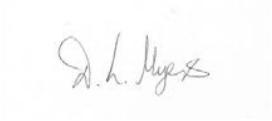
REC
Resource & Environmental Consultants Ltd

Client **Linx Printing Technologies Limited**
Linx House
8 Stocks Bridge Way
St Ives
Cambridgeshire
PE27 5JL

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**St Ives**
Plant	**Environmental Chamber Room 2**
Sampling Date	**4th November 2015**
Report Date	**2nd December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	***Print***	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

mCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME
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UKAS TESTING
1783

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Contents

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
Environmental Chamber Room 2	**Total organic carbon**

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

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

Summary Of Results

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives Environmental Chamber Room 2	Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
	Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	04/11/15	09:45	11:15	16.5	75	1.2	0.2	7.1

* at reference conditions	Stack Gas Weight		0 °C	Without correction for moisture	
	29.00	Kg/kmol	101.3 kPa	Oxygen	No Correction %

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^3 273 K, 101.3 kPa
** Analysis not required — # - UKAS accredited only
ND Non detectable — ## - Not Accredited
s - Subcontracted laboratory analysis — N/A Not applicable

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

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

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Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
Environmental Chamber Room 2		Date	Start	End	mg/m^{3}*	mg/m^{3}*	mg/m^{3}*	mg/m^{3}*	g/h
TOC	Test 1	04/11/15	09:45	10:15	30.5	75	1.3	0.2	13.1
TOC	Test 2	04/11/15	10:15	10:45	17.7	75	1.2	0.2	7.6
TOC	Test 3	04/11/15	10:45	11:15	1.2	75	1.2	0.2	0.5

* at ref Conditions	Stack Gas Weight 29.00 Kg/kmol	0 °C 101.3 kPa	Without correction for moisture Oxygen No Correction %

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^{3}	273 K, 101.3 kPa
**	Analysis not required	#	UKAS accredited only
ND	Non detectable	##	Not Accredited
s	Subcontracted laboratory analysis	N/A	Not applicable

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

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

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Operating Information

The table below shows details of the operating information on each sampling date for: **Environmental Chamber Room 2**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
04/11/2015	Environmental Test Chamber	Continuous	N/A	Methyl Ethyl Ketone	None	Three printers being tested at 50°C

There are no CEM's available 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.
The homogeneity test is not applicable to duct areas less than $1m^2$.

All monitoring was performed in accordance with the relevant procedures.

The sampling location is a vertical duct.

Only one sample port was available on the vertical duct.

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	**Linx Printing Technologies Limited**
Site	**St Ives**
Plant	**Environmental Chamber Room 2**
Sampling Date	**4th November 2015**
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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013
Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.
Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Report authorised by:	Derek Myers	MM02 115	-	30/09/2017	31/05/2018	30/11/2018	30/11/2018	30/11/2018
Team leader:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Team leader:	Aidan Wrynne	MM08 921	-	31/05/2017	31/05/2017	31/11/2018	30/11/2017	30/06/2018

Equipment References

Equipment	Reference Number
FID	**AQ271**
Heated Line	**HL40**
Heated Filter	**Sintered**
Stack Thermocouple	**PTTS97**
Timer / Stopwatch	**ST41**
Barometer	**WS03**
Pitot	**PT129**
Thermometer	**TK28**
Manometer	**PI03**

APPENDIX 2

Date	04/11/2015
Time	11:35
Pitot Cp	1.01

Barometric pressure	101.0	kPa
Duct static pressure	0.01	kPa
Stack Area	0.031	m^2

Stack Diameter (circular)	0.20	m

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s
1	A						B					
2	A						B					
3	A						B					
4	A						B					
5	A	5.0	1.1	53	<15	4.6	B					
6	A	7.1	1.1	53	<15	4.6	B					
7	A	12.9	1.2	53	<15	4.8	B					
8	A	15.0	1.0	53	<15	4.3	B					
9	A						B					
10	A						B					
11	A						B					
12	A						B					

Average Pitot DP	1.12	mmH_2O
Average Temperature	326.2	K
Average Velocity	4.6	m/s
Average volumetric flow rate	0.14	m^3/s at stack conditions
Average volumetric flow rate	0.12	m^3/s (wet STP)

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

a	Angel of gas flow less than 15° with regard to duct axis		YES
b	No local negative flow		YES
c	Minimum pitot greater than 5Pa		YES
d	Ratio of highest to lowest local gas velocity less than 3:1		YES
	Minimum local gas velocity	4.3	
	Maximum local gas velocity	4.8	
	Ratio of highest to lowest local gas velocity	1.10	

Preliminary Velocity Traverse Data

Date 04/11/2015

From 09:45 to 10:15 30 minute mean

Volatile organic compounds	vppm, wet	19.00	mg/m³*	30.54

From 10:15 to 10:45 30 minute mean

Volatile organic compounds	vppm, wet	11.03	mg/m³*	17.72

.

From 10:45 to 11:15 30 minute mean

Volatile organic compounds	vppm, wet	0.77	mg/m³*	1.23

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity ***k*** = 2
Nitrogen	%	99.999	VCK01959	-	± 2
Volatile organic compounds	vppm	74.7	VC59841	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	08:54	Final Time	17:55
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	74.70	0.12	75.08

Exhaust Gas Continuous Analysis Data

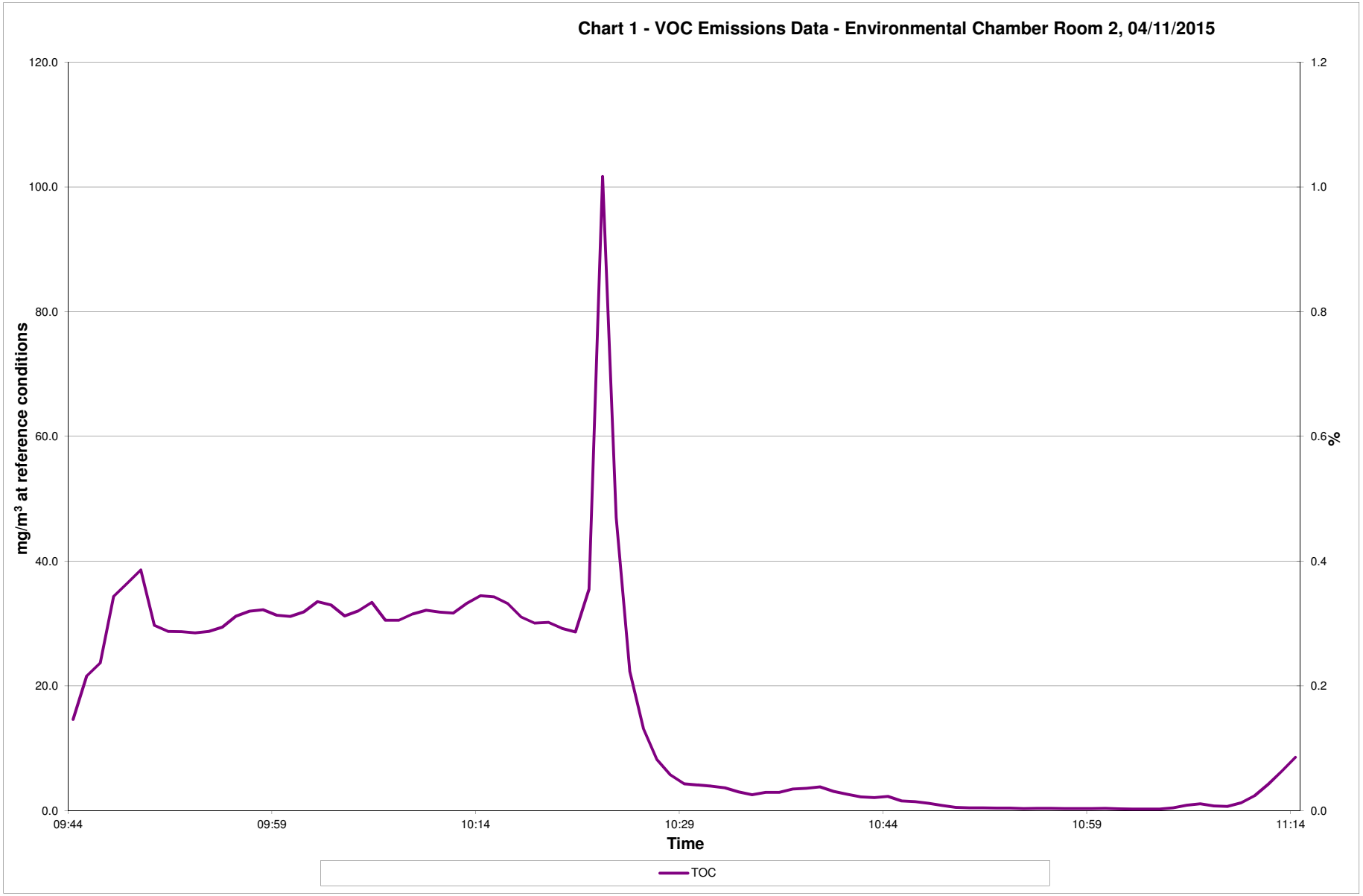


Chart 1 - VOC Emissions Data - Environmental Chamber Room 2, 04/11/2015
120.0
100.0
80.0
60.0
40.0
20.0
0.0
mg/m3 at reference conditions
1.2
1.0
0.8
0.6
0.4
0.2
0.0
%
09:44
09:59
10:14
10:29
10:44
10:59
11:14
Time
TOC

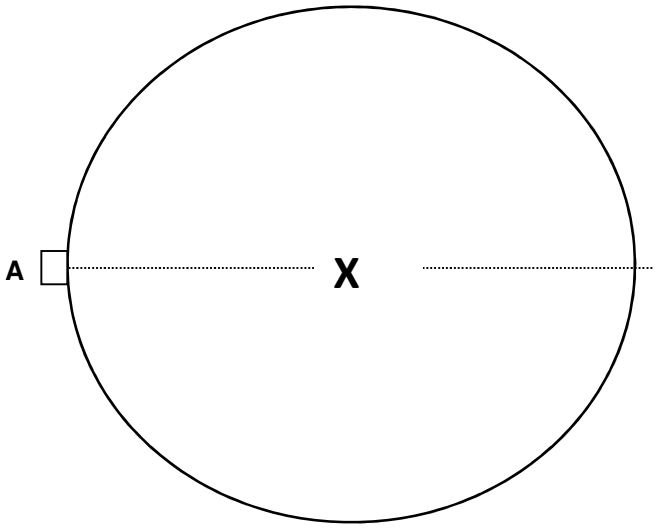
APPENDIX 3

Diagram Of The Sampling Location

Diagram of sampling points across the cross section of the duct (not to scale).

Traverse length = 0.20 m

Point	% of D	Location cm
1	50.0	10.0



General Calculations

Stack area:

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

D = Diameter (m)
π = 3.142

Pressure conversion:

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

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

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

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

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

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

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

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

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

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

Flow Calculations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Concentration Calculations

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

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

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

Mass Emission

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

c = Concentration
q = Volume flow rate

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

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

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

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

Convert wet gas to dry gas

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

Convert dry gas to wet gas

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

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

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

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Where:

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

Calculation of partial uncertainties

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

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

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

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

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

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

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

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

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

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

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

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

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

and

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

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

Combined uncertainty

$u(C_{,ppm}) =$

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

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

Uncertainty of NOx measurements

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

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

Combined uncertainty NOx measurements

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

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

Uncertainty of mass concentration at oxygen reference concentration

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

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

Where:

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

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

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

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	19.0	11.0	0.8
Measured concentration	mg/m^3	30.5	17.7	1.2
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A
Calibration gas	ppm	74.7	74.7	74.7
Calibration gas	mg/m^3	120.1	120.1	120.1
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0
Correction of Lack of Fit				
Lack of fit	% range	2.0	2.0	2.0
	$u(Corr_{+fit})$	0.11	0.11	0.11
Corrections of Zero and Span Drift	(*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))			
Zero Drift	% range	0.00	0.00	0.00
	$u(Corr_{+0dr})$	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	$u(Corr_{+sdr})$	0.00	0.00	0.00
Correction of Repeatability of Measurement				
Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	$u(Corr_{+rep})$	0.00	0.00	0.00
Correction of adjustment				
losses in the line	% range	0.27	0.27	0.27
	$u(Corr_{+loss})$	0.03	0.02	0.00
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	$u(Corr_{+cal})$	0.19	0.11	0.01
Correction of Influence of Interferents				
N_2O	% range			
	$u(Corr_{,N2O})$	0.00	0.00	0.00
CO_2	% range			
	$u(Corr_{,CO2})$	0.00	0.00	0.00
CH_4	% range			
	$u(Corr_{,CH4})$	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
$u(\Sigma Corrint) = \max\lvert S_{Int.p}; S_{Int.n} \rvert$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16
Correction of Influence Quantities				
Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	$u(Corr_{+flow})$	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	$u(Corr_{,press})$	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	$u(Corr_{,temp})$	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	$u(Corr_{,volt})$	0.10	0.10	0.10
Maximum standard uncertainty	$u(Corr_{,max})$	0.19	0.11	0.11
5% of maximum standard uncertainty	$u(Corr_{,5\%})$	0.01	0.01	0.01

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

Influence Quantitiy Variations

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

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.41	0.38	0.36
Combined uncertainty	mg/m^3	0.66	0.61	0.59
Combined uncertainty at oxygen reference	mg/m^3	0.66	0.61	0.59
Expanded uncertainty expressed with a level of confidence of 95%, k=2				
Overall uncertainty	ppm	0.8	0.8	0.7
Overall uncertainty	mg/m^3	1.3	1.2	1.2
Overall uncertainty relative to measured value	%	4.3	6.9	95.3
Overall uncertainty relative to range	%	8.8	8.2	7.8
Overall uncertainty relative to ELV	%	1.1	1.0	1.0

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

REC
Resource & Environmental Consultants Ltd

Client **Linx Printing Technologies Limited**
Linx House
8 Stocks Bridge Way
St Ives
Cambridgeshire
PE27 5JL

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**St Ives**
Plant	**Fume Cupboard Extract Vent**
Sampling Date	**4th November 2015**
Report Date	**2nd December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	*Print*	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	*Sign*		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

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Contents

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
Fume Cupboard Extract Vent	**Total organic carbon**

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

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

Summary Of Results

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives Fume Cupboard Extract Vent	Sampling Time Date	Start	End	Emission Result mg/m³*	Authorised Limit mg/m³*	Uncertainty +/- mg/m³*	Detection Limit mg/m³*	Mass Emission g/h
TOC	04/11/15	11:20	12:50	2.3	75	1.2	0.2	2.9

* at reference conditions	Stack Gas Weight 29.00 Kg/kmol	0 °C 101.3 kPa	Without correction for moisture Oxygen No Correction %

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

Throughout Report:

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

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

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

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Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives Fume Cupboard Extract Vent		Sampling Time Date	Start	End	Emission Result mg/m³*	Authorised Limit mg/m³*	Uncertainty +/- mg/m³*	Detection Limit mg/m³*	Mass Emission g/h
TOC	Test 1	04/11/15	11:20	11:50	6.0	75	1.2	0.2	7.7
TOC	Test 2	04/11/15	11:50	12:20	0.3	75	1.2	0.2	0.4
TOC	Test 3	04/11/15	12:20	12:50	0.5	75	1.2	0.2	0.6

* at ref Conditions	Stack Gas Weight 29.00 Kg/kmol	0 °C 101.3 kPa	Without correction for moisture Oxygen No Correction %

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

Throughout Report:

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

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

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

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Operating Information

The table below shows details of the operating information on each sampling date for: **Fume Cupboard Extract Vent**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
04/11/2015	Laboratory Fume Cupboard	Continuous	N/A	Methyl Ethyl Ketone, Acetone & Ethanol	None	Normal Operation

There are no CEM's available 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.
The homogeneity test is not applicable to duct areas less than $1m^2$.

All monitoring was performed in accordance with the relevant procedures.

The sampling location is a vertical duct.

Only one sample port was available on the vertical duct.

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.

REC Resource & Environmental Consultants Ltd

Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

Client	**Linx Printing Technologies Limited**
Site	**St Ives**
Plant	**Fume Cupboard Extract Vent**
Sampling Date	**4th November 2015**
Report Date	**2nd December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	*Print*	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	*Sign*		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013
Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.
Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Report authorised by:	Derek Myers	MM02 115	-	30/09/2017	31/05/2018	30/11/2018	30/11/2018	30/11/2018
Team leader:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Team leader:	Aidan Wrynne	MM08 921	-	31/05/2017	31/05/2017	31/11/2018	30/11/2017	30/06/2018

Equipment References

Equipment	Reference Number
FID	**AQ271**
Heated Line	**HL40**
Heated Filter	**Sintered**
Stack Thermocouple	**PTTS97**
Timer / Stopwatch	**ST41**
Barometer	**WS03**
Pitot	**PT129**
Thermometer	**TK28**
Manometer	**PI03**

APPENDIX 2

Date	04/11/2015
Time	09:32
Pitot Cp	1.01

Barometric pressure	101.0	kPa
Duct static pressure	0.06	kPa
Stack Area	0.031	m^2

Stack Diameter (circular)	0.20	m

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s
1	A						B					
2	A						B					
3	A						B					
4	A						B					
5	A	5.0	7.8	21	<15	11.5	B					
6	A	7.1	8.4	21	<15	11.8	B					
7	A	12.9	9.3	22	<15	12.5	B					
8	A	15.0	9.8	22	<15	12.8	B					
9	A						B					
10	A						B					
11	A						B					
12	A						B					

Average Pitot DP	8.80	mmH_2O
Average Temperature	294.7	K
Average Velocity	12.1	m/s
Average volumetric flow rate	0.38	m^3/s at stack conditions
Average volumetric flow rate	0.35	m^3/s (wet STP)

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

a	Angel of gas flow less than 15° with regard to duct axis		YES
b	No local negative flow		YES
c	Minimum pitot greater than 5Pa		YES
d	Ratio of highest to lowest local gas velocity less than 3:1		YES
	Minimum local gas velocity	11.5	
	Maximum local gas velocity	12.8	
	Ratio of highest to lowest local gas velocity	1.12	

Preliminary Velocity Traverse Data

Date 04/11/2015

From		to		30 minute mean		
Volatile organic compounds			vppm, wet	3.76	mg/m³*	6.05

From		to		30 minute mean		
Volatile organic compounds			vppm, wet	0.21	mg/m³*	0.34

.

From		to		30 minute mean		
Volatile organic compounds			vppm, wet	0.30	mg/m³*	0.48

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity ***k*** = 2
Nitrogen	%	99.999	VCK01959	-	± 2
Volatile organic compounds	vppm	74.7	VC59841	10	± 2

Zero And Span Gas Details

Species	units	Initial Time	08:54	Final Time	17:55
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	74.70	0.12	75.08

Exhaust Gas Continuous Analysis Data

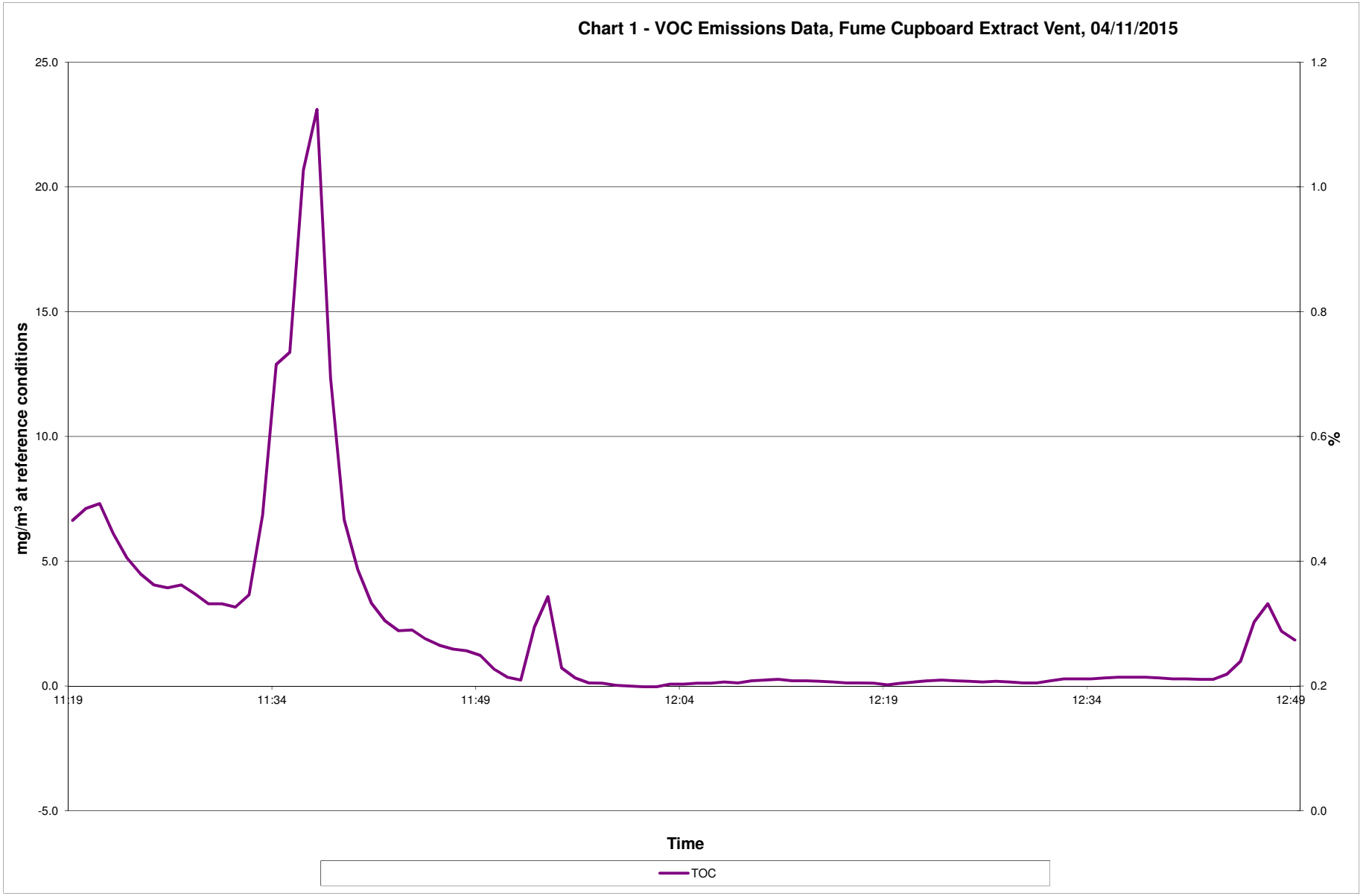


Chart 1 - VOC Emissions Data, Fume Cupboard Extract Vent, 04/11/2015
mg/m3 at reference conditions
%
Time
TOC
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
11:19
11:34
11:49
12:04
12:19
12:34
12:49

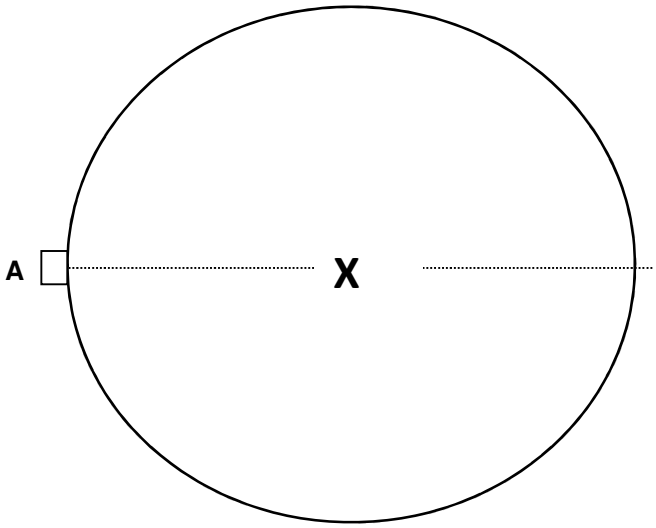
APPENDIX 3

Diagram Of The Sampling Location

Diagram of sampling points across the cross section of the duct (not to scale).

Traverse length = 0.20 m

Point	% of D	Location cm
1	50.0	10.0



General Calculations

Stack area:

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

D = Diameter (m)
π = 3.142

Pressure conversion:

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

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

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

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

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

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

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

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

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

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

Flow Calculations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Concentration Calculations

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

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

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

Mass Emission

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

c = Concentration
q = Volume flow rate

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

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

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

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

Convert wet gas to dry gas

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

Convert dry gas to wet gas

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

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

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

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Where:

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

Calculation of partial uncertainties

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

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

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

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

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

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

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

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

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

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

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

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

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

and

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

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

Combined uncertainty

$u(C_{,ppm}) =$

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

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

Uncertainty of NOx measurements

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

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

Combined uncertainty NOx measurements

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

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

Uncertainty of mass concentration at oxygen reference concentration

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

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

Where:

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

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

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

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	3.8	0.2	0.3
Measured concentration	mg/m^3	6.0	0.3	0.5
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A
Calibration gas	ppm	74.7	74.7	74.7
Calibration gas	mg/m^3	120.1	120.1	120.1
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0
Correction of Lack of Fit				
Lack of fit	% range	2.0	2.0	2.0
	$u(Corr_{+fit})$	0.11	0.11	0.11
Corrections of Zero and Span Drift	(*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))			
Zero Drift	% range	0.00	0.00	0.00
	$u(Corr_{+0dr})$	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	$u(Corr_{+sdr})$	0.00	0.00	0.00
Correction of Repeatability of Measurement				
Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	$u(Corr_{+rep})$	0.00	0.00	0.00
Correction of adjustment				
losses in the line	% range	0.27	0.27	0.27
	$u(Corr_{+loss})$	0.01	0.00	0.00
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	$u(Corr_{+cal})$	0.04	0.00	0.00
Correction of Influence of Interferents				
N_2O	% range			
	$u(Corr_{+N2O})$	0.00	0.00	0.00
CO_2	% range			
	$u(Corr_{+CO2})$	0.00	0.00	0.00
CH_4	% range			
	$u(Corr_{+CH4})$	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
$u(\Sigma Corrint) = \max\lvert S_{Int.p}; S_{Int.n} \rvert$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16
Correction of Influence Quantities				
Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	$u(Corr_{+flow})$	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	$u(Corr_{+press})$	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	$u(Corr_{+temp})$	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	$u(Corr_{+volt})$	0.10	0.10	0.10
Maximum standard uncertainty	$u(Corr_{+max})$	0.11	0.11	0.11
5% of maximum standard uncertainty	$u(Corr_{+5\%})$	0.01	0.01	0.01

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

Influence Quantitiy Variations

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

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.37	0.36	0.36
Combined uncertainty	mg/m^3	0.59	0.59	0.59
Combined uncertainty at oxygen reference	mg/m^3	0.59	0.59	0.59
Expanded uncertainty expressed with a level of confidence of 95%, k=2				
Overall uncertainty	ppm	0.7	0.7	0.7
Overall uncertainty	mg/m^3	1.2	1.2	1.2
Overall uncertainty relative to measured value	%	19.5	344.7	246.0
Overall uncertainty relative to range	%	7.9	7.8	7.8
Overall uncertainty relative to ELV	%	1.0	1.0	1.0

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

REC
Resource & Environmental Consultants Ltd

Client **Linx Printing Technologies Limited**
Linx House
8 Stocks Bridge Way
St Ives
Cambridgeshire
PE27 5JL

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**St Ives**
Plant	**Labs**
Sampling Date	**4th November 2015**
Report Date	**2nd December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	***Print***	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

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UKAS TESTING
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Contents

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
Labs	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

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

Summary Of Results

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives Labs	Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
	Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	04/11/15	13:05	14:35	3.8	75	1.2	0.2	12.8

* at reference conditions	Stack Gas Weight		0 °C	Without correction for moisture	
	29.00	Kg/kmol	101.3 kPa	Oxygen	No Correction %

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^3 273 K, 101.3 kPa
** Analysis not required — # - UKAS accredited only
ND Non detectable — ## - Not Accredited
s - Subcontracted laboratory analysis — N/A Not applicable

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

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

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Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives Labs		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
		Date	Start	End	mg/m^{3}*	mg/m^{3}*	mg/m^{3}*	mg/m^{3}*	g/h
TOC	Test 1	04/11/15	13:05	13:35	2.9	75	1.2	0.2	9.9
TOC	Test 2	04/11/15	13:35	14:05	4.5	75	1.2	0.2	15.3
TOC	Test 3	04/11/15	14:05	14:35	3.9	75	1.2	0.2	13.2

* at ref Conditions	Stack Gas Weight 29.00 Kg/kmol	0 °C 101.3 kPa	Without correction for moisture Oxygen No Correction %

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^{3}	273 K, 101.3 kPa
**	Analysis not required	#	UKAS accredited only
ND	Non detectable	##	Not Accredited
s	Subcontracted laboratory analysis	N/A	Not applicable

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

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

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Operating Information

The table below shows details of the operating information on each sampling date for: **Labs**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
04/11/2015	Laboratory	Continuous	N/A	Methyl Ethyl Ketone, Acetone & Ethanol	None	Normal Operation

There are no CEM's available 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.
The homogeneity test is not applicable to duct areas less than $1m^2$.

All monitoring was performed in accordance with the relevant procedures.

The sampling location is a vertical duct.

Only one sample port was available on the vertical duct.

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.

Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

Client	**Linx Printing Technologies Limited**
Site	**St Ives**
Plant	**Labs**
Sampling Date	**4th November 2015**
Report Date	**2nd December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	*Print*	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	*Sign*		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013
Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.
Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Report authorised by:	Derek Myers	MM02 115	-	30/09/2017	31/05/2018	30/11/2018	30/11/2018	30/11/2018
Team leader:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Team leader:	Aidan Wrynne	MM08 921	-	31/05/2017	31/05/2017	31/11/2018	30/11/2017	30/06/2018

Equipment References

Equipment	Reference Number
FID	**AQ271**
Heated Line	**HL40**
Heated Filter	**Sintered**
Stack Thermocouple	**PTTS97**
Timer / Stopwatch	**ST41**
Barometer	**WS03**
Pitot	**PT129**
Thermometer	**TK28**
Manometer	**PI03**

APPENDIX 2

Date	04/11/2015
Time	10:15
Pitot Cp	1.01

Barometric pressure	101.0	kPa
Duct static pressure	0.08	kPa
Stack Area	0.071	m^2

Stack Diameter (circular)	0.30	m

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s
1	A						B					
2	A						B					
3	A	5.0	18.0	22	<15	17.4	B					
4	A	5.3	15.1	22	<15	15.9	B					
5	A	7.5	10.8	22	<15	13.5	B					
6	A	10.7	10.0	22	<15	12.9	B					
7	A	19.3	16.1	22	<15	16.4	B					
8	A	22.5	12.4	22	<15	14.4	B					
9	A	24.7	9.6	22	<15	12.7	B					
10	A	25.0	9.0	22	<15	12.3	B					
11	A						B					
12	A						B					

Average Pitot DP	12.43	mmH_2O
Average Temperature	295.2	K
Average Velocity	14.4	m/s
Average volumetric flow rate	1.02	m^3/s at stack conditions
Average volumetric flow rate	0.94	m^3/s (wet STP)

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

a	Angel of gas flow less than 15° with regard to duct axis		YES
b	No local negative flow		YES
c	Minimum pitot greater than 5Pa		YES
d	Ratio of highest to lowest local gas velocity less than 3:1		YES
	Minimum local gas velocity	12.3	
	Maximum local gas velocity	17.4	
	Ratio of highest to lowest local gas velocity	1.42	

Preliminary Velocity Traverse Data

Date 04/11/2015

From 13:05 to 13:35 30 minute mean

Volatile organic compounds	vppm, wet	1.82	mg/m³*	2.93

From 13:35 to 14:05 30 minute mean

Volatile organic compounds	vppm, wet	2.80	mg/m³*	4.51

.

From 14:05 to 14:35 30 minute mean

Volatile organic compounds	vppm, wet	2.42	mg/m³*	3.88

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity ***k*** = 2
Nitrogen	%	99.999	VCK01959	-	± 2
Volatile organic compounds	vppm	74.7	VC59841	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	08:54	Final Time	17:55
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	74.70	0.12	75.08

Exhaust Gas Continuous Analysis Data

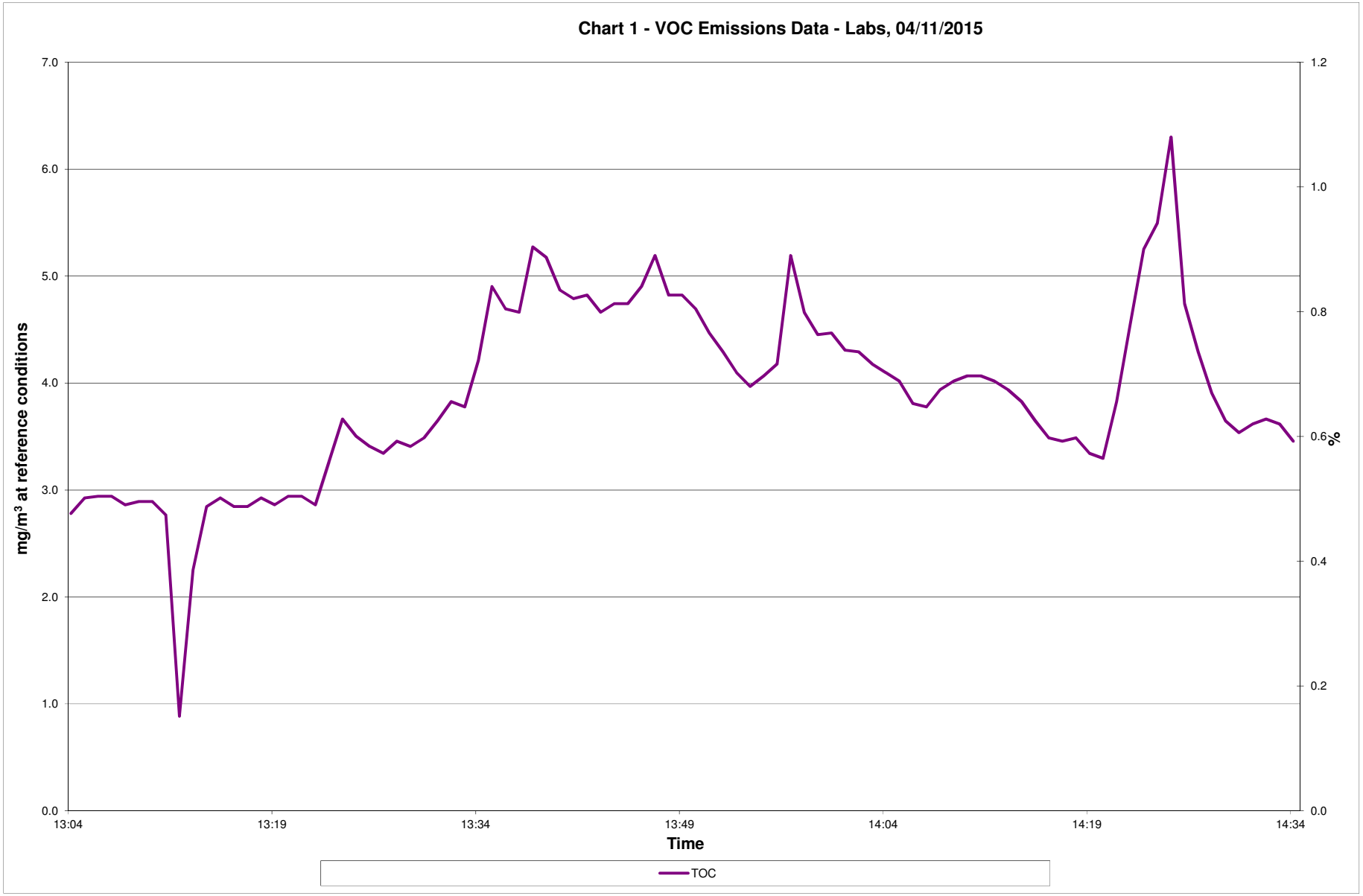


Chart 1 - VOC Emissions Data - Labs, 04/11/2015
mg/m3 at reference conditions
%
Time
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
13:04
13:19
13:34
13:49
14:04
14:19
14:34
TOC

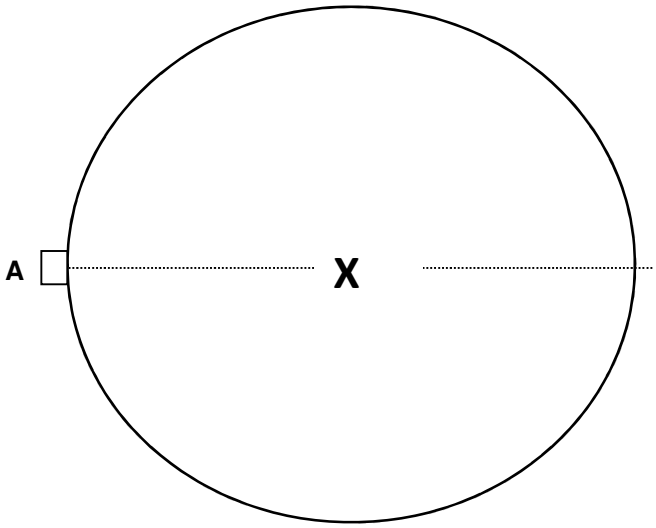
APPENDIX 3

Diagram Of The Sampling Location

Diagram of sampling points across the cross section of the duct (not to scale).

Traverse length = 0.30 m

Point	% of D	Location cm
1	50.0	15.0



General Calculations

Stack area:

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

D = Diameter (m)
π = 3.142

Pressure conversion:

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

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

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

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

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

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

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

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

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

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

Flow Calculations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Concentration Calculations

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

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

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

Mass Emission

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

c = Concentration
q = Volume flow rate

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

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

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

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

Convert wet gas to dry gas

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

Convert dry gas to wet gas

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

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

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

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Where:

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

Calculation of partial uncertainties

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

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

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

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

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

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

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

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

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

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

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

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

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

and

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

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

Combined uncertainty

$u(C_{,ppm}) =$

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

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

Uncertainty of NOx measurements

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

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

Combined uncertainty NOx measurements

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

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

Uncertainty of mass concentration at oxygen reference concentration

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

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

Where:

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

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

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

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	1.8	2.8	2.4
Measured concentration	mg/m^3	2.9	4.5	3.9
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A
Calibration gas	ppm	74.7	74.7	74.7
Calibration gas	mg/m^3	120.1	120.1	120.1
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0
Correction of Lack of Fit				
Lack of fit	% range	2.0	2.0	2.0
	$u(Corr_{+fit})$	0.11	0.11	0.11
Corrections of Zero and Span Drift	(*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))			
Zero Drift	% range	0.00	0.00	0.00
	$u(Corr_{+0dr})$	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	$u(Corr_{+sdr})$	0.00	0.00	0.00
Correction of Repeatability of Measurement				
Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	$u(Corr_{+rep})$	0.00	0.00	0.00
Correction of adjustment				
losses in the line	% range	0.27	0.27	0.27
	$u(Corr_{+loss})$	0.00	0.00	0.00
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	$u(Corr_{+cal})$	0.02	0.03	0.02
Correction of Influence of Interferents				
N_2O	% range			
	$u(Corr_{+N2O})$	0.00	0.00	0.00
CO_2	% range			
	$u(Corr_{+CO2})$	0.00	0.00	0.00
CH_4	% range			
	$u(Corr_{+CH4})$	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
$u(\Sigma Corrint) = \max\lvert S_{Int.p}; S_{Int.n} \rvert$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16
Correction of Influence Quantities				
Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	$u(Corr_{+flow})$	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	$u(Corr_{+press})$	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	$u(Corr_{+temp})$	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	$u(Corr_{+volt})$	0.10	0.10	0.10
Maximum standard uncertainty	$u(Corr_{+max})$	0.11	0.11	0.11
5% of maximum standard uncertainty	$u(Corr_{+5\%})$	0.01	0.01	0.01

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

Influence Quantitiy Variations

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

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

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

Overall uncertainty	ppm	0.7	0.7	0.7
Overall uncertainty	mg/m^3	1.2	1.2	1.2
Overall uncertainty relative to measured value	%	40.1	26.1	30.3
Overall uncertainty relative to range	%	7.8	7.8	7.8
Overall uncertainty relative to ELV	%	1.0	1.0	1.0

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

REC
Resource & Environmental Consultants Ltd

Client **Linx Printing Technologies Limited**
Linx House
8 Stocks Bridge Way
St Ives
Cambridgeshire
PE27 5JL

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**St Ives**
Plant	**RASTA**
Sampling Date	**4th November 2015**
Report Date	**7th December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	***Print***	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	***Sign***		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

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1783

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Company Registration No 03133832

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Contents

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
RASTA	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

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

Summary Of Results

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives RASTA	Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
	Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	04/11/15	14:40	16:10	2.9	75	1.2	0.2	1.2

* at reference conditions	Stack Gas Weight		0 °C	Without correction for moisture	
	29.00	Kg/kmol	101.3 kPa	Oxygen	No Correction %

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^3 273 K, 101.3 kPa
** Analysis not required — # - UKAS accredited only
ND Non detectable — ## - Not Accredited
s - Subcontracted laboratory analysis — N/A Not applicable

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

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

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Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives RASTA		Sampling Time Date	Start	End	Emission Result mg/m³*	Authorised Limit mg/m³*	Uncertainty +/- mg/m³*	Detection Limit mg/m³*	Mass Emission g/h
TOC	Test 1	04/11/15	14:40	15:10	2.9	75	1.2	0.2	1.2
TOC	Test 2	04/11/15	15:10	15:40	3.0	75	1.2	0.2	1.2
TOC	Test 3	04/11/15	15:40	16:10	2.9	75	1.2	0.2	1.2

* at ref Conditions	Stack Gas Weight 29.00 Kg/kmol	0 °C 101.3 kPa	Without correction for moisture Oxygen No Correction %

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

Throughout Report:

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

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

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

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Operating Information

The table below shows details of the operating information on each sampling date for: **RASTA**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
04/11/2015	Ink Printer Test Rig RASTA	Batch	N/A	Methyl Ethyl Ketone	None	200 ml/day of solvent

There are no CEM's available 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.
The homogeneity test is not applicable to duct areas less than $1m^2$.

All monitoring was performed in accordance with the relevant procedures.

The sampling location is a horizontal duct.

Only one sample port was available on the horizontal duct.

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	**Linx Printing Technologies Limited**
Site	**St Ives**
Plant	**RASTA**
Sampling Date	**4th November 2015**
Report Date	**7th December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by: *Print* **Harpreet Badwal**

MCERTS No. **MM03 149** **Level 2 TE: 1,2,3,4**

Report Approved by: *Sign*

Print **Derek Myers**

MCERTS No. **MM02 115** **Level 2 TE: 1,2,3,4**

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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013
Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.
Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Report authorised by:	Derek Myers	MM02 115	-	30/09/2017	31/05/2018	30/11/2018	30/11/2018	30/11/2018
Team leader:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Team leader:	Aidan Wrynne	MM08 921	-	31/05/2017	31/05/2017	31/11/2018	30/11/2017	30/06/2018

Equipment References

Equipment	Reference Number
FID	**AQ271**
Heated Line	**HL40**
Heated Filter	**Sintered**
Stack Thermocouple	**PTTS97**
Timer / Stopwatch	**ST41**
Barometer	**WS03**
Pitot	**PT129**
Thermometer	**TK28**
Manometer	**PI03**

APPENDIX 2

Date	04/11/2015
Time	13:40
Pitot Cp	1.01

Barometric pressure	101.0	kPa
Duct static pressure	-0.70	kPa
Stack Area	0.013	m^2

Stack Diameter (circular)	0.13	m

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s
1	A						B					
2	A						B					
3	A						B					
4	A						B					
5	A						B					
6	A	5.0	4.8	17	<15	8.9	B					
7	A	8.0	5.0	17	<15	9.1	B					
8	A						B					
9	A						B					
10	A						B					
11	A						B					
12	A						B					

Average Pitot DP	4.89	mmH_2O
Average Temperature	290.2	K
Average Velocity	9.0	m/s
Average volumetric flow rate	0.12	m^3/s at stack conditions
Average volumetric flow rate	0.11	m^3/s (wet STP)

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

a	Angel of gas flow less than 15° with regard to duct axis		YES
b	No local negative flow		YES
c	Minimum pitot greater than 5Pa		YES
d	Ratio of highest to lowest local gas velocity less than 3:1		YES
	Minimum local gas velocity	8.9	
	Maximum local gas velocity	9.1	
	Ratio of highest to lowest local gas velocity	1.02	

Preliminary Velocity Traverse Data

Date 04/11/2015

From 14:40 to 15:10 30 minute mean

Volatile organic compounds	vppm, wet	1.83	mg/m³*	2.94

From 15:10 to 15:40 30 minute mean

Volatile organic compounds	vppm, wet	1.87	mg/m³*	3.01

.

From 15:40 to 16:10 30 minute mean

Volatile organic compounds	vppm, wet	1.79	mg/m³*	2.88

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity ***k*** = 2
Nitrogen	%	99.999	VCK01959	-	± 2
Volatile organic compounds	vppm	74.7	VC59841	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	08:54	Final Time	17:55
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	74.70	0.12	75.08

Exhaust Gas Continuous Analysis Data

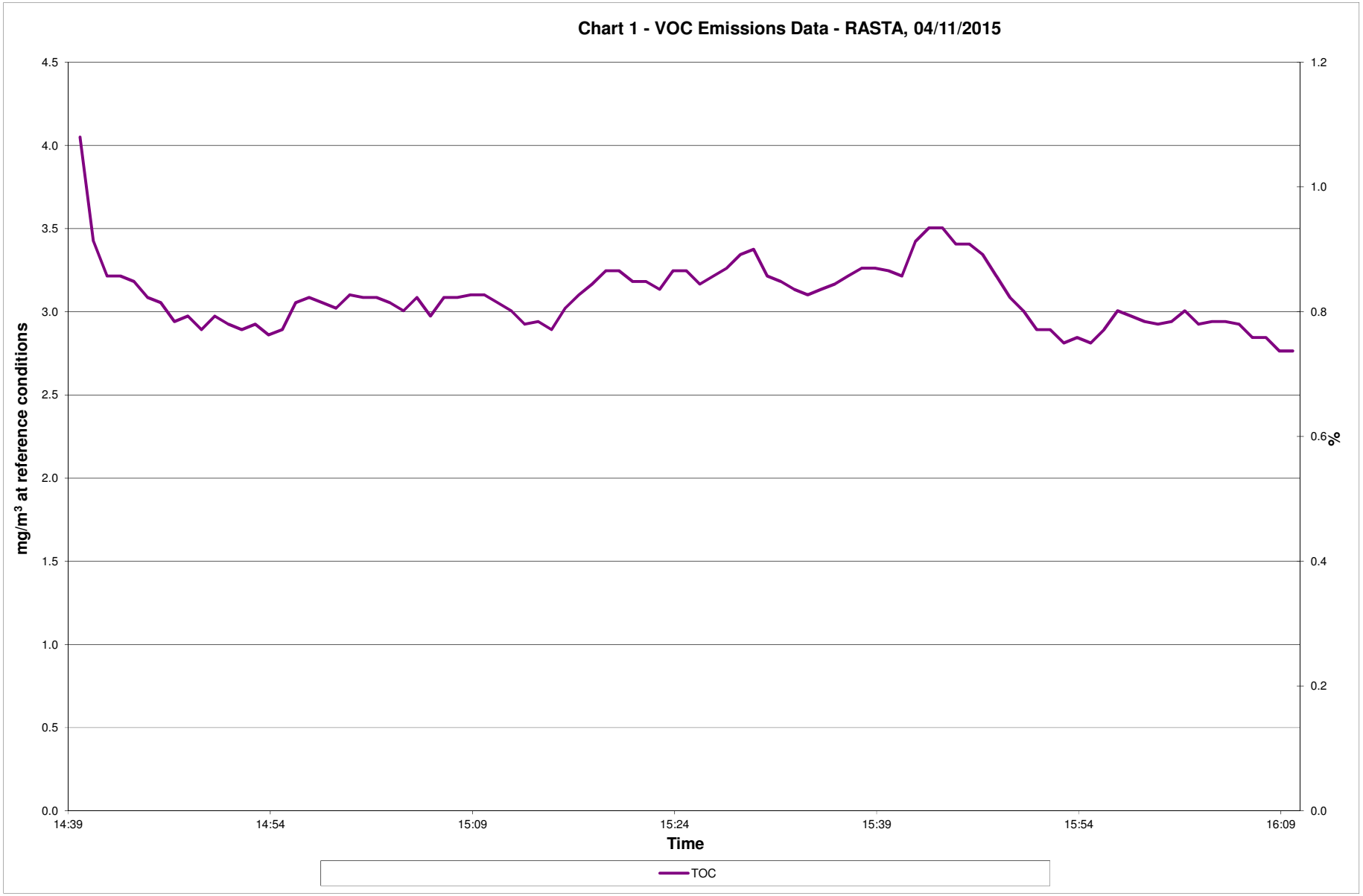


Chart 1 - VOC Emissions Data - RASTA, 04/11/2015
mg/m3 at reference conditions
%
Time
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
14:39
14:54
15:09
15:24
15:39
15:54
16:09
TOC

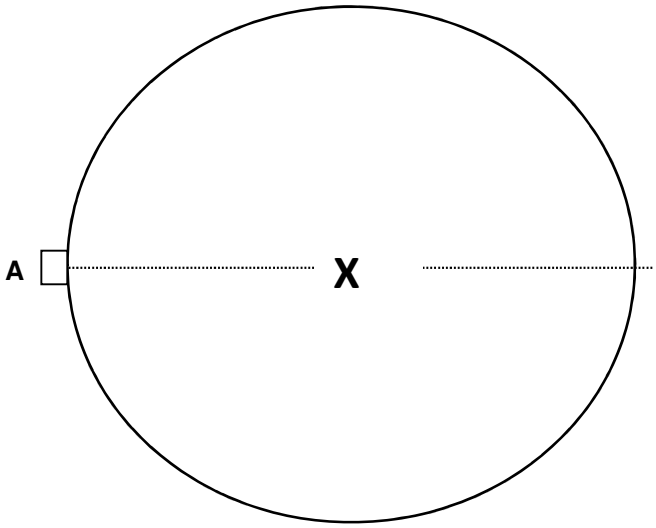
APPENDIX 3

Diagram Of The Sampling Location

Diagram of sampling points across the cross section of the duct (not to scale).

Traverse length = 0.13 m

Point	% of D	Location cm
1	50.0	6.5



General Calculations

Stack area:

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

D = Diameter (m)
π = 3.142

Pressure conversion:

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

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

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

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

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

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

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

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

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

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

Flow Calculations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Concentration Calculations

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

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

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

Mass Emission

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

c = Concentration
q = Volume flow rate

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

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

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

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

Convert wet gas to dry gas

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

Convert dry gas to wet gas

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

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

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

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Where:

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

Calculation of partial uncertainties

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

Where:

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

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

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

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

Where:

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

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

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

Where:

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

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

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

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

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

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

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

Where:

c_j is the sensitivity coefficient of the influence quantity

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

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

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

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

and

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

Where:

c_j is the sensitivity coefficient of the interferent j

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

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

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

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

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

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

Combined uncertainty

$u(C_{,ppm}) =$

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

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

Uncertainty of NOx measurements

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

Where:

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

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

η is the NOx converter efficiency

Combined uncertainty NOx measurements

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

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

Uncertainty of mass concentration at oxygen reference concentration

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

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

Where:

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

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

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

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	1.8	1.9	1.8
Measured concentration	mg/m^3	2.9	3.0	2.9
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A
Calibration gas	ppm	74.7	74.7	74.7
Calibration gas	mg/m^3	120.1	120.1	120.1
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0
Correction of Lack of Fit				
Lack of fit	% range	2.0	2.0	2.0
	$u(Corr_{+fit})$	0.11	0.11	0.11
Corrections of Zero and Span Drift	(*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))			
Zero Drift	% range	0.00	0.00	0.00
	$u(Corr_{+0dr})$	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	$u(Corr_{+sdr})$	0.00	0.00	0.00
Correction of Repeatability of Measurement				
Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	$u(Corr_{+rep})$	0.00	0.00	0.00
Correction of adjustment				
losses in the line	% range	0.27	0.27	0.27
	$u(Corr_{+loss})$	0.00	0.00	0.00
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	$u(Corr_{+cal})$	0.02	0.02	0.02
Correction of Influence of Interferents				
N_2O	% range			
	$u(Corr_{+N2O})$	0.00	0.00	0.00
CO_2	% range			
	$u(Corr_{+CO2})$	0.00	0.00	0.00
CH_4	% range			
	$u(Corr_{+CH4})$	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
$u(\Sigma Corrint) = \max\lvert S_{Int.p}; S_{Int.n} \rvert$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16
Correction of Influence Quantities				
Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	$u(Corr_{+flow})$	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	$u(Corr_{+press})$	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	$u(Corr_{+temp})$	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	$u(Corr_{+volt})$	0.10	0.10	0.10
Maximum standard uncertainty	$u(Corr_{+max})$	0.11	0.11	0.11
5% of maximum standard uncertainty	$u(Corr_{+5\%})$	0.01	0.01	0.01

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

Influence Quantitiy Variations

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

Measurement uncertainty		Test 1	Test 2	Test 3
Combined uncertainty	ppm	0.37	0.37	0.37
Combined uncertainty	mg/m^3	0.59	0.59	0.59
Combined uncertainty at oxygen reference	mg/m^3	0.59	0.59	0.59
Expanded uncertainty expressed with a level of confidence of 95%, k=2				
Overall uncertainty	ppm	0.7	0.7	0.7
Overall uncertainty	mg/m^3	1.2	1.2	1.2
Overall uncertainty relative to measured value	%	39.9	39.0	40.7
Overall uncertainty relative to range	%	7.8	7.8	7.8
Overall uncertainty relative to ELV	%	1.0	1.0	1.0

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

REC
Resource & Environmental Consultants Ltd

Client **Linx Printing Technologies Limited**
Linx House
8 Stocks Bridge Way
St Ives
Cambridgeshire
PE27 5JL

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**St Ives**
Plant	**Environmental Chamber Room 1**
Sampling Date	**4th November 2015**
Report Date	**2nd December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by: ***Print*** **Harpreet Badwal**

MCERTS No. **MM03 149** **Level 2 TE: 1,2,3,4**

Report Approved by: ***Sign***

Print **Derek Myers**

MCERTS No. **MM02 115** **Level 2 TE: 1,2,3,4**

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Contents

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
Environmental Chamber Room 1	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

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

Summary Of Results

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives Environmental Chamber Room 1	Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
	Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	04/11/15	16:15	17:45	7.6	75	1.2	0.2	3.2

* at reference conditions	Stack Gas Weight		0 °C	Without correction for moisture	
	29.00	Kg/kmol	101.3 kPa	Oxygen	No Correction %

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^3 273 K, 101.3 kPa
** Analysis not required — # - UKAS accredited only
ND Non detectable — ## - Not Accredited
s - Subcontracted laboratory analysis — N/A Not applicable

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

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

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Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
Environmental Chamber Room 1		Date	Start	End	mg/m^{3}*	mg/m^{3}*	mg/m^{3}*	mg/m^{3}*	g/h
TOC	Test 1	04/11/15	16:15	16:45	8.3	75	1.2	0.2	3.5
TOC	Test 2	04/11/15	16:45	17:15	11.1	75	1.2	0.2	4.7
TOC	Test 3	04/11/15	17:15	17:45	3.4	75	1.2	0.2	1.5

* at ref Conditions	Stack Gas Weight 29.00 Kg/kmol	0 °C 101.3 kPa	Without correction for moisture Oxygen No Correction %

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^{3}	273 K, 101.3 kPa
**	Analysis not required	#	UKAS accredited only
ND	Non detectable	##	Not Accredited
s	Subcontracted laboratory analysis	N/A	Not applicable

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

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

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Operating Information

The table below shows details of the operating information on each sampling date for: **Environmental Chamber Room 1**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
04/11/2015	Environmental Test Chamber	Continuous	N/A	Methyl Ethyl Ketone	None	1 printer tested at 5°C

There are no CEM's available 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.
The homogeneity test is not applicable to duct areas less than $1m^2$.

All monitoring was performed in accordance with the relevant procedures.

The sampling location is a vertical duct.

Only one sample port was available on the vertical duct.

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	**Linx Printing Technologies Limited**
Site	**St Ives**
Plant	**Environmental Chamber Room 1**
Sampling Date	**4th November 2015**
Report Date	**2nd December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	*Print*	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	*Sign*		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013
Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.
Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Report authorised by:	Derek Myers	MM02 115	-	30/09/2017	31/05/2018	30/11/2018	30/11/2018	30/11/2018
Team leader:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Team leader:	Aidan Wrynne	MM08 921	-	31/05/2017	31/05/2017	31/11/2018	30/11/2017	30/06/2018

Equipment References

Equipment	Reference Number
FID	**AQ271**
Heated Line	**HL40**
Heated Filter	**Sintered**
Stack Thermocouple	**PTTS97**
Timer / Stopwatch	**ST41**
Barometer	**WS03**
Pitot	**PT129**
Thermometer	**TK28**
Manometer	**PI03**

APPENDIX 2

Date	04/11/2015
Time	12:02
Pitot Cp	1.01

Barometric pressure	101.0	kPa
Duct static pressure	0.01	kPa
Stack Area	0.031	m^2

Stack Diameter (circular)	0.20	m

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s
1	A						B					
2	A						B					
3	A						B					
4	A						B					
5	A	5.0	1.0	7	<15	4.0	B					
6	A	7.1	0.7	7	<15	3.4	B					
7	A	12.9	0.8	7	<15	3.6	B					
8	A	15.0	1.2	7	<15	4.4	B					
9	A						B					
10	A						B					
11	A						B					
12	A						B					

Average Pitot DP	0.93	mmH_2O
Average Temperature	280.2	K
Average Velocity	3.9	m/s
Average volumetric flow rate	0.12	m^3/s at stack conditions
Average volumetric flow rate	0.12	m^3/s (wet STP)

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

a	Angel of gas flow less than 15° with regard to duct axis		YES
b	No local negative flow		YES
c	Minimum pitot greater than 5Pa		YES
d	Ratio of highest to lowest local gas velocity less than 3:1		YES
	Minimum local gas velocity	3.4	
	Maximum local gas velocity	4.4	
	Ratio of highest to lowest local gas velocity	1.31	

Preliminary Velocity Traverse Data

Date 04/11/2015

From	16:15	to	16:45	30 minute mean		
Volatile organic compounds			vppm, wet	5.14	mg/m³*	8.26

From	16:45	to	17:15	30 minute mean		
Volatile organic compounds			vppm, wet	6.89	mg/m³*	11.07

.

From	17:15	to	17:45	30 minute mean		
Volatile organic compounds			vppm, wet	2.14	mg/m³*	3.45

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity ***k*** = 2
Nitrogen	%	99.999	VCK01959	-	± 2
Volatile organic compounds	vppm	74.7	VC59841	100	± 2

Zero And Span Gas Details

Species	units	Initial Time	08:54	Final Time	17:55
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	74.70	0.12	75.08

Exhaust Gas Continuous Analysis Data

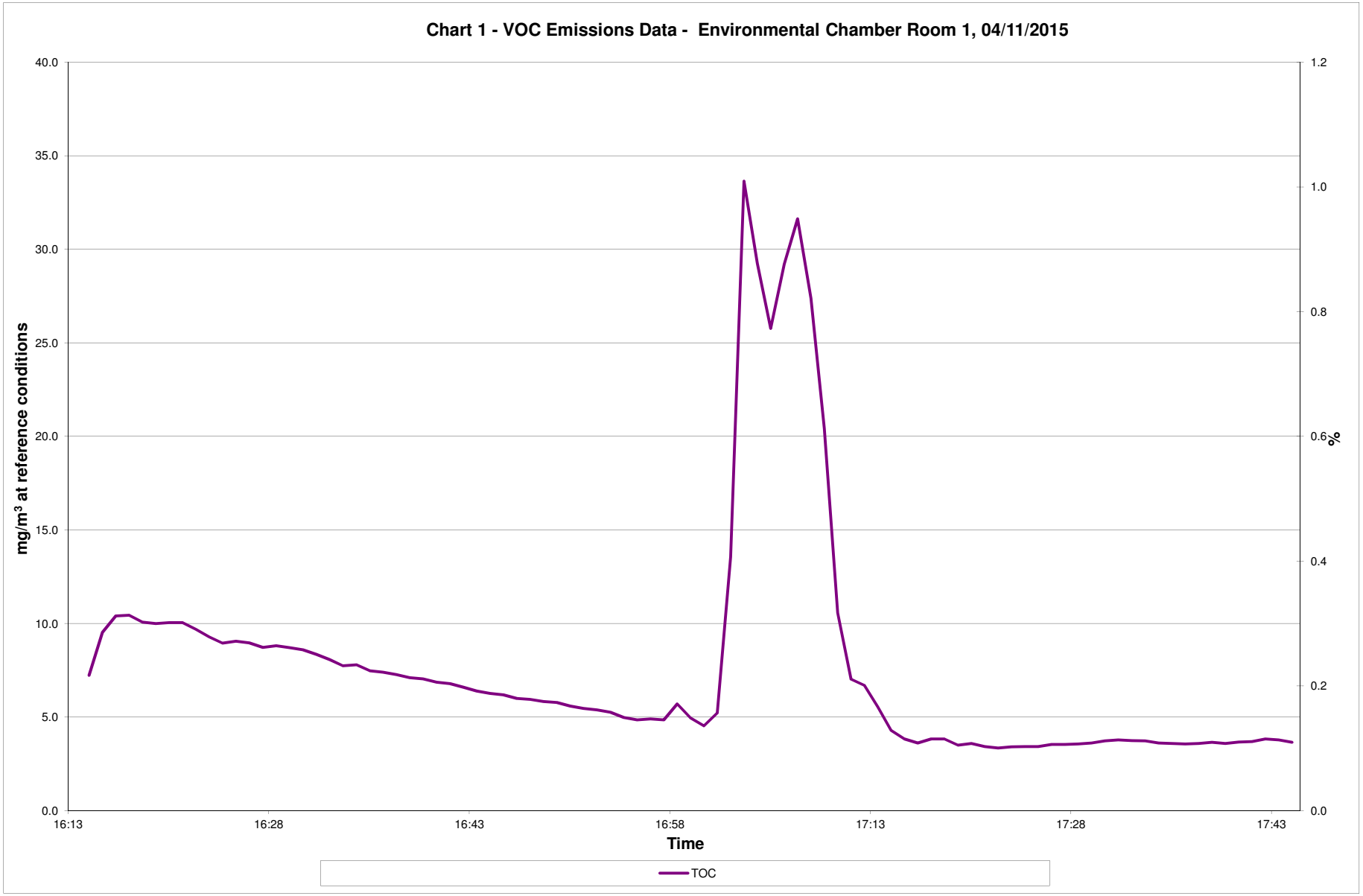


Chart 1 - VOC Emissions Data - Environmental Chamber Room 1, 04/11/2015
mg/m3 at reference conditions
%
Time
TOC
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
16:13
16:28
16:43
16:58
17:13
17:28
17:43

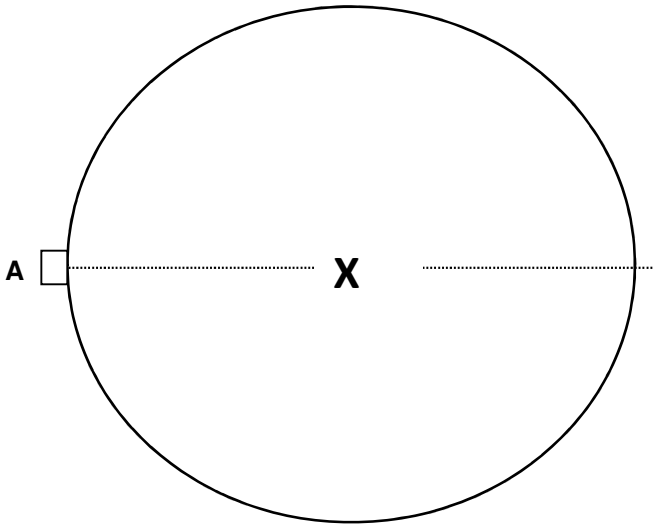
APPENDIX 3

Diagram Of The Sampling Location

Diagram of sampling points across the cross section of the duct (not to scale).

Traverse length = 0.20 m

Point	% of D	Location cm
1	50.0	10.0



General Calculations

Stack area:

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

D = Diameter (m)
π = 3.142

Pressure conversion:

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

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

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

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

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

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

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

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

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

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

Flow Calculations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Concentration Calculations

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

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

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

Mass Emission

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

c = Concentration
q = Volume flow rate

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

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

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

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

Convert wet gas to dry gas

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

Convert dry gas to wet gas

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

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

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

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Where:

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

Calculation of partial uncertainties

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

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

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

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

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

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

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

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

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

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

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

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

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

and

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

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

Combined uncertainty

$u(C_{,ppm}) =$

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

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

Uncertainty of NOx measurements

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

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

Combined uncertainty NOx measurements

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

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

Uncertainty of mass concentration at oxygen reference concentration

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

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

Where:

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

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

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

		Test 1	Test 2	Test 3
Limit value	mg/m^3	75	75	75
Limit value	ppm	46.7	46.7	46.7
Measured concentration	ppm	5.1	6.9	2.1
Measured concentration	mg/m^3	8.3	11.1	3.4
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A	N/A
Calibration gas	ppm	74.7	74.7	74.7
Calibration gas	mg/m^3	120.1	120.1	120.1
Analyser range	ppm	9.3	9.3	9.3
Analyser range	mg/m^3	15.0	15.0	15.0
Correction of Lack of Fit				
Lack of fit	% range	2.0	2.0	2.0
	$u(Corr_{+fit})$	0.11	0.11	0.11
Corrections of Zero and Span Drift	(*All drift is calculated for ∴ the residual is assumed to be < 5% u(max))			
Zero Drift	% range	0.00	0.00	0.00
	$u(Corr_{+0dr})$	0.00	0.00	0.00
Span Drift	% range	0.00	0.00	0.00
	$u(Corr_{+sdr})$	0.00	0.00	0.00
Correction of Repeatability of Measurement				
Repeatability SD at span level	% range	0.0	0.0	0.0
(Not reported)	$u(Corr_{+rep})$	0.00	0.00	0.00
Correction of adjustment				
losses in the line	% range	0.27	0.27	0.27
	$u(Corr_{+loss})$	0.01	0.01	0.00
Uncertainty of calibration gas	% range	2.0	2.0	2.0
	$u(Corr_{+cal})$	0.05	0.07	0.02
Correction of Influence of Interferents				
N_2O	% range			
	$u(Corr_{+N2O})$	0.00	0.00	0.00
CO_2	% range			
	$u(Corr_{+CO2})$	0.00	0.00	0.00
CH_4	% range			
	$u(Corr_{+CH4})$	0.00	0.00	0.00
Total of interferent influences	% range	2.50	2.50	2.50
$u(\Sigma Corrint) = \max\lvert S_{Int.p}; S_{Int.n} \rvert$	$u(\Sigma Corr_{int})$	0.16	0.16	0.16
Correction of Influence Quantities				
Sensitivity to sample volume flow	% range	1.60	1.60	1.60
	$u(Corr_{+flow})$	0.09	0.09	0.09
Sensitivity to atmospheric pressure	% range			
(Not reported)	$u(Corr_{+press})$	0.00	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40	-2.40
	$u(Corr_{+temp})$	-0.28	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50	0.50
(Not reported)	$u(Corr_{+volt})$	0.10	0.10	0.10
Maximum standard uncertainty	$u(Corr_{+max})$	0.11	0.11	0.11
5% of maximum standard uncertainty	$u(Corr_{+5\%})$	0.01	0.01	0.01

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

Influence Quantitiy Variations

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

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

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

Overall uncertainty	ppm	0.7	0.7	0.7
Overall uncertainty	mg/m^3	1.2	1.2	1.2
Overall uncertainty relative to measured value	%	14.3	10.8	34.1
Overall uncertainty relative to range	%	7.9	8.0	7.8
Overall uncertainty relative to ELV	%	1.0	1.0	1.0

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

REC
Resource & Environmental Consultants Ltd

Client **Linx Printing Technologies Limited**
Linx House
8 Stocks Bridge Way
St Ives
Cambridgeshire
PE27 5JL

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**St Ives**
Plant	**Wet Test Stack 1 (Room Extract)**
Sampling Date	**2nd & 3rd November 2015**
Report Date	**7th December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	*Print*	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	*Sign*		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

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UKAS TESTING
1783

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Contents

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
Wet Test Stack 1 (Room Extract)	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

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

Summary Of Results

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives	Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
Wet Test Stack 1 (Room Extract)	Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	02/11/15	16:50	17:50	30.8	75	1.3	0.2	131.7
TOC	03/11/15	08:30	09:00	17.5	75	1.2	0.2	74.9

* at reference conditions	Stack Gas Weight		0 °C	Without correction for moisture		
	29.00	Kg/kmol	101.3 kPa	Oxygen	No Correction	%

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^3	273 K, 101.3 kPa
**	Analysis not required	#	UKAS accredited only
ND	Non detectable	##	Not Accredited
s	Subcontracted laboratory analysis	N/A	Not applicable

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

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

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Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
Wet Test Stack 1 (Room Extract)		Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	Test 1	02/11/15	16:50	17:20	41.5	75	1.4	0.2	177.5
TOC	Test 2	02/11/15	17:20	17:50	20.1	75	1.2	0.2	85.9
TOC	Test 3	03/11/15	08:30	09:00	17.5	75	1.2	0.2	74.9

* at ref Conditions	Stack Gas Weight 29.00 Kg/kmol	0 °C 101.3 kPa	Without correction for moisture Oxygen No Correction %

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^3	273 K, 101.3 kPa
**	Analysis not required	#	UKAS accredited only
ND	Non detectable	##	Not Accredited
s	Subcontracted laboratory analysis	N/A	Not applicable

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

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

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Operating Information

The table below shows details of the operating information on each sampling date for: **Wet Test Stack 1 (Room Extract)**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
2nd & 3rd November 2015	LEV From Ink Printer Testing Room	Continuous	Natural Gas	Methyl - Ethyl Ketone, Acetone & Ethanol	Bag Filter	Normal Operation

There are no CEM's available 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.
The homogeneity test is not applicable to duct areas less than $1m^2$.

All monitoring was performed in accordance with the relevant procedures.

The sampling location is a vertical rectangular duct.

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.

Resource & Environmental Consultants Ltd

Part 2: Supporting Information

Report for the Periodic Monitoring of Emissions to Air.

Client	**Linx Printing Technologies Limited**
Site	**St Ives**
Plant	**Wet Test Stack 1 (Room Extract)**
Sampling Date	**2nd & 3rd November 2015**
Report Date	**7th December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	*Print*	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	*Sign*		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013
Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.
Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Report authorised by:	Derek Myers	MM02 115	-	30/09/2017	31/05/2018	30/11/2018	30/11/2018	30/11/2018
Team leader:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Team leader:	Aidan Wrynne	MM08 921	-	31/05/2017	31/05/2017	31/11/2018	30/11/2017	30/06/2018

Equipment References

Equipment	Reference Number
FID	**AQ271**
Heated Line	**HL40**
Heated Filter	**Sintered**
Stack Thermocouple	**PTTS97**
Timer / Stopwatch	**ST41**
Barometer	**WS03**
Pitot	**PT129**
Thermometer	**TK28**
Manometer	**PI03**

APPENDIX 2

Date	02/11/2015
Time	16:43
Pitot Cp	1.01

Barometric pressure	102.3	kPa
Duct static pressure	0.00	kPa
Stack Area	0.665	m^2

Stack Depth (rectangular)	0.70	m
Stack Depth (rectangular)	0.95	m

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s
1	A						B					
2	A	5.0	0.1	14	<15	1.3	B					
3	A	10.5	0.1	14	<15	1.3	B					
4	A	17.5	0.1	14	<15	1.3	B					
5	A	24.5	0.3	14	<15	2.2	B					
6	A	31.5	0.2	14	<15	1.8	B					
7	A	38.5	0.2	14	<15	1.8	B					
8	A	45.5	0.1	14	<15	1.3	B					
9	A	52.5	0.3	14	<15	2.2	B					
10	A	59.5	0.5	14	<15	2.9	B					
11	A	65.0	0.4	14	<15	2.6	B					
12	A						B					

Average Pitot DP	0.22	mmH_2O
Average Temperature	287.2	K
Average Velocity	1.9	m/s
Average volumetric flow rate	1.24	m^3/s at stack conditions
Average volumetric flow rate	1.19	m^3/s (wet STP)

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

a	Angel of gas flow less than 15° with regard to duct axis		YES
b	No local negative flow		YES
c	Minimum pitot greater than 5Pa		NO
d	Ratio of highest to lowest local gas velocity less than 3:1		YES
	Minimum local gas velocity	1.3	
	Maximum local gas velocity	2.9	
	Ratio of highest to lowest local gas velocity	2.24	

Preliminary Velocity Traverse Data

Date 02/11/2015

From 16:50 to 17:20 30 minute mean

Volatile organic compounds	vppm, wet	25.80	mg/m³*	41.46

From 17:20 to 17:50 30 minute mean

Volatile organic compounds	vppm, wet	12.48	mg/m³*	20.06

.

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity ***k*** = 2
Nitrogen	%	99.999	VCK01959	-	± 2
Volatile organic compounds	vppm	74.7	VC59841	10	± 2

Zero And Span Gas Details

Species	units	Initial Time	15:23	Final Time	18:08
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	74.70	-0.39	74.10

Exhaust Gases Continuous Analysis Data

Date 03/11/2015

From 08:30 to 09:00 30 minute mean

Volatile organic compounds	vppm, wet	10.88	mg/m³*	17.48

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity ***k*** = 2
Nitrogen	%	99.999	VCK01959	-	± 2
Volatile organic compounds	vppm	74.7	VC59841	10	± 2

Zero And Span Gas Details

Species	units	Initial Time	08:19	Final Time	10:10
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	74.70	-0.21	74.14

Exhaust Gases Continuous Analysis Data, Continued

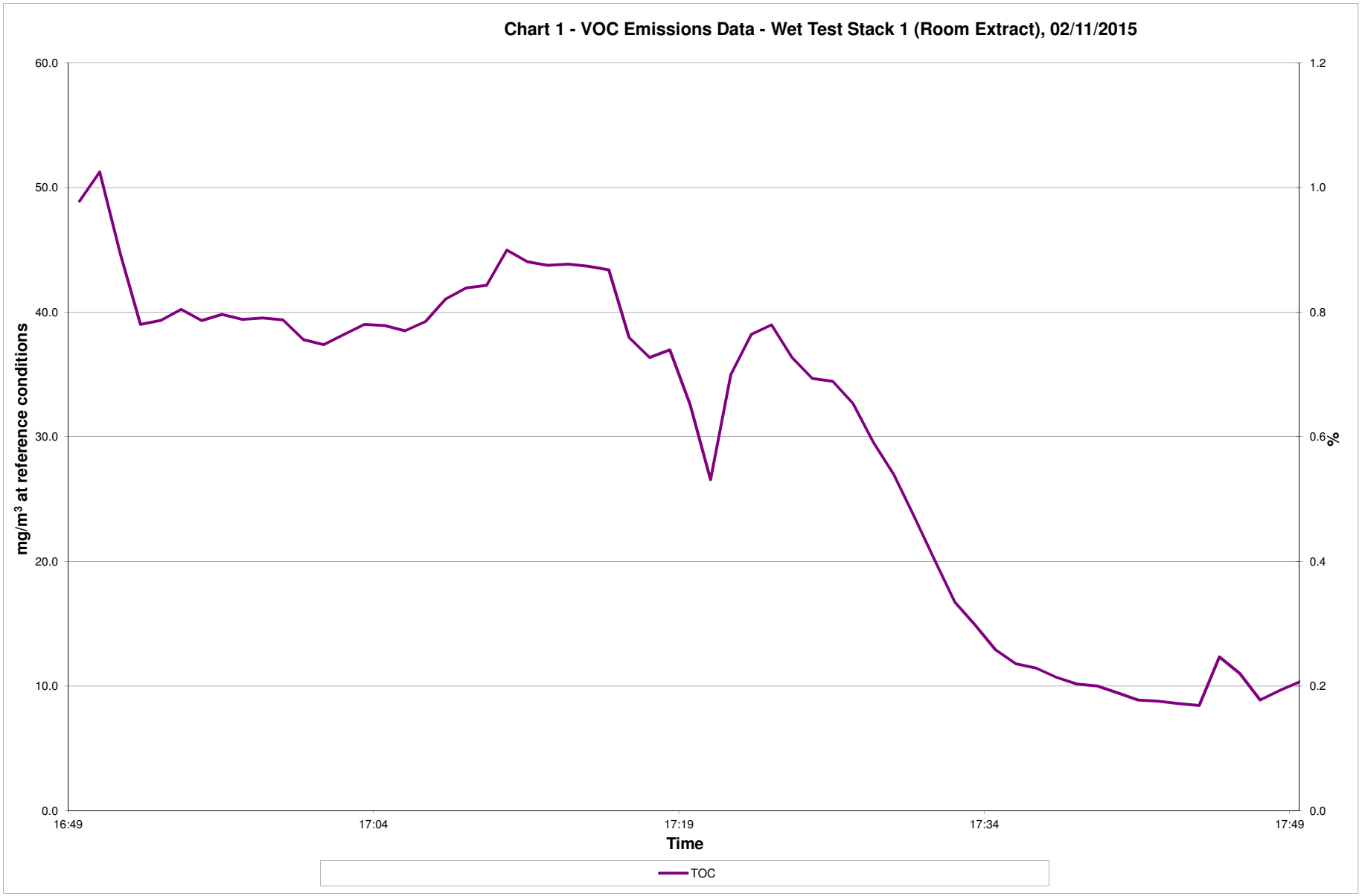


Chart 1 - VOC Emissions Data - Wet Test Stack 1 (Room Extract), 02/11/2015
mg/m3 at reference conditions
%
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
16:49
17:04
17:19
17:34
17:49
Time
TOC

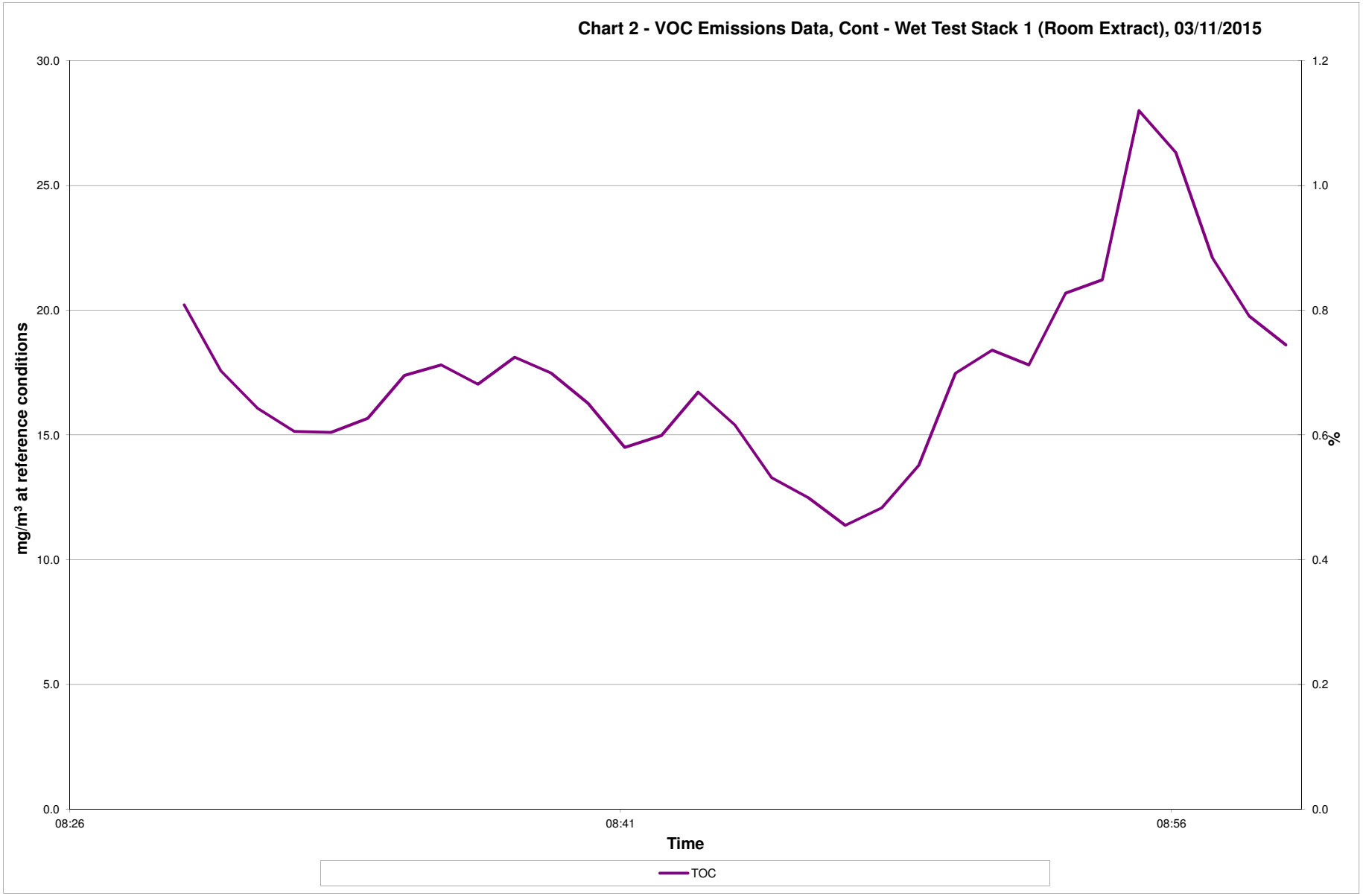


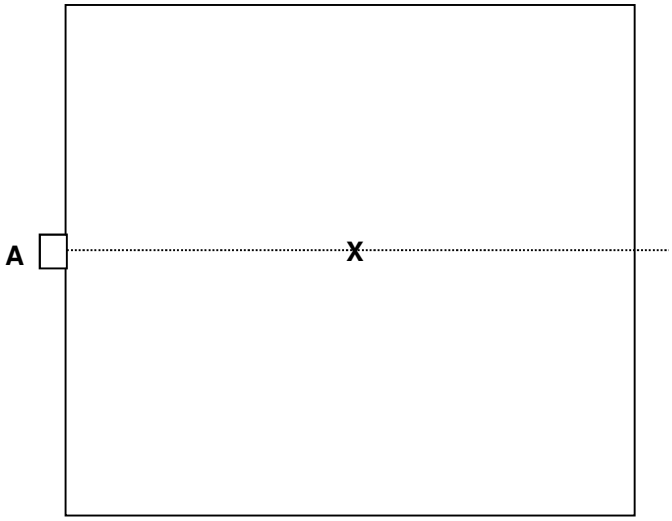
Chart 2 - VOC Emissions Data, Cont - Wet Test Stack 1 (Room Extract), 03/11/2015
mg/m3 at reference conditions
%
Time
08:26
08:41
08:56
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
TOC

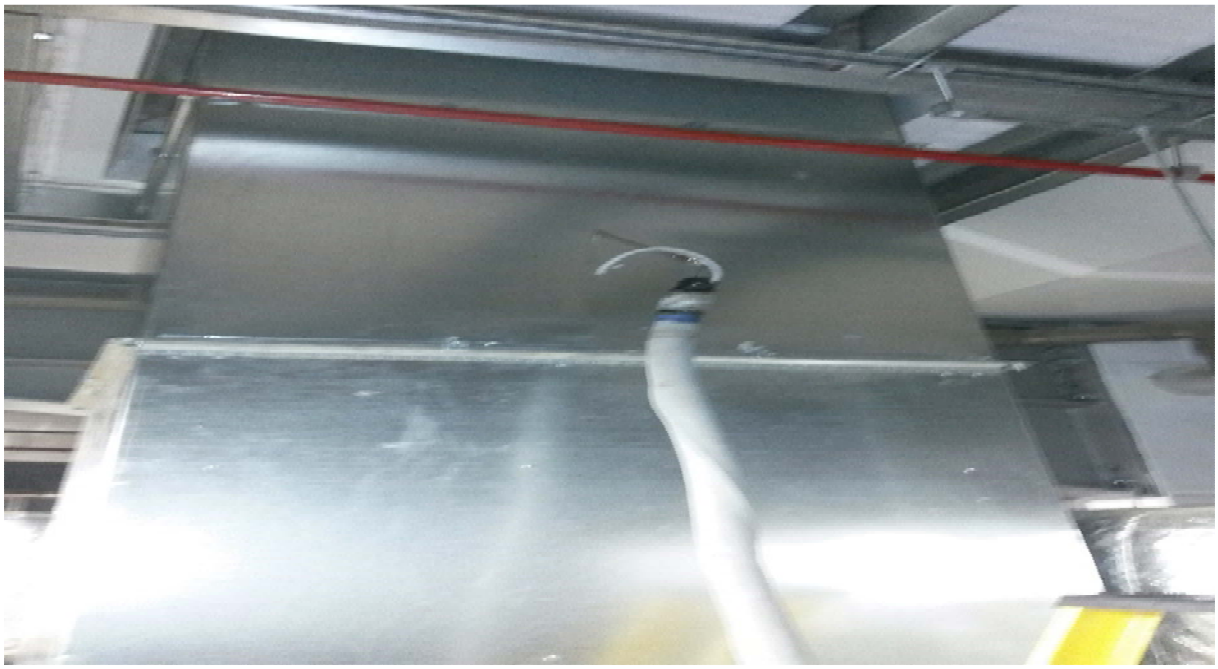
APPENDIX 3

Diagram Of The Sampling Location

Diagram of sampling points across the cross section of the duct (not to scale).

Traverse length = 0.70 m x 0.95m





General Calculations

Stack area:

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

D = Diameter (m)
π = 3.142

Pressure conversion:

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

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

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

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

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

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

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

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

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

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

Flow Calculations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Concentration Calculations

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

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

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

Mass Emission

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

c = Concentration
q = Volume flow rate

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

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

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

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

Convert wet gas to dry gas

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

Convert dry gas to wet gas

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

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

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

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Where:

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

Calculation of partial uncertainties

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

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

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

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

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

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

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

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

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

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

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

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

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

and

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

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

Combined uncertainty

$u(C_{,ppm}) =$

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

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

Uncertainty of NOx measurements

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

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

Combined uncertainty NOx measurements

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

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

Uncertainty of mass concentration at oxygen reference concentration

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

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

Where:

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

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

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

		Test 1	Test 2
Limit value	mg/m^3	75	75
Limit value	ppm	46.7	46.7
Measured concentration	ppm	25.8	12.5
Measured concentration	mg/m^3	41.5	20.1
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A
Calibration gas	ppm	74.7	74.7
Calibration gas	mg/m^3	120.1	120.1
Analyser range	ppm	9.3	9.3
Analyser range	mg/m^3	15.0	15.0

Correction of Lack of Fit

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

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

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

Correction of Repeatability of Measurement

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

Correction of adjustment

losses in the line	% range	0.09	0.09
	$u(Corr_{+loss})$	0.01	0.01
Uncertainty of calibration gas	% range	2.0	2.0
	$u(Corr_{+cal})$	0.26	0.12

Correction of Influence of Interferents

N_2O	% range		
	$u(Corr_{+N2O})$	0.00	0.00
CO_2	% range		
	$u(Corr_{+CO2})$	0.00	0.00
CH_4	% range		
	$u(Corr_{+CH4})$	0.00	0.00
Total of interferent influences	% range	2.50	2.50
$u(\Sigma Corrint) = \max\lvert S_{Int.p}; S_{Int.n} \rvert$	$u(\Sigma Corr_{int})$	0.16	0.16

Correction of Influence Quantities

Sensitivity to sample volume flow	% range	1.60	1.60
	$u(Corr_{+flow})$	0.09	0.09
Sensitivity to atmospheric pressure	% range		
(Not reported)	$u(Corr_{+press})$	0.00	0.00
Sensitivity to ambient temperature	% range	-2.40	-2.40
	$u(Corr_{+temp})$	-0.28	-0.28
Sensitivity to electrical voltage	% range	0.50	0.50
(Not reported)	$u(Corr_{+volt})$	0.10	0.10
Hide		0.00	0.00
Maximum standard uncertainty	$u(Corr_{+max})$	0.26	0.12
5% of maximum standard uncertainty	$u(Corr_{+5\%})$	0.01	0.01

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

Influence Quantitiy Variations

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

Measurement uncertainty		Test 1	Test 2
Combined uncertainty	ppm	0.45	0.39
Combined uncertainty	mg/m^3	0.72	0.62
Combined uncertainty at oxygen reference	mg/m^3	0.72	0.62

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

Overall uncertainty	ppm	0.9	0.8
Overall uncertainty	mg/m^3	1.4	1.2
Overall uncertainty relative to measured value	%	3.5	6.2
Overall uncertainty relative to range	%	9.6	8.3
Overall uncertainty relative to ELV	%	1.2	1.0

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

Uncertainty Estimate For The Measurement Of Total Organic Carbon

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

		Test 1
Limit value	mg/m^3	75
Limit value	ppm	46.7
Measured concentration	ppm	10.9
Measured concentration	mg/m^3	17.5
Concentration at O_2 ref. concentration	mg/m^3	N/A

Calibration gas	ppm	74.7
Calibration gas	mg/m^3	120.1
Analyser range	ppm	9.3
Analyser range	mg/m^3	15.0

Correction of Lack of Fit

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

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

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

Correction of Repeatability of Measurement

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

Correction of adjustment

losses in the line	% range	0.15
	$u(Corr_{+loss})$	0.01
Uncertainty of calibration gas	% range	2.0
	$u(Corr_{+cal})$	0.11

Correction of Influence of Interferents

N_2O	% range	
	$u(Corr_{+N2O})$	0.00
CO_2	% range	
	$u(Corr_{+CO2})$	0.00
CH_4	% range	
	$u(Corr_{+CH4})$	0.00
Total of interferent influences	% range	2.50
$u(\Sigma Corrint) = \max\lvert S_{Int.p}; S_{Int.n} \rvert$	$u(\Sigma Corr_{int})$	0.16

Correction of Influence Quantities

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

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

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

Influence Quantitiy Variations

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

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

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

Overall uncertainty	ppm	0.8
Overall uncertainty	mg/m^3	1.2
Overall uncertainty relative to measured value	%	7.0
Overall uncertainty relative to range	%	8.2
Overall uncertainty relative to ELV	%	1.0

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

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Resource & Environmental Consultants Ltd

Client **Linx Printing Technologies Limited**
Linx House
8 Stocks Bridge Way
St Ives
Cambridgeshire
PE27 5JL

Part 1: Executive Summary

Report for the Periodic Monitoring of Emissions to Air.

Site	**St Ives**
Plant	**Wet Test Stack 2 (Individual Test Rig Extract)**
Sampling Date	**2nd & 3rd November 2015**
Report Date	**7th December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by: *Print* **Harpreet Badwal**

MCERTS No. **MM03 149** **Level 2 TE: 1,2,3,4**

Report Approved by: *Sign*

Print **Derek Myers**

MCERTS No. **MM02 115** **Level 2 TE: 1,2,3,4**

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Contents

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
Wet Test Stack 2 (Individual Test Rig Extract)	Total organic carbon

Special Monitoring Requirements

There were no special requirements for this monitoring campaign.

Summary of Methods

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

Summary Of Results

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives	Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
Wet Test Stack 2 (Individual Test Rig Extract)	Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	02/11/15	16:00	16:30	446.4	75	9.0	0.2	1360.6
TOC	03/11/15	09:05	10:05	521.5	75	10.5	0.2	1589.5

* at reference conditions	Stack Gas Weight	0 °C	Without correction for moisture
	29.00 Kg/kmol	101.3 kPa	Oxygen No Correction %

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^3 273 K, 101.3 kPa
** Analysis not required — # - UKAS accredited only
ND Non detectable — ## - Not Accredited
s - Subcontracted laboratory analysis — N/A Not applicable

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

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

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Summary Of Results, Exhaust Gases

The table presents the atmospheric emissions from the tests undertaken on behalf of **Linx Printing Technologies Limited**
The results were measured from the sample positions downstream of the arrestment plant.

Emission at St Ives		Sampling Time			Emission Result	Authorised Limit	Uncertainty +/-	Detection Limit	Mass Emission
Wet Test Stack 2 (Individual Test Rig Extract)		Date	Start	End	mg/m^3*	mg/m^3*	mg/m^3*	mg/m^3*	g/h
TOC	Test 1	02/11/15	16:00	16:30	446.4	75	9.0	0.2	1360.6
TOC	Test 2	03/11/15	09:05	09:35	504.2	75	10.2	0.2	1536.7
TOC	Test 3	03/11/15	09:35	10:05	538.8	75	10.9	0.2	1642.2

* at ref Conditions	Stack Gas Weight 29.00 Kg/kmol	0 °C 101.3 kPa	Without correction for moisture Oxygen No Correction %

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^3 273 K, 101.3 kPa
** Analysis not required — # - UKAS accredited only
ND Non detectable — ## - Not Accredited
s - Subcontracted laboratory analysis — N/A Not applicable

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

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

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Operating Information

The table below shows details of the operating information on each sampling date for: **Wet Test Stack 2 (Individual Test Rig Extract)**

Date	Process type	Process duration	Fuel	Feedstock	Abatement	Load
2nd & 3rd November 2015	Ink Printer Testing Individual Rig Extraction	Continuous	N/A	Methyl - Ethyl Ketone & Acetone	None	Normal Operation

There are no CEM's available 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.
The homogeneity test is not applicable to duct areas less than $1m^2$.

All monitoring was performed in accordance with the relevant procedures.

The sampling location is a vertical duct.

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	**Linx Printing Technologies Limited**
Site	**St Ives**
Plant	**Wet Test Stack 2 (Individual Test Rig Extract)**
Sampling Date	**2nd & 3rd November 2015**
Report Date	**7th December 2015**
Job Number	**EM-2112**
Permit Number	**B18/14**

Report Prepared by:	*Print*	**Harpreet Badwal**	
	MCERTS No.	**MM03 149**	**Level 2 TE: 1,2,3,4**
Report Approved by:	*Sign*		
	Print	**Derek Myers**	
	MCERTS No.	**MM02 115**	**Level 2 TE: 1,2,3,4**

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APPENDIX 1

Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

Documented in-house procedure TPM01/A to the main procedural requirements of BS EN ISO 16911-1:2013
Velocity and temperature measurements are performed using a calibrated Pitot tube, a calibrated pressure differential reading device and a calibrated thermocouple. Velocity and possible flow deviation measurements are carried out at selected, representative points in the gas stream.

Total organic carbon

Documented in-house procedure TPM/13 to the main procedural requirements of BS EN 12619:2013.
Continuous analysis using probe, sample line and multi range Flame Ionisation Detector (FID) analyser. The analyser is calibrated before and during the tests using certified gas mixtures of nitrogen, oxygen and propane. Sampling points are selected in accordance with the findings of any BS EN 15259 assessment.

Sampling Project Personnel Competency And Expiry Dates

		MCERTS No	Level 1	Level 2	TE1	TE2	TE3	TE4
Report prepared by:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Report authorised by:	Derek Myers	MM02 115	-	30/09/2017	31/05/2018	30/11/2018	30/11/2018	30/11/2018
Team leader:	Harpreet Badwal	MM03 149	-	30/09/2018	30/09/2018	30/04/2019	31/10/2019	31/10/2019
Team leader:	Aidan Wrynne	MM08 921	-	31/05/2017	31/05/2017	31/11/2018	30/11/2017	30/06/2018

Equipment References

Equipment	Reference Number
FID	**AQ271**
Heated Line	**HL40**
Heated Filter	**Sintered**
Stack Thermocouple	**PTTS97**
Timer / Stopwatch	**ST41**
Barometer	**WS03**
Pitot	**PT129**
Thermometer	**TK19**
Manometer	**PI03**

APPENDIX 2

Date	02/11/2015
Time	16:00
Pitot Cp	1.01

Barometric pressure	102.3	kPa
Duct static pressure	-1.02	kPa
Stack Area	0.071	m^2

Stack Diameter (circular)	0.30	m

Traverse Point	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s	Traverse Line	Depth cm	ΔP mmH_2O	T °C	Angle °	velocity m/s
1	A						B					
2	A						B					
3	A	5.0	8.8	17	<15	12.0	B	5.0	7.4	17	<15	11.1
4	A	5.3	12.2	17	<15	14.2	B	5.3	8.3	17	<15	11.7
5	A	7.5	12.4	17	<15	14.3	B	7.5	8.1	17	<15	11.5
6	A	10.7	11.0	17	<15	13.5	B	10.7	8.9	17	<15	12.1
7	A	19.3	10.1	17	<15	12.9	B	19.3	10.5	17	<15	13.1
8	A	22.5	8.8	17	<15	12.0	B	22.5	12.1	17	<15	14.1
9	A	24.7	8.1	17	<15	11.5	B	24.7	13.5	17	<15	14.9
10	A	25.0	7.3	17	<15	11.0	B	25.0	11.6	17	<15	13.8
11	A						B					
12	A						B					

Average Pitot DP	9.85	mmH_2O
Average Temperature	290.2	K
Average Velocity	12.7	m/s
Average volumetric flow rate	0.90	m^3/s at stack conditions
Average volumetric flow rate	0.85	m^3/s (wet STP)

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

a	Angel of gas flow less than 15° with regard to duct axis		YES
b	No local negative flow		YES
c	Minimum pitot greater than 5Pa		YES
d	Ratio of highest to lowest local gas velocity less than 3:1		YES
	Minimum local gas velocity	11.0	
	Maximum local gas velocity	14.9	
	Ratio of highest to lowest local gas velocity	1.35	

Preliminary Velocity Traverse Data

Date 02/11/2015

From 16:00 to 16:30 30 minute mean

Volatile organic compounds	vppm, wet	277.78	mg/m³*	446.44

Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity ***k*** = 2
Nitrogen	%	99.999	VCK01959	-	± 2
Volatile organic compounds	vppm	74.7	VC59841	10	± 2

Zero And Span Gas Details

Species	units	Initial Time	15:23	Final Time	18:08
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	74.70	-0.39	74.10

Exhaust Gases Continuous Analysis Data

Date 03/11/2015

From 09:05 to 09:35 30 minute mean

Volatile organic compounds	vppm, wet	313.73	mg/m³*	504.21

From 09:35 to 10:05 30 minute mean

Volatile organic compounds	vppm, wet	335.28	mg/m³*	538.84

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Sampling Detection Limits

Volatile organic compounds	vppm	0.10	mg/m³*	0.16

Reference Gas Details

Species	Units	Value	Cylinder Reference	Analyser Range	Uncertainity ***k*** = 2
Nitrogen	%	99.999	VCK01959	-	± 2
Volatile organic compounds	vppm	74.7	VC59841	10	± 2

Zero And Span Gas Details

Species	units	Initial Time	16:05	Final Time	10:10
		Initial Zero	Initial Span	Final Zero	Final Span
Volatile organic compounds	vppm	0.00	74.70	-0.21	74.14

Exhaust Gases Continuous Analysis Data, Continued

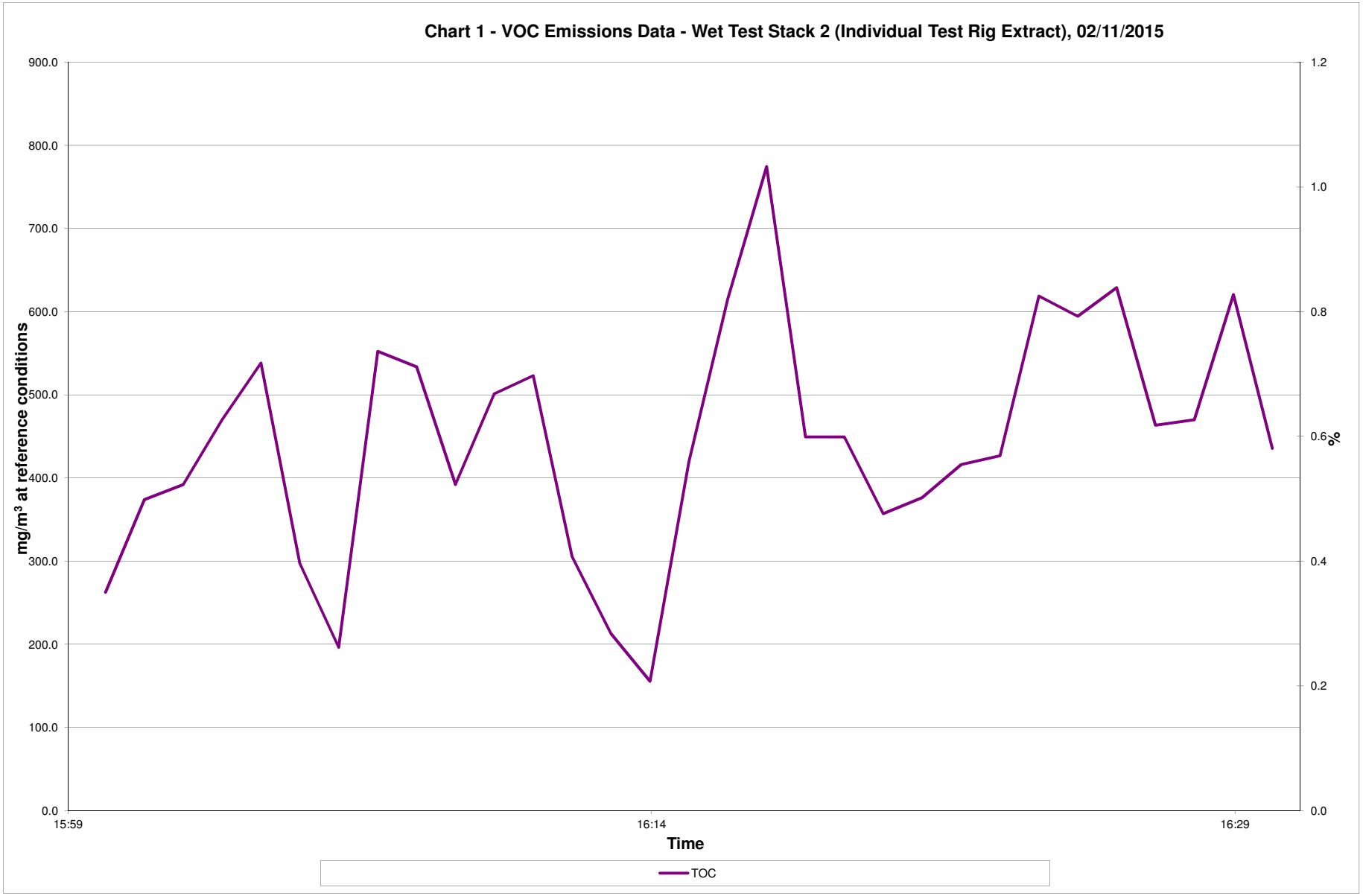


Chart 1 - VOC Emissions Data - Wet Test Stack 2 (Individual Test Rig Extract), 02/11/2015
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
mg/m3 at reference conditions
1.2
1.0
0.8
0.6
0.4
0.2
0.0
%
15:59
16:14
16:29
Time
TOC

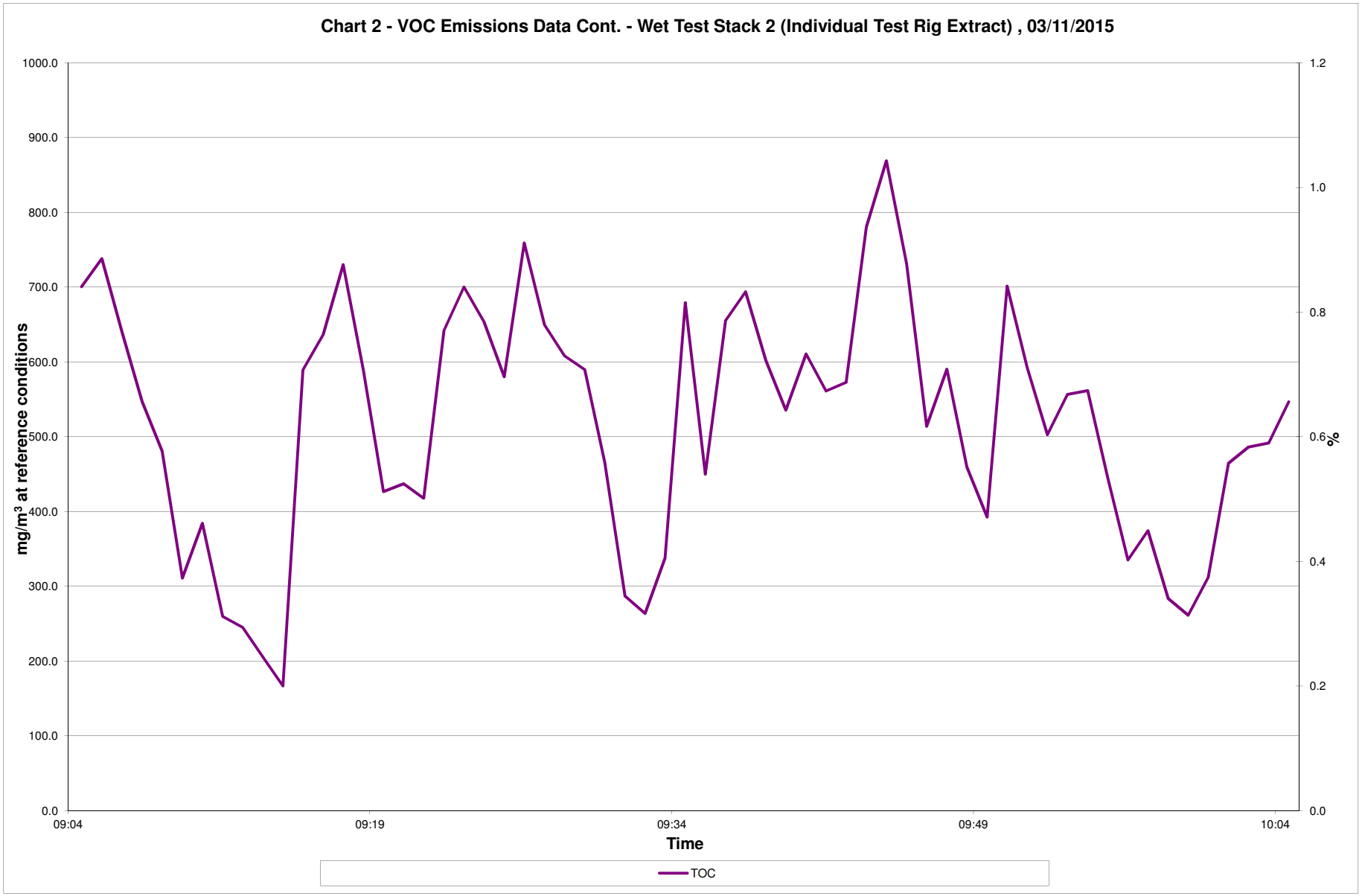


Chart 2 - VOC Emissions Data Cont. - Wet Test Stack 2 (Individual Test Rig Extract) , 03/11/2015
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
mg/m3 at reference conditions
1.2
1.0
0.8
0.6
0.4
0.2
0.0
%
09:04
09:19
09:34
09:49
10:04
Time
TOC

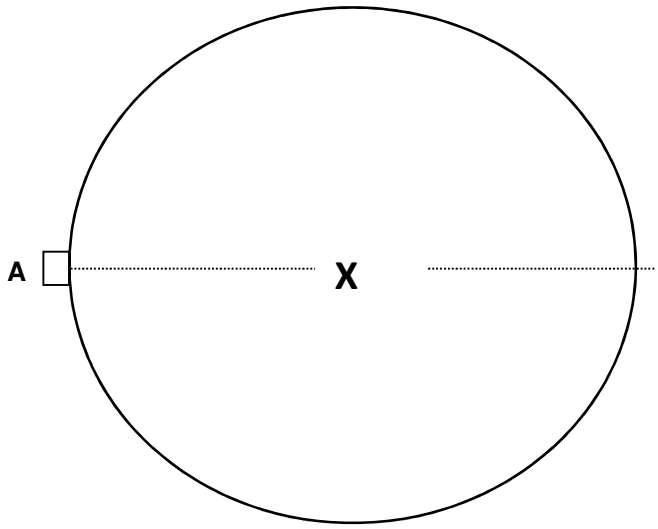
APPENDIX 3

Diagram Of The Sampling Location

Diagram of sampling points across the cross section of the duct (not to scale).

Traverse length = 0.30 m

Point	% of D	Location cm
1	50.0	15.0



General Calculations

Stack area:

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

D = Diameter (m)
π = 3.142

Pressure conversion:

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

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

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

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

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

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

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

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

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

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

Flow Calculations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Concentration Calculations

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

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

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

Mass Emission

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

c = Concentration
q = Volume flow rate

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

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

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

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

Convert wet gas to dry gas

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

Convert dry gas to wet gas

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

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

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

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

molar volume at 273K = 22.4 litres

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Where:

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

Calculation of partial uncertainties

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

Where:

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

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

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

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

Where:

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

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

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

Where:

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

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

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

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

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

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

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

Where:

c_j is the sensitivity coefficient of the influence quantity

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

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

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

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

and

Where:

c_j is the sensitivity coefficient of the interferent j

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

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

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

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

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

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

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

Combined uncertainty

$u(C_{,ppm}) =$

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

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

Uncertainty of NOx measurements

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

Where:

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

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

η is the NOx converter efficiency

Combined uncertainty NOx measurements

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

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

Uncertainty of mass concentration at oxygen reference concentration

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

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

Where:

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

APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

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

		Test 1
Limit value	mg/m^3	75
Limit value	ppm	46.7
Measured concentration	ppm	277.8
Measured concentration	mg/m^3	446.4
Concentration at O_2 ref. concentration	mg/m^3	N/A

Calibration gas	ppm	74.7
Calibration gas	mg/m^3	120.1
Analyser range	ppm	9.3
Analyser range	mg/m^3	15.0

Correction of Lack of Fit

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

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

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

Correction of Repeatability of Measurement

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

Correction of adjustment

losses in the line	% range	0.09
	$u(Corr_{+loss})$	0.15
Uncertainty of calibration gas	% range	2.0
	$u(Corr_{+cal})$	2.78

Correction of Influence of Interferents

N_2O	% range	
	$u(Corr_{+N2O})$	0.00
CO_2	% range	
	$u(Corr_{+CO2})$	0.00
CH_4	% range	
	$u(Corr_{+CH4})$	0.00
Total of interferent influences	% range	2.50
$u(\Sigma Corrint) = \max\lvert S_{Int.p}; S_{Int.n} \rvert$	$u(\Sigma Corr_{int})$	0.16

Correction of Influence Quantities

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

Maximum standard uncertainty	$u(Corr_{+max})$	2.78
5% of maximum standard uncertainty	$u(Corr_{+5\%})$	0.14

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

Influence Quantitiy Variations

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

Measurement uncertainty		Test 1
Combined uncertainty	ppm	2.80
Combined uncertainty	mg/m^3	4.50
Combined uncertainty at oxygen reference	mg/m^3	4.50

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

Overall uncertainty	ppm	5.6
Overall uncertainty	mg/m^3	9.0
Overall uncertainty relative to measured value	%	2.0
Overall uncertainty relative to range	%	60.0
Overall uncertainty relative to ELV	%	7.5

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

Uncertainty Estimate For The Measurement Of Total Organic Carbon

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

		Test 1	Test 2
Limit value	mg/m^3	75	75
Limit value	ppm	46.7	46.7
Measured concentration	ppm	313.7	335.3
Measured concentration	mg/m^3	504.2	538.8
Concentration at O_2 ref. concentration	mg/m^3	N/A	N/A
Calibration gas	ppm	74.7	74.7
Calibration gas	mg/m^3	120.1	120.1
Analyser range	ppm	9.3	9.3
Analyser range	mg/m^3	15.0	15.0

Correction of Lack of Fit

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

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

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

Correction of Repeatability of Measurement

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

Correction of adjustment

losses in the line	% range	0.15	0.15
	$u(Corr_{+loss})$	0.27	0.29
Uncertainty of calibration gas	% range	2.0	2.0
	$u(Corr_{+cal})$	3.14	3.35

Correction of Influence of Interferents

N_2O	% range		
	$u(Corr_{+N2O})$	0.00	0.00
CO_2	% range		
	$u(Corr_{+CO2})$	0.00	0.00
CH_4	% range		
	$u(Corr_{+CH4})$	0.00	0.00
Total of interferent influences	% range	2.50	2.50
$u(\Sigma Corrint) = \max\lvert S_{Int.p}; S_{Int.n} \rvert$	$u(\Sigma Corr_{int})$	0.16	0.16

Correction of Influence Quantities

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

Maximum standard uncertainty	$u(Corr_{+max})$	3.14	3.35
5% of maximum standard uncertainty	$u(Corr_{+5\%})$	0.16	0.17

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

Influence Quantitiy Variations

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

Measurement uncertainty		Test 1	Test 2
Combined uncertainty	ppm	3.16	3.38
Combined uncertainty	mg/m^3	5.08	5.43
Combined uncertainty at oxygen reference	mg/m^3	5.08	5.43

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

Overall uncertainty	ppm	6.3	6.8
Overall uncertainty	mg/m^3	10.2	10.9
Overall uncertainty relative to measured value	%	2.0	2.0
Overall uncertainty relative to range	%	67.7	72.4
Overall uncertainty relative to ELV	%	8.5	9.0

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