sup>3</sup> /s at stack conditions
Average volumetric flow rate	0.03	m³/s (wet STP)
Average volumetric flow rate		m³/s (dry STP)
Average volumetric flow rate		m <sup>3</sup> /s (dry, STP, reference oxygen concentraion)

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

а	Angel of gas flow less than 15° with regard to duct axis				
b	No local negative flow				
С	Minimum pitot greater than 5Pa				
d	Ratio of highest to lowest local gas velocity less than 3:1				
	Minimum local gas velocity	4.5			
	Maximum local gas velocity 4.5				
	Ratio of highest to lowest local gas velocity 1.00				

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Date	16/01/2015						
From	09:20	to	09:50	30 minute mean			
Volatile orga	nic compounds		vppm, wet	4.89	mg/m³*	7.	85
<b>F</b>	00.50	4.	10-00	00			
From	09:50	to	10:20	30 minute mean		-	
Volatile orga	nic compounds		vppm, wet	4.30	mg/m <sup>3*</sup>	6.	92
From	10:20	to	10:50	30 minute mean			
Volatile orga	nic compounds		vppm, wet	6.07	mg/m³*	9.	75
Sampling De	etection Limits						
Volatile orga	nic compounds		vppm	0.10	mg/m³*	0.	16
Reference G	as Details						
Species			Units	Value	Cylinder	Analyser	Uncertainity
					Reference	Range	k = 2
Nitrogen			%	99 999	VC174989	-	+ 2

Zero And Span Gas Details

Volatile organic compounds

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

vppm

78.8

VCSMG4537

100

±2

Xaarjet Ltd., Huntingdon, Permit Number: B22/11, R/15-5965, v1 Visit 1 of 2015

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# **General Calculations**

Stack area:

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

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):

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

VWC (%) =Water vapour content on wet basis, in volume % (m³ of water vapour in m³ of wet gas)Vm(std) =Dry gas volume measured, corrected to standard conditions (m³)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) = yd =	Dry gas meter volume at standard conditions (m <sup>3</sup> ) Gas meter calibration coefficient
(V2-V1) =	Dry gas meter volume at actual conditions (m <sup>3</sup> )
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.

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# **Flow Calculations**

### Velocity:

From reference calculations (taken from ISO 10780):

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

Average velocity (m/s)

v = C =velocity calculation constant = 129

Ts = Average stack temperature (K)

Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol Ms =

K= Pitot calibration coefficient

Pe = Absolute gas pressure (kPa)

 $\Delta p = \Delta p$  = Average pitot tube pressure differencial (kPa)

### Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m<sup>3</sup>/s)

Average velocity (m/s) v =

Stack cross-sectional area (m<sup>2</sup>) A =

### 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<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/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):

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

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/s)

Ta = Temperature at actual conditions (K)

Tm =Reference Temperatue (K)

Absolute gas pressure at actual conditions (kPa) pa =

Reference pressure (kPa) pm =

### Volume flow rate corrected for oxygen

From reference calculations (taken from BS ISO 9096):

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

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

O2, ref = Reference oxygen concentration (%)

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## **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 conditionsca =Actual concentrationO2, 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 gascdry =Concentration dry gasHa =Water vapour content (%vol)

**Conversion of parts per million (ppm) to mg/m<sup>3</sup>** 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

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

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### Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

### Model equation

Model equation			p
$C_{ppm} = C_{readi}$	$_{ng} + Corr_{fit} + Corr_{0,dr} + Corr_{s,dr} + Corr_{s,dr}$	$Corr_{rep} + Corr_{adj} + $	$\sum Cor_{inf} + Cor_{int}$
Where:			i=l
C ,ppm	<ul> <li>concentration in ppm</li> </ul>		Corr <sub>rep</sub> = correction of repeatability of measurement
C <sub>NO,reading</sub>	<ul> <li>concentration given by analyse</li> </ul>	r	Corr <sub>adj</sub> = correction of adjustment
Corr <sub>fit</sub>	<ul> <li>correction of lack of fit</li> </ul>		<i>Corr</i> <sub>inf</sub> = correction of influence quantities
Corr <sub>0,dr</sub>	<ul> <li>correction of zero drift</li> </ul>		Corr <sub>int</sub> = correction of interferents
Corr <sub>s,dr</sub>	= correction of span drift		
Calculation of	partial uncertainties		
	· · · · · · · · · · · · · · · · · · ·	14/1	
u(Con <sub>fit</sub> )	$=$ $\left( \underbrace{X_{fit,max}}_{} \right)$	where:	to the mention of the second test for the second test
	$(100 \times range)$	X <sub>fit,max</sub>	is the maximum allowable deviation from linearity
	$\overline{\sqrt{3}}$		
Expressed as %	6 of the range and calculated by applying a	rectangular probabilit	y distribution
	X	~~~	V
u(Con <sub>0,dr</sub> )	$=$ $\frac{X_{0,dr}}{\sqrt{2}}$ $U(C)$	off <sub>s,dr</sub> ) =	$\frac{X_{s,dr}}{\overline{\Box}}$
	$\sqrt{3}$		$\sqrt{3}$
u(Corr)	= max (Some : Some)	= Sran	
a(conrep)	(Co,rep ; Csrep)	Where:	
		S <sub>r.0</sub>	is the standard uncertainty at zero level
		S	is the standard uncertainty at span level
		-1,5	
u(Corr <sub>adi</sub> )	= u(Corr <sub>loss</sub> ) + u(Corr <sub>cal</sub> )	Where:	
	C	u(Corr <sub>loss</sub> )	is the uncertainty due to losses in sample line
u(Corr <sub>loss</sub> )	= C <sub>j,loss</sub>	u(Corr <sub>col</sub> )	is the uncertainty due to losses in sample line
( 1000)	$\sqrt{3}$	Ci.lose	is the concentration of sample loss at span level
u(Corr <sub>eal</sub> )	= U <sub>cal</sub>	U	is the expanded uncertainty of the calibration gas
( Cal	2	Cal	
	$(x - x)^2 + (x - x)^2$	$-r$ ) $\times$ (r	$(-r)^{+}$
u(Corr <sub>inf</sub> )	$= C_{j} \sqrt{\frac{(x_{j,\max} - x_{j,adj}) + (x_{j,i})}{(x_{j,\max} - x_{j,adj})}}$	$\min - x_{j,adj} / (x_{j,\max})$	$-x_{j,adj}$ $+ (x_{j,\min} - x_{j,adj})$
	S V	3	
		where:	
		C <sub>j</sub>	is the sensitivity coefficient of the influence quantity
		<b>X</b> <sub>j,min</sub>	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
	2	V Int 1 Int	2
u(Corr <sub>int</sub> )	$= \frac{C_j}{1} \frac{III_{j,\max} + III_{j,\min}}{1}$	$\times Im_{j,\max} + Im_{j,\min}$	1
	$Int_{j,test}$	3	
and		Where:	
		c <sub>j</sub>	is the sensitivity coefficient of the interferent j
$u(\Sigma Corr_{int})$	$= \max[S_{Int,p}; S_{Int,n}]$	Int <sub>j,test</sub>	is the concentration of the interferent j used to determine c <sub>j</sub>
		Int <sub>j,min</sub>	is the minimum value of the interferent j quantity during monitoring
		Int <sub>j,max</sub>	is the maximum value of the interferent j quantity during monitoring
		Int <sub>j,adj</sub>	is the concentration of the interferent j in the cal gas used to adjust the analyse
		S int,p	is the sum of interferents with positive impact
		S int,n	is the sum of interferents with negative impact
Combined unc	ertainty		
	_		
u(C, <sub>ppm</sub> )	=		
$\sqrt{u^2(corr_{fit})}$	$+u^2(corr_{0,dr})+u^2(corr_{s,dr})+u^2(corr)$	$r_{rep}$ )+ $u^2(corr_{s,vf})$ +	$u^{2}(corr_{a, press}) + u^{2}(corr_{temp}) + u^{2}(corr_{volt}) + u^{2}(corr_{adj}) + S_{Int}^{2}$
	led upgertainty $(k-2)$ $U(C)$	(c)	
overall expand	$U(C_m) = U(C_m)$	$u(C_m) \times \kappa$	
Uncertainty of	NOx measurements	\// L =	
	$C_{NOr} \times R \times \eta$	where:	is the concentration of NOV measured by the available
u(C <sub>NOx</sub> , <sub>conv</sub> )	$=$ $\frac{1}{\sqrt{2}}$		is the ratio of NO:Nox in the stock and
	<b>N</b> 5	η	is the NOx converter efficiency
Combined unc	ertainty NOx measurements	·	···· · · · · · · · · · · · · · · · · ·
u(C <sub>NOx</sub> , stack)	=		
$u^2(a a m)$	$u^{2}(aam) + u^{2}(aam) + u^{2}(aam)$	$(1 + u^2)$	$(2) + u^2 (2) $
$\sqrt{u} (corr_{fit})^+$	$u (corr_{0,dr}) + u (corr_{s,dr}) + u (corr_{rep})$	$+u (corr_{s,vf})+u (corr_{s,vf})$	$2OPT_{a,press}$ + $u$ ( $COPT_{temp}$ ) + $u$ ( $COPT_{volt}$ ) + $u$ ( $COPT_{adj}$ ) + $S_{Int}$ + $u$ ( $COPT_{NOX,conv}$ )
Uncertainty of	mass concentration at oxygen reference	concentration	
u(C, <sub>02 ref</sub> )	=		
		-( ) (	$(u^2(0))$
$u^2(corr_{fit})+u$	$^{2}(corr_{0,dr})+u^{2}(corr_{s,dr})+u^{2}(corr_{rep})+$	$u^2(corr_{s,vf}) + u^2(corr_{s,vf})$	$r_{a,press}$ + $u^{2}(corr_{temp})$ + $u^{2}(corr_{volt})$ + $u^{2}(corr_{adj})$ + $S_{Int}^{2}$ + $\left \frac{u^{2}(C_{2,meas,dry})}{(21 - O_{2})^{2}}\right ^{2}$
Where <sup>.</sup>			(-2,meas,dry)
u(C,O <sub>2 raf</sub> )	<ul> <li>uncertainty associated with the</li> </ul>	mass concentration a	at O <sub>2</sub> ref. concentration in mg/m <sup>3</sup>
C,O <sub>2 ref</sub>	<ul> <li>mass concentration at O<sub>2</sub> refer</li> </ul>	ence concentration	in mg/m <sup>3</sup>
O2 mar-	= 0 <sub>2</sub> measured concentration		in % volume
∠,medS	- <u>_</u>		

- % (relative to  $O_{2 \text{ meas}}$ ) in
- uncertainty associated to the measured  $\mathrm{O}_{\mathrm{2}}$  concentration

=

u((O<sub>2,meas)dry)</sub>

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

Analyser Type/Model	Sick	Maihak	1		
Reference Oxygen %		0	( 0 = No corre	ction)	
		Toot 1	Tost 2	Toot 2	1
Limit value	ma/m <sup>3</sup>	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 <sup>3</sup>	7.9 N/A	6.9 N/A	9.8 N/A	
	mq/m	IN/A	IN/A	11/74	
Calibration gas	ppm	78.8	78.8	78.8	
Calibration gas	mg/m <sup>3</sup>	126.6	126.6	126.6	
Analyser range	ppm mg/m <sup>3</sup>	9.3	9.3	9.3	
rinal joor range	mg/m	1010	1010	10.0	
Correction of Lack of Fit					
Lack of fit	% range	2.0	2.0	2.0	
	u(con, <sub>fit</sub> )	0.11	0.11	0.11	
Corrections of Zero and Span Drift	(*All drift is c	alculated for .	. the residual is	assumed to b	e < 5% u(max) )
Zero Drift	% range	0.00	0.00	0.00	
Span Drift	u(Corr, <sub>0dr</sub> )	0.00	0.00	0.00	
Span Diff	u(Corr, <sub>sdr</sub> )	0.00	0.00	0.00	
Correction of Repeatability of Measurement	0(	0.0	0.0		
(Not reported)	% range	0.0	0.0	0.0	
(not reported)	a(consrep)	0.00	0.00	0.00	
Correction of adjustment		1			
losses in the line	% range	0.18	0.18	0.18	
Uncertainty of calibration das	% range	2.0	2.0	2.0	
Choonanny of cambration gao	u(Corr, <sub>cal</sub> )	0.05	0.04	0.06	
Correction of Influence of Interferents	% rongo				
N20	u(Corr.N20)	0.00	0.00	0.00	
CO <sub>2</sub>	% range				
	u(Corr, <sub>CO2</sub> )	0.00	0.00	0.00	
CH <sub>4</sub>	% range	0.00	0.00	0.00	
Total of interferent influences	% range	2.50	2.50	2.50	
$u(\Sigma Corrint) = \max[S_{Int,p}; S_{Int,n}]$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16	
Correction of Influence Quantities					
Sensitivity to sample volume flow	% range	1.60	1.60	1.60	1
	u(Corr, <sub>flow</sub> )	0.09	0.09	0.09	
Sensitivity to atmospheric pressure	% range				
(Not reported)	u(Corr, <sub>press</sub> )	0.00	0.00	0.00	
Sensitivity to ambient temperature	u(Corr.toma)	-0.28	-0.28	-2.40	
Sensitivity to electrical voltage	% range	0.50	0.50	0.50	
(Not reported)	u(Corr, <sub>volt</sub> )	0.10	0.10	0.10	
Oxygen reference concentration					
Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!	
Overall uncertainty of O <sub>2</sub> measurement	$U(O_2,meas)$	#REF!	#REF!	#REF!	
	u(Corr, <sub>O2</sub> )	N/A	N/A	N/A	
Maximum standard uncertainty	u(Corr)	0.11	0.11	0.11	l I
5% of maximum standard uncertainty	u(Corr, <sub>5%</sub> )	0.01	0.01	0.01	
<b>.</b>					
Interforent Concentration Variations	Minimum	Movimum	Value et eel	Derformence	Unite
CH4 range	0	10	0	50	mg/m <sup>3</sup>
N <sub>2</sub> O range	0	0	0	20	mg/m <sup>3</sup>
CO <sub>2</sub> range	8	12	0	15	mg/m <sup>3</sup>
Oxygen effect	Minimum	Maximum 20	Value at cal	Performance 2	Units
Oxygen ellect	0	20	0	2	mg/m
Influence Quantitiy Variations					
	Minimum	Maximum	Value at cal	Performance	Units
Sensitivity to sample volume flow	55 90	65 100	60 99	5	i/n kPa
Sensitivity to ambient temperature	278	313	288	10	K
Sensitivity to electrical voltage	187	250	230	5	V
Macauramentumenteint		Tort 4	Tort 0	Test 0	
Combined uncertainty	ppm	0.37	0.37	0.37	
Combined uncertainty	mg/m <sup>3</sup>	0.59	0.59	0.59	
Combined uncertainty at oxygen reference	mg/m <sup>3</sup>	0.59	0.59	0.59	
Evenended uponteinty overseed with a lower (	anae of 05% '				
Expanded uncertainty expressed with a level of confid	ppm	07	07	0.7	1
Overall uncertainty	mg/m <sup>3</sup>	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	70	0.9	0.9	0.9	1

Expanded uncertainty at oxygen reference conditions expressed with a level of confidence of 95%, k=2								
Overall uncertainty mg/m <sup>3</sup> 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 19
Sampling Date	16th January 2015
Report Date	26th February 2015
Job Number	EM02708
Permit Number	B22/11

Report P	repared	by:	Print
----------	---------	-----	-------

**Report Approved by:** 

MCERTS No.

MCERTS No.

Sign

Print

Emily Buffam

MM04 502

Level 2 TE: 1,2,3,4

Emily Buffam

MM04 502

Level 2 TE: 1,2,3,4

REC Environmental Monitoring 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832



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- Page 3 Special Monitoring Requirements
- Page 3 Summary Of Methods
- Page 4 Summary Of Results, Exhaust Gases
- Page 5 Operating Information
- Page 5 Comments On Monitoring Procedures

### Page 6 Part 2: Supporting Information

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- Page 18 Uncertainty Estimate Calculations Instrumental Techniques

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Page 20 Uncertainty Estimates:- TOC

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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
тос	TPM/13	BS EN 12619 : 2013

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# 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.

Emis	sion at	at Sampling		Emission	Authorised	Uncertainty	Detection	Mass	
Huntingdon			Time		Result	Limit	+/-	Limit	Emission
LE	V 19	Date	Start	End	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	mg/m <sup>3</sup> *	g/h
тос	Test 1	16/01/15	11:00	11:30	3.69	75	1.17	0.16	6.80
тос	Test 2	16/01/15	11:30	12:00	2.67	75	1.17	0.16	4.91
тос	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)	Nm <sup>3</sup>	273 K, 101.3 kPa		
	**	Analysis not required	# - UI	AS accredited only		
	ND	Non detectable	## - N	ot Accredited		
	s - Subcontracted laboratory analysis			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.





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### **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.

Xaarjet Ltd.
Huntingdon
LEV 19
16th January 2015
26th February 2015
EM02708
B22/11

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



REC Environmental Monitoring 10 Broad Lane Moldgreen Huddersfield HD5 9BX

Tel: 0845 676 9303 Company Registration No 03133832



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# **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.

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## Sampling Project Personnel Competency And Expiry Dates

Report prepared by:	Emily Buffam	MCERTS No MM04 502	Level 1 -	Level 2 30/06/2016	TE1 30/06/2016	TE2 31/08/2016	TE3 31/08/2016	TE4 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		

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				_	
Date	16/01/2015	Barometric pr	essure 100.4	kPa	Stack Diameter
Time	09:10	Duct static pro	essure 0.08	kPa	
Pitot Cp	1.02	Stack Area	0.096	m <sup>2</sup>	
		Oxygen		%	Carbon dioxide

Stack Diameter (circular)	0.35	m
		m
		m
Carbon dioxide		%

Traverse	Traverse	Depth	ΔΡ	Т	Angle	velocity	Traverse	Depth	ΔP	Т	Angle	velocity
Point	Line	cm	mmH <sub>2</sub> O	°C	0	m/s	Line	cm	mmH <sub>2</sub> O	°C	0	m/s
1	А	5.0					В	5.0				
2	А	5.0					В	5.0				
3	А	5.0	2.1	19	<15	6.0	В	5.0				
4	А	6.2	2.2	19	<15	6.2	В	6.2				
5	А	8.8	1.9	19	<15	5.7	В	8.8				
6	А	12.5	1.8	19	<15	5.6	В	12.5				
7	А	22.5	2.0	19	<15	5.9	В	22.5				
8	А	26.3	1.9	19	<15	5.7	В	26.3				
9	А	28.8	1.7	19	<15	5.4	В	28.8				
10	А	30.0	1.6	19	<15	5.3	В	30.0				
11	А	30.0					В	30.0				
12	А	30.0					В	30.0				

Average Pitot DP	1.93	mmH₂O
Average Temperature	292.2	к
Average Velocity	5.7	m/s
Average volumetric flow rate	0.55	m <sup>3</sup> /s at stack conditions
Average volumetric flow rate	0.51	m <sup>3</sup> /s (wet STP)
Average volumetric flow rate		m³/s (dry STP)
Average volumetric flow rate		m <sup>3</sup> /s (dry, STP, reference oxygen concentraion)

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

а	Angel of gas flow less than 15° with regard to duct axis					
b	No local negative flow					
с	Minimum pitot greater than 5Pa					
d	Ratio of highest to lowest local gas velocity less than 3:1					
	Minimum local gas velocity	5.3				
	6.2					
	1.17					

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Date	16/01/2015							
From	11:00	to	11:30	30 minute mean	l			
Volatile orga	nic compounds		vppm, wet	2.30 mg/m <sup>3*</sup> 3.69				
From	11:30	to	12:00	30 minute mean	l			
Volatile organic compounds			vppm, wet	1.66 mg/m <sup>3*</sup> 2.67				
From	12:00	to	12:42	30 minute mean	I			
Volatile organic compounds			vppm, wet	2.61	mg/m <sup>3*</sup>	mg/m <sup>3*</sup> 4.19		
Sampling De	etection Limits							
Volatile organic compounds			vppm	0.10	mg/m³*	0.16		
Reference G	as Details							
Species			Units	Value	Cylinder	Analyser	Uncertainity	
					Reference	Kange	<i>k</i> = 2	
Nitrogen			%	99.999	VC174989	-	± 2	
Volatile orga	nic 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

Xaarjet Ltd., Huntingdon, Permit Number: B22/11, R/15-5966, v1 Visit 1 of 2015

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# **General Calculations**

Stack area:

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

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):

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

VWC (%) =Water vapour content on wet basis, in volume % (m³ of water vapour in m³ of wet gas)Vm(std) =Dry gas volume measured, corrected to standard conditions (m³)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) = yd =	Dry gas meter volume at standard conditions (m <sup>3</sup> ) Gas meter calibration coefficient
(V2-V1) =	Dry gas meter volume at actual conditions (m <sup>3</sup> )
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.

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# **Flow Calculations**

### Velocity:

From reference calculations (taken from ISO 10780):

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

Average velocity (m/s)

v = C =velocity calculation constant = 129

Ts = Average stack temperature (K)

Molar mass of gas; assume 29 kg/kmol unless the molar mass is < 27 kg/kmol or > 31 g/kmol Ms =

K= Pitot calibration coefficient

Pe = Absolute gas pressure (kPa)

 $\Delta p = \Delta p$  = Average pitot tube pressure differencial (kPa)

### Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m<sup>3</sup>/s)

Average velocity (m/s) v =

Stack cross-sectional area (m<sup>2</sup>) A =

### 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<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/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):

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

qm = Corrected volume flowrate (m<sup>3</sup>/s)

qva = Volume flow rate at actual conditions (m<sup>3</sup>/s)

Ta = Temperature at actual conditions (K)

Tm =Reference Temperatue (K)

Absolute gas pressure at actual conditions (kPa) pa =

Reference pressure (kPa) pm =

### Volume flow rate corrected for oxygen

From reference calculations (taken from BS ISO 9096):

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

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

O2, ref = Reference oxygen concentration (%)

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## **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 conditionsca =Actual concentrationO2, 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 gascdry =Concentration dry gasHa =Water vapour content (%vol)

**Conversion of parts per million (ppm) to mg/m<sup>3</sup>** 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

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

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### Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

### Model equation

woder equation				р		
$C_{ppm} = C_{readi}$	$_{ng} + Corr_{fit} + Corr_{fit}$	$+Corr_{b,dr}+Corr_{s,dr}+Corr_{b,dr}+Cor$	$prr_{rep} + Corr_{adj} + $	$\sum Corr_{inf} + C$	orr <sub>int</sub>	
Where:				<i>i</i> =1		
C_ppm	= co	ncentration in ppm		Corr rep	=	correction of repeatability of measurement
C <sub>NO reading</sub>	= со	ncentration given by analyser		Corr adi	=	correction of adjustment
Corr fit	= со	rrection of lack of fit		Corr inf	=	correction of influence quantities
Corrod	= co	rrection of zero drift		Corr int	=	correction of interferents
Corr <sub>s.dr</sub>	= C0	rrection of span drift		m		
o,u.						
Calculation of	partial uncert	ainties				
u(Corr <sub>fit</sub> )	= (	X <sub>fit,max</sub>	Where:			
	(1	.00×range)	X <sub>fit,max</sub>	is the maximu	ım allowab	le deviation from linearity
		$\sqrt{3}$				
Expressed as %	6 of the range	and calculated by applying a re	ectangular probability	/ distribution		
	v		··· )	V		
u(COII <sub>0,dr</sub> )	= <u>A</u>		s,dr) =	$\frac{\Lambda_{s,dr}}{\Gamma}$		
	۱	3		√3		
u(Corr <sub>rep</sub> )	= ma	ax (S <sub>0.rep</sub> ; S <sub>srep</sub> )	= S <sub>rep</sub>			
( 100)		( 0,00 ) 0000	Where:			
			S <sub>r,0</sub>	is the standar	d uncertai	nty at zero level
			S <sub>r,s</sub>	is the standar	d uncertai	nty at span level
			,.			
u(Corr <sub>adj</sub> )	= u(0	Corr <sub>loss</sub> ) + u(Corr <sub>cal</sub> )	Where:			
	(	-	u(Corr <sub>loss</sub> )	is the uncerta	inty due to	losses in sample line
u(Corr <sub>loss</sub> )	= -		u(Corr <sub>cal</sub> )	is the uncerta	inty due to	losses in sample line
		<b>√</b> 3	cj, <sub>loss</sub>	is the concen	tration of s	ample loss at span level
u(Corr <sub>cal</sub> )	= 1	J <sub>cal</sub>	U <sub>cal</sub>	is the expand	ed uncerta	inty of the calibration gas
		2				
u(Corr.,)	_	$(x_{i,\text{max}} - x_{i,adi})^2 + (x_{i,\text{min}})^2$	$(x_{i,max}) \times (x_{i,max})$	$-x_{i,adj} + (x_{i,mi})$	$x_{i,adj}$	2
u(Con inf)	= c	j <u>(                                   </u>	3		3,,,	_
		•	Where:			
			Cj	is the sensitiv	ity coeffici	ent of the influence quantity
			× <sub>i.min</sub>	is the minimu	m value of	the influence quantity during monitoring
			X <sub>i max</sub>	is the maximu	im value of	the influence quantity during monitoring
			x <sub>i.adi</sub>	is the value o	f the influe	nce quantity during adjustment
				_		
(2)		$c_i = \left  Int_{i,max}^2 + Int_{i,min} \right\rangle$	$\times Int_{i, max} + Int_{i, min}$	2		
u(Corr <sub>int</sub> )	=	$\frac{f}{t}$ $\sqrt{\frac{f}{t}}$	3	_		
and		j,test	Whore:			
and			C	is the sensitiv	ity coeffici	ent of the interferent i
$\mu(\Sigma Corr_{int})$	= m	2. 2 xe	Intime	is the concen	tration of t	ne interferent i used to determine c
-(	- 11	$[O_{Int,p}, O_{Int,n}]$	Intimin	is the minimu	m value of	the interferent i quantity during monitoring
			Int	is the maxim	im value of	the interferent i quantity during monitoring
			Int,	is the concor	tration of t	a interferent i in the cal gas used to adjust the analyse
			s s	is the sum of	interferent	with positive impact
			S int,p	is the sum of	interferent	s with positive impact
Combined unc	ertaintv		3 int,n	is the sum of	menerent	s with negative impact
Combined and	ortainty					
и(С, <sub>ppm</sub> )	=					
$\sqrt{\mu^2 (corr_a)}$	$+ u^2 (corr_{o})$	$)+u^2(corr_{,})+u^2(corr_{,})$	$+u^2(corr_{c})+u^2(corr_{c})$	$u^2(corr)$ +	- u <sup>2</sup> (corr	$+u^{2}(corr_{+})+u^{2}(corr_{+})+S_{+}^{2}$
V <sup>II</sup> (continue)	(*****0,di	(eevers,dr) eever	$p$ ) · · · · $(s \circ \cdot \cdot s, v_f)$ · · ·	(eerra, press)	(	imp) · · · · (· · · · volt) · · · · (· · · · adj) · · ~ Int
Overall expand	led uncertaint	$U(C_m) = u$	$u(C_m) \times k$			
Uncertainty of	NOx measure	ments				
-	-	, A D V P	Where:			
u(C <sub>NOx</sub> , <sub>conv</sub> )	= _	$\frac{1}{NOx} \times K \times \eta$	C <sub>NOx</sub>	is the concen	tration of N	IOx measured by the analyser
		√3	R	is the ratio of	NO:Nox in	the stack gas
Combined unc	ertainty NOx	measurements	η	is the NOx co	nverter eff	ciency
	,,					
U(C <sub>NOx</sub> , stack)	=					
$\sqrt{u^2(corr_{fit})}+$	$u^2(corr_{0,dr})$ +	$-u^2(corr_{s,dr})+u^2(corr_{rep})+u^2(corr_{$	$-u^2(corr_{s,vf})+u^2(corr_{s,vf})$	$corr_{a, press}$ ) + $u^2$	$corr_{temp}$ )-	$-u^{2}(corr_{volt})+u^{2}(corr_{adj})+S_{lnt}^{2}+u^{2}(corr_{NOx,conv})$
Uncertainty of	mass concen	tration at oxygen reference of	concentration			
u(C, <sub>(2) rof</sub> )	=					
( - / UZ THT /	-					$(-u^2(0))$
$u^2(corr_{fit})+u$	$^{2}(corr_{0,dr})+u$	$u^{2}(corr_{s,dr}) + u^{2}(corr_{rep}) + u$	$^{2}(corr_{s,vf})+u^{2}(corr_{s,vf})$	$(r_{a, press}) + u^2 (contact)$	$rr_{temp}$ )+ $u$	$S_{u}^{2}(corr_{volt}) + u^{2}(corr_{adj}) + S_{lnt}^{2} + \left  \frac{u(O_{2,meas,dry})}{(21 - O)^{2}} \right ^{2}$
Whore:						$(21 O_{2,meas,dry})$
		certainty associated with the n	nass concentration of	t O <sub>e</sub> ref. concentr	ation	in ma/m <sup>3</sup>
C O <sub>2</sub> , c (	_ un	ass concentration at O. referer	ne concentration			in ma/m <sup>3</sup>
0,02,ret	- 116					in % volume
✓2,meas	_ 0 <sub>2</sub>	measured concentration				

O2 measured concentration = uncertainty associated to the measured  $\mathrm{O}_{\mathrm{2}}$  concentration =

u((O<sub>2,meas)dry)</sub>

- in % volume
- % (relative to  $O_{2 \text{ meas}}$ ) in

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

Analyser Type/Model	1				
Reference Oxygen %	0 ( 0 = No correction)				
		-			
Limitualua	( 3	Test 1	Test 2	Test 3	
Limit value	mg/m <sup>-</sup>	46.7	46.7	46.7	
Measured concentration	ppm	2.3	1.7	2.6	
Measured concentration	mg/m <sup>3</sup>	3.7	2.7	4.2	
Concentration at O <sub>2</sub> ref. concentration	mg/m <sup>3</sup>	N/A	N/A	N/A	
	1				
Calibration gas	ppm	78.8	78.8	78.8	
Analyser range	mg/m <sup>-</sup>	9.3	9.3	9.3	
Analyser range	mg/m <sup>3</sup>	15.0	15.0	15.0	
ļ			•		
Correction of Lack of Fit					
Lack of fit	% range	2.0	2.0	2.0	
	u(Corr, <sub>fit</sub> )	0.11	0.11	0.11	
Corrections of Zero and Span Drift	(*All drift in a	algulated for	the residual is	accumed to be	> < E% u(mov))
Zero Drift	% range	0.00	0.00	0.00	e < 5% d(max) )
	u(Corr, <sub>0dr</sub> )	0.00	0.00	0.00	
Span Drift	% range	0.00	0.00	0.00	
	u(Corr, <sub>sdr</sub> )	0.00	0.00	0.00	
Correction of Repeatability of Measurement	% range	0.0	0.0	0.0	
(Not reported)	u(Corr)	0.00	0.0	0.0	
(Hot reported)	=(==:::iup/	0.00	0.00	0.00	
Correction of adjustment					
losses in the line	% range	0.18	0.18	0.18	
	u(Corr, <sub>loss</sub> )	0.00	0.00	0.00	
Uncertainty of calibration gas	% range	2.0	2.0	2.0	
	u(Corr, <sub>cal</sub> )	0.02	0.02	0.03	
Correction of Influence of Interferents					
N <sub>2</sub> O	% range				
	u(Corr, <sub>N2O</sub> )	0.00	0.00	0.00	
CO <sub>2</sub>	% range				
	u(Corr, <sub>CO2</sub> )	0.00	0.00	0.00	
CH <sub>4</sub>	% range	0.00	0.00	0.00	
Total of interferent influences	% range	2.50	2.50	2.50	
$u(\Sigma Corrint) = \max[S_{lnt,n}; S_{lnt,n}]$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16	
Correction of Influence Quantities					
Sensitivity to sample volume flow	% range	1.60	1.60	1.60	
-	u(Corr, <sub>flow</sub> )	0.09	0.09	0.09	
Sensitivity to atmospheric pressure	% range	0.00	0.00	0.00	
(Not reported) Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40	
	u(Corr.toma)	-0.28	-0.28	-0.28	
Sensitivity to electrical voltage	% range	0.50	0.50	0.50	
(Not reported)	u(Corr, <sub>volt</sub> )	0.10	0.10	0.10	
Oxygen reference concentration	1				
Measured oxygen	%	#DIV/0!	#DIV/0!	#DIV/0!	
Overall uncertainty of O <sub>2</sub> measurement	U(Corr oc)	#REF!	#REF!	#REF! N/A	
	4(0011,02)	10/1	1077	10/1	
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 Variation-	Minim	Movie	Volue et '	Dorform	Linita
CH, range	Minimum	10		50	Units
N <sub>2</sub> O range	0	0	0	20	mg/m <sup>3</sup>
CO <sub>2</sub> range	8	12	0	15	ma/m <sup>3</sup>
Oxygen effect variations	Minimum	Maximum	Value at cal	Performance	Units
Oxygen effect	0	20	0	2	mg/m <sup>3</sup>
Influence Quantitiy Variations	Minimum	Maximum	Value et eel	Derformence	Linita
Sensitivity to sample volume flow	Minimum 55	Maximum	Value at cal	Performance	Units
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	1 -	Test 1	Test 2	Test 3	
Combined uncertainty	ppm	0.37	0.37	0.37	
Combined uncertainty	mg/m <sup>°</sup>	0.59	0.59	0.59	
Somblied uncertainty at oxygen relefence	ing/m⁻	0.08	0.08	0.09	
Expanded uncertainty expressed with a level of confide	ence of 95%, k	=2			
Overall uncertainty	ppm	0.7	0.7	0.7	
Overall uncertainty	mg/m <sup>3</sup>	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 <sup>3</sup>	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.