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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**

> MM03 149 MCERTS No. 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







REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303 Company Registration No 03133832



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Monitoring Objectives

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

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

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

| Sampling Location | Emission |
|------------------------------|----------------------|
| 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 |
| тос | TPM/13 | BS EN 12619 : 2013 |
| | | |

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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 | Sampling | | | Emission | Authorised | Uncertainty | Detection | Mass |
|------------------------------|----------|-------|-------|----------|------------|-------------|-----------|----------|
| St Ives | Time | | | Result | Limit | +/- | Limit | Emission |
| Environmental Chamber Room 2 | Date | Start | End | mg/m³* | mg/m³* | mg/m³* | mg/m³∗ | g/h |
| тос | 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)

** 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.



Nm³ 273 K, 101.3 kPa



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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.

| | sion at lves | Sampling Time | | | Emission Result | Authorised Limit | Uncertainty +/- | Detection Limit | Mass Emission |
|-----------------|-----------------|------------------|-------|-------|--------------------|---------------------|--------------------|--------------------|------------------|
| Environmental C | Chamber Room 2 | Date | Start | End | mg/m³∗ | mg/m ³ * | mg/m³* | mg/m³* | g/h |
| TOC | Test 1 | 04/11/15 | 09:45 | 10:15 | 30.5 | 75 | 1.3 | 0.2 | 13.1 |
| тос | Test 2 | 04/11/15 | 10:15 | 10:45 | 17.7 | 75 | 1.2 | 0.2 | 7.6 |
| тос | Test 3 | 04/11/15 | 10:45 | 11:15 | 1.2 | 75 | 1.2 | 0.2 | 0.5 |

| I | * at ref | Stack Gas Weight | 0 °C | Without correction for moisture |
|---|------------|------------------|-----------|---------------------------------|
| | Conditions | 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)

** Analysis not required #- UKAS accredited only
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s - Subcontracted laboratory analysis N/A Not applicable

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Nm³ 273 K, 101.3 kPa



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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 1 m².

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 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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Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6357, v1

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APPENDIX 1

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Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

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

Total organic carbon

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

Sampling Project Personnel Competency And Expiry Dates

| Report prepared by: | Harpreet Badwal | MCERTS No MM03 149 | Level 1 | Level 2 30/09/2018 | TE1 30/09/2018 | TE2 30/04/2019 | TE3 31/10/2019 | TE4 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 |

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APPENDIX 2

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| 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 | m² |

| Stack Diameter (circular) | 0.20 | n |
|---------------------------|------|---|
| | | |

| Traverse | Traverse | Depth | ΔΡ | T | Angle | velocity | Traverse | Depth | ΔΡ | Т | Angle | velocity |
|----------|----------|-------|--------------------|----|-------|----------|----------|-------|--------------------|----|-------|----------|
| Point | Line | cm | mmH ₂ O | °C | 0 | m/s | Line | cm | mmH ₂ O | °C | 0 | m/s |
| 1 | Α | | | | | | В | | | | | |
| 2 | Α | | | | | | В | | | | | |
| 3 | Α | | | | | | В | | | | | |
| 4 | Α | | | | | | В | | | | | |
| 5 | Α | 5.0 | 1.1 | 53 | <15 | 4.6 | В | | | | | |
| 6 | Α | 7.1 | 1.1 | 53 | <15 | 4.6 | В | | | | | |
| 7 | Α | 12.9 | 1.2 | 53 | <15 | 4.8 | В | | | | | |
| 8 | Α | 15.0 | 1.0 | 53 | <15 | 4.3 | В | | | | | |
| 9 | Α | | | | | | В | | | | | |
| 10 | Α | | | | | | В | | | | | |
| 11 | Α | | | | | | В | | | | | |
| 12 | Α | | | | | | В | | | | | |

| Average Pitot DP | 1.12 | mmH ₂ O |
|------------------------------|-------|---------------------------------------|
| Average Temperature | 326.2 | К |
| 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 | | | | |
| d | Ratio of highest to lowest local gas velocity less than 3:1 | | | |
| | Minimum local gas velocity | 4.3 | | |
| Maximum local gas velocity 4.8 | | | | |
| Ratio of highest to lowest local gas velocity 1.10 | | | | |

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| D . | 04/44/0045 |
|------------|------------|
| Date | 04/11/2015 |

| From | 09:45 | to | 10:15 | 30 minute mean | | |
|-----------------|-------------|----|-----------|----------------|--------|-------|
| Volatile organi | c compounds | | vppm, wet | 19.00 | mg/m³* | 30.54 |
| | | | | | | |
| From | 10:15 | to | 10:45 | 30 minute mean | | |
| Volatile organi | c compounds | | vppm, wet | 11.03 | mg/m³* | 17.72 |
| | | | | | | |
| From | 10:45 | to | 11:15 | 30 minute mean | | |
| Volatile organi | c compounds | | vppm, wet | 0.77 | mg/m³* | 1.23 |

Sampling Detection Limits

| Volatile organic compounds | vppm | 0.10 | mg/m³* | 0.16 |
|----------------------------|------|------|--------|------|

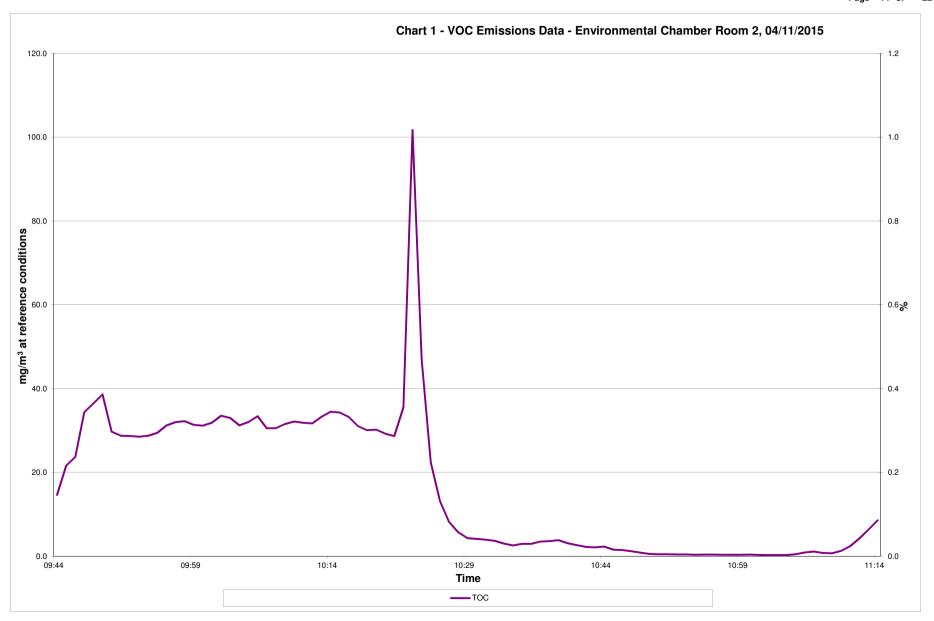
Reference Gas Details

| 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



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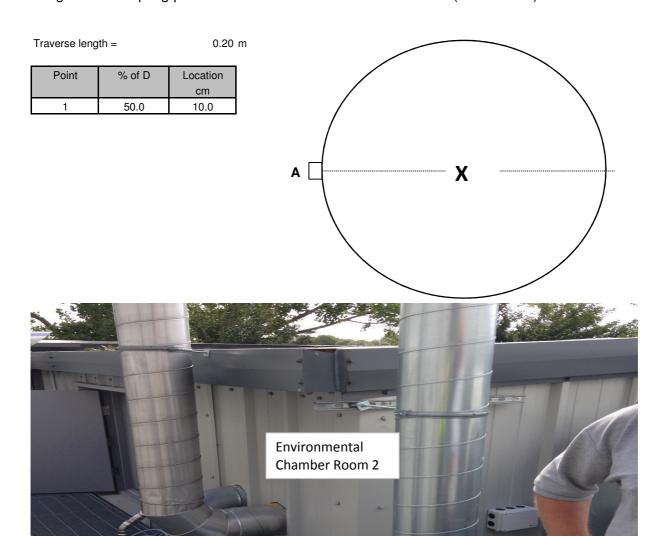
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APPENDIX 3

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Diagram Of The Sampling Location

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



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General Calculations

Stack area:

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

D = Diameter (m) $\pi = 3.142$

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 % (m³ of water vapour in m³ of wet gas)

Vm(std) = Dry gas volume measured, corrected to standard conditions (m³)

mWC = Mass of water collected in the impingers (g)

Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)

Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)

From reference calculations (taken from BS EN 14790):

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

Vm(std) = Dry gas meter volume at standard conditions (m³)

yd = Gas meter calibration coefficient

(V2-V1) = Dry gas meter volume at actual conditions (m³)

Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)

pm = Absolute pressure at the gas meter (kPa) pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):

From reference calculations (taken from EA TGN M2):

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

Estimating Measurment Uncertainty

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

Flow Calculations

Velocity:

From reference calculations (taken from ISO 10780):

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

 \overline{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 coefficientPe = Absolute gas pressure (kPa)

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

Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m³/s)

v = v Average velocity (m/s)

A =Stack cross-sectional area (m²)

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 (m³/s)

qva = Volume flow rate at actual conditions (m³/s) Ha = Moisture at actual conditions (%volume)

Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure

From reference calculations (taken from BS ISO 9096):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/s)

O2,m = Actual oxygen concentration (%)

O2,ref = Reference oxygen concentration (%)

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Concentration Calculations

Concentration:

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

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

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

Mass Emission

Mass emission= $c \times q_m$

c = Concentration q = Volume flow rate

Concentration corrected for oxygen:

From reference calculations (taken from BS ISO 9096):

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

cm = Concentration at reference 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 gascdry = Concentration dry gasHa = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m³

From reference calculations (taken from EA TGN M2):

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Corr_{rep} Corr_{adj} Corr_{inf} correction of repeatability of measurement $C_{,ppm}$ concentration in ppm concentration given by analyser C_{NO.reading} correction of adjustment Corr fit correction of lack of fit correction of influence quantities

Corr _{0,dr} correction of zero drift Corr s,dr correction of span drift

Calculation of partial uncertainties

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

Where: $X_{\text{fit,max}}$

is the maximum allowable deviation from linearity

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

$$u(\mathsf{Corr}_{0,\mathsf{dr}}) \qquad \qquad = \qquad \frac{X_{0,\mathit{dr}}}{\sqrt{3}} \qquad \qquad u(\mathsf{Corr}_{\mathsf{s},\mathsf{dr}}) \qquad \qquad = \qquad \frac{X_{\mathit{s},\mathit{dr}}}{\sqrt{3}}$$

max (S_{0,rep}; S_{srep}) u(Corr_{rep}) Where:

is the standard uncertainty at zero level is the standard uncertainty at span level

$$u(\text{Corr}_{\text{ad}}) \hspace{0.5cm} = \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) + u(\text{Corr}_{\text{cal}}) \hspace{0.5cm} \text{Where:} \\ \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} \text{is the uncertainty due to losses in sample line} \\ \hspace{0.5cm} u(\text{Corr}_{\text{cal}}) \hspace{0.5cm} u(\text{Corr}_{\text{cal}}) \hspace{0.5cm} \text{is the uncertainty due to losses in sample line} \\ \hspace{0.5cm} cj_{\text{loss}} \hspace{0.5cm} cj_{\text{loss}} \hspace{0.5cm} \text{is the concentration of sample loss at span level} \\ \hspace{0.5cm} u(\text{Corr}_{\text{cal}}) \hspace{0.5cm} u(\text{Corr}_{\text{cal}}) \hspace{0.5cm} \text{is the concentration of sample loss at span level} \\ \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} u(\text{Corr}_{\text{cal}}) \hspace{0.5cm} \text{is the concentration of sample loss at span level} \\ \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} \text{is the concentration of sample loss at span level} \\ \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} \text{is the concentration of sample loss at span level} \\ \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} \text{is the concentration of sample loss at span level} \\ \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} \text{is the concentration of sample loss at span level} \\ \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5cm} \text{is the concentration of sample loss at span level} \\ \hspace{0.5cm} u(\text{Corr}_{\text{loss}}) \hspace{0.5$$

$$u(Corr_{cal}) = \frac{U_{cal}}{2}$$
 is the expanded uncertainty of the calibration gas
$$\frac{U_{cal}}{2}$$

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

is the sensitivity coefficient of the influence quantity is the minimum value of the influence quantity during monitoring is the maximum value of the influence quantity during monitoring is the value of the influence quantity during adjustment

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

is the sensitivity coefficient of the interferent i

 c_{j} Int_{j,test} $= \max \left[S_{Int,p}; S_{Int,n} \right]$ $u(\Sigma Corr_{int})$ is the concentration of the interferent j used to determine c is the minimum value of the interferent j quantity during monitoring is the maximum value of the interferent i quantity during monitoring

 $\mathsf{Int}_{\mathsf{j},\mathsf{adj}}$ is the concentration of the interferent j in the cal gas used to adjust the analyse

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

Combined uncertainty

 $u(C_{,ppm})$

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

Overall expanded uncertainty (k = 2)

$$U(C_m) = u(C_m) \times k$$

Uncertainty of NOx measurements

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

is the NOx converter efficiency

Combined uncertainty NOx measurements

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

Uncertainty of mass concentration at oxygen reference concentration

u(C, O2 ref)

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{o,dr}) + u^2(corr_{s,dr}) + u^2(corr_{rep}) + u^2(corr_{s,vf}) + u^2(corr_{s,vf}) + u^2(corr_{s,ves}) + u^2(corr_{temp}) + u^2(corr_{temp}) + u^2(corr_{odt}) +$$

u(C,O_{2,ref)} uncertainty associated with the mass concentration at O₂ ref. concentration mg/m³ C,O_{2,ref} mg/m³ mass concentration at O₂ reference concentration O2 measured concentration % volume uncertainty associated to the measured O2 concentration % (relative to O_{2 meas}) Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6357, v1

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APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

| Analyser Type/Model | | Maihak 0 | (0 - No co:::- | otion) | |
|---|--|---------------|-----------------|---------------|-----------|
| Reference Oxygen % | L | U | (0 = No corre | Guorij | |
| | | Test 1 | Test 2 | Test 3 | |
| imit value | mg/m ³ | 75 | 75 | 75 | |
| Limit value Measured concentration | ppm | 46.7 19.0 | 46.7 11.0 | 46.7 0.8 | |
| Measured concentration | ppm mg/m ³ | 30.5 | 17.7 | 1.2 | |
| Concentration at O ₂ ref. concentration | mg/m ³ | N/A | N/A | N/A | |
| 2 | ing/iii | | | | |
| 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 | | | | assumed to be | e < 5% u(|
| Zero Drift | % range | 0.00 | 0.00 | 0.00 | |
| Span Drift | u(Corr, _{0dr}) % range | 0.00 | 0.00 | 0.00 | |
| эран Биіт | u(Corr, _{sdr}) | 0.00 | 0.00 | 0.00 | |
| | u(OOH,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 | 0/ | 0.07 | 0.07 | 0.07 | |
| osses in the line | % range u(Corr, _{loss}) | 0.27 | 0.27 0.02 | 0.27 0.00 | |
| Incertainty of calibration gas | % range | 2.0 | 2.0 | 2.0 | |
| Shoomanny or cambration gas | u(Corr, _{cal}) | 0.19 | 0.11 | 0.01 | |
| | - (/Ga)/ | | | | |
| Correction of Influence of Interferents | | | | | |
| N ₂ O | % range | | | | |
| | u(Corr, _{N2O}) | 0.00 | 0.00 | 0.00 | |
| CO ₂ | % range | 0.00 | 0.00 | 2.22 | |
| CH₄ | u(Corr, _{CO2}) % range | 0.00 | 0.00 | 0.00 | |
| 5F14 | u(Corr, _{CH4}) | 0.00 | 0.00 | 0.00 | |
| Total of interferent influences | % range | 2.50 | 2.50 | 2.50 | |
| $u(\Sigma Corrint) = \max_{S_{Int,p}; S_{Int,n}} [S_{Int,p}; S_{Int,n}]$ | $u(\Sigma Corr_{int})$ | 0.16 | 0.16 | 0.16 | |
| | | | | | |
| Correction of Influence Quantities | | | | | |
| Sensitivity to sample volume flow | % range | 1.60 | 1.60 | 1.60 | |
| | u(Corr, _{flow}) | 0.09 | 0.09 | 0.09 | |
| Sensitivity to atmospheric pressure | % range | 0.00 | 0.00 | 0.00 | |
| Not reported) Sensitivity to ambient temperature | u(Corr, _{press}) % range | 0.00 -2.40 | 0.00 -2.40 | 0.00 -2.40 | |
| sensitivity to ambient temperature | 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 | |
| | | | | | |
| nterferent Concentration Variations | Minimum | Maximum | Value at cal | Performance | Units |
| CH ₄ range | 0 | 10 | 0 | 50 | mg/m |
| I ₂ O range | 0 | 0 | 0 | 20 | mg/m |
| CO ₂ range | 8 | 12 | 0 | 15 | mg/m |
| Oxygen effect variations | Minimum | Maximum | Value at cal | | Units |
| Oxygen effect | 0 | 20 | 0 | 2 | mg/m |
| nfluence Quantitiy Variations | | | | | |
| midence Quantity variations | Minimum | Maximum | Value at cal | Performance | Units |
| Sensitivity to sample volume flow | 55 | 65 | 60 | 5 | I/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 | 10.00 | Test 1 | Test 2 | Test 3 | |
| Combined uncertainty Combined uncertainty | ppm ma/m³ | 0.41 | 0.38 0.61 | 0.36 0.59 | |
| Combined uncertainty Combined uncertainty at oxygen reference | mg/m ³ mg/m ³ | 0.66 | 0.61 | 0.59 | |
| Somblined uncertainty at oxygen reference | mg/m | 0.00 | 0.01 | 0.05 | |
| 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 | |
| | % | 8.8 | 8.2 | 7.8 | |
| Overall uncertainty relative to range Overall uncertainty relative to ELV | % | 1.1 | 1.0 | 1.0 | |

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

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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







REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303 Company Registration No 03133832



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| Page 22 | Uncertainty Estimates:- TOC |

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Monitoring Objectives

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

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

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

| Sampling Location | Emission |
|----------------------------|----------------------|
| 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 |
| тос | TPM/13 | BS EN 12619 : 2013 |
| | | |

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

| * 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)

** 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.



Nm³ 273 K, 101.3 kPa



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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.

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

| * at ref | Stack Gas Weight | 0 °C | Without correction for moisture |
|------------|------------------|-----------|---------------------------------|
| Conditions | 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)

** 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.



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Nm³ 273 K, 101.3 kPa



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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 1m².

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 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







REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303

Company Registration No 03133832



Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6358, v1

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APPENDIX 1

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Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

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

Total organic carbon

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

Sampling Project Personnel Competency And Expiry Dates

| Report prepared by: | Harpreet Badwal | MCERTS No MM03 149 | Level 1 | Level 2 30/09/2018 | TE1 30/09/2018 | TE2 30/04/2019 | TE3 31/10/2019 | TE4 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 |

Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6358, v1

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APPENDIX 2

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| 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 | m² |

| Stack Diameter (circular) | 0.20 | m |
|---------------------------|------|---|
| | | _ |

| Traverse | Traverse | Depth | ΔΡ | T | Angle | velocity | Traverse | Depth | ΔΡ | T | Angle | velocity |
|----------|----------|-------|--------------------|----|-------|----------|----------|-------|--------------------|----|-------|----------|
| Point | Line | cm | mmH ₂ O | °C | 0 | m/s | Line | cm | mmH ₂ O | °C | 0 | m/s |
| 1 | Α | | | | | | В | | | | | |
| 2 | Α | | | | | | В | | | | | |
| 3 | Α | | | | | | В | | | | | |
| 4 | Α | | | | | | В | | | | | |
| 5 | Α | 5.0 | 7.8 | 21 | <15 | 11.5 | В | | | | | |
| 6 | Α | 7.1 | 8.4 | 21 | <15 | 11.8 | В | | | | | |
| 7 | Α | 12.9 | 9.3 | 22 | <15 | 12.5 | В | | | | | |
| 8 | Α | 15.0 | 9.8 | 22 | <15 | 12.8 | В | | | | | |
| 9 | Α | | | | | | В | | | | | |
| 10 | Α | | | | | | В | | | | | |
| 11 | Α | | | | | | В | | | | | |
| 12 | Α | | | | | | В | | | | | |

| Average Pitot DP | 8.80 | mmH ₂ O |
|------------------------------|-------|---------------------------------------|
| Average Temperature | 294.7 | К |
| 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 | | | |
| d | Ratio of highest to lowest local gas velocity less than 3:1 | | |
| | Minimum local gas velocity | 11.5 | |
| | Maximum local gas velocity | 12.8 | |
| | Ratio of highest to lowest local gas velocity | 1.12 | |

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± 2

10

| Date | 04/11/2015 |
|------|------------|
| | |

| From | 11:20 | to | 11:50 | 30 minute mean | | | |
|----------------|---|----|-----------|----------------|-----------|----------|--------------|
| Volatile organ | nic compounds | | vppm, wet | 3.76 | mg/m³* | 6. | 05 |
| From | 11:50 | to | 12:20 | 30 minute mean | | | |
| | nic compounds | | vppm, wet | 0.21 | mg/m³* | 0. | 34 |
| | | | | | | | |
| From | 12:20 | to | 12:50 | 30 minute mean | | | |
| Volatile orgar | nic compounds | | vppm, wet | 0.30 | mg/m³* | 0.48 | |
| Sampling De | tection Limits | | | | | | |
| | ling Detection Limits le organic compounds vppm 0.10 mg/m³* | | 0 | 0.16 | | | |
| Volatile organ | no compounds | | νррііі | 0.10 | mg/m | 0. | 10 |
| Reference G | as Details | | | | | | |
| Species | | | Units | Value | Cylinder | Analyser | Uncertainity |
| | | | | | Reference | Range | k = 2 |
| Nitrogon | | | 0/. | 00 000 | VCK01050 | _ | + 2 |

Zero And Span Gas Details

Volatile organic compounds

| 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 |

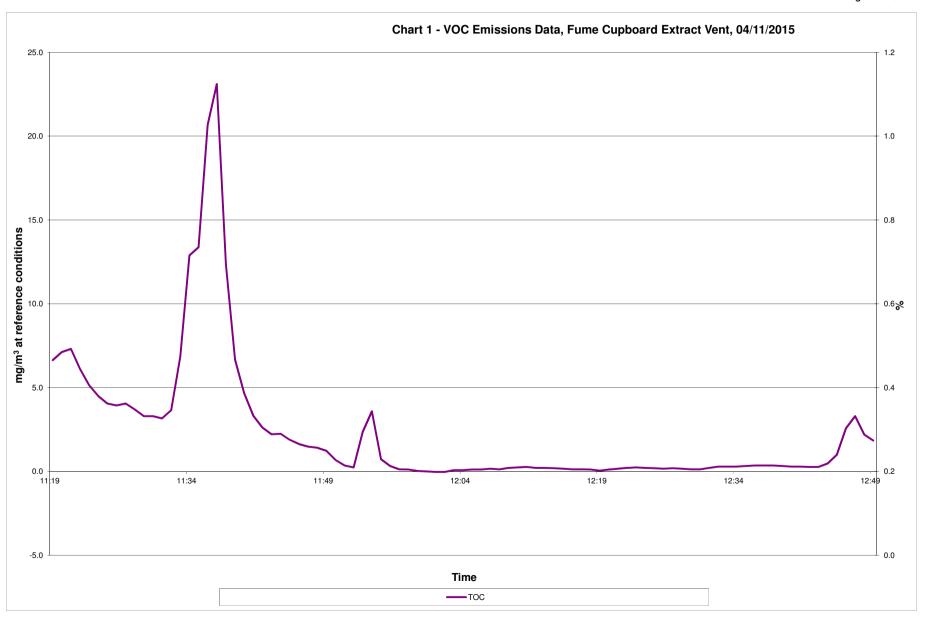
74.7

VC59841

vppm

Exhaust Gas Continuous Analysis Data





Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6358, v1

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APPENDIX 3

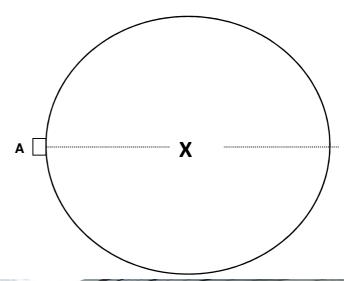
Diagram Of The Sampling Location

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) $\pi = 3.142$

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 % (m³ of water vapour in m³ of wet gas)

Vm(std) = Dry gas volume measured, corrected to standard conditions (m³)

mWC = Mass of water collected in the impingers (g)

Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)

Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)

From reference calculations (taken from BS EN 14790):

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

Vm(std) = Dry gas meter volume at standard conditions (m³)

yd = Gas meter calibration coefficient

(V2-V1) = Dry gas meter volume at actual conditions (m³)

Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)

pm = Absolute pressure at the gas meter (kPa) pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):

From reference calculations (taken from EA TGN M2):

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

Estimating Measurment Uncertainty

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

Flow Calculations

Velocity:

From reference calculations (taken from ISO 10780):

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

 \overline{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 coefficientPe = Absolute gas pressure (kPa)

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

Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m³/s)

 \bar{v} = Average velocity (m/s)

A =Stack cross-sectional area (m²)

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 (m³/s)

qva = Volume flow rate at actual conditions (m³/s) Ha = Moisture at actual conditions (%volume)

Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure

From reference calculations (taken from BS ISO 9096):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/s)

O2,m = Actual oxygen concentration (%)

O2,ref = Reference oxygen concentration (%)

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Concentration Calculations

Concentration:

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

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

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

Mass Emission

Mass emission= $c \times q_m$

c = Concentration q = Volume flow rate

Concentration corrected for oxygen:

From reference calculations (taken from BS ISO 9096):

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

cm = Concentration at reference 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 gascdry = Concentration dry gasHa = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m³

From reference calculations (taken from EA TGN M2):

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

correction of repeatability of measurement $C_{,ppm}$ concentration in ppm

Corr_{rep} Corr_{adj} Corr_{inf} concentration given by analyser C_{NO.reading} correction of adjustment Corr fit correction of lack of fit correction of influence quantities Corr _{0,dr} correction of zero drift

Corr s,dr correction of span drift

Calculation of partial uncertainties

u(Corr_{fit}) $\left(\frac{X_{fit,\max}}{100 \times range}\right)$ Where: $X_{\text{fit,max}}$ is the maximum allowable deviation from linearity

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

u(Corr_{0.dr})

max (S_{0,rep}; S_{srep}) u(Corr_{rep}) Where:

is the standard uncertainty at zero level is the standard uncertainty at span level

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

 $u(Corr_{loss})$ is the uncertainty due to losses in sample line is the uncertainty due to losses in sample line is the concentration of sample loss at span level

 $u(Corr_{cal})$ is the expanded uncertainty of the calibration gas

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

is the sensitivity coefficient of the influence quantity

is the minimum value of the influence quantity during monitoring is the maximum value of the influence quantity during monitoring is the value of the influence quantity during adjustment

 $= \frac{c_{j}}{Int_{j,lest}} \sqrt{\frac{Int_{j,max}^{2} + Int_{j,min} \times Int_{j,max} + Int_{j,min}^{2}}{3}}$

 c_{j} Int_{j,test} is the sensitivity coefficient of the interferent i $= \max \left[S_{Int,p}; S_{Int,n} \right]$ $u(\Sigma Corr_{int})$ is the concentration of the interferent j used to determine c is the minimum value of the interferent j quantity during monitoring is the maximum value of the interferent i quantity during monitoring

 $\mathsf{Int}_{\mathsf{j},\mathsf{adj}}$ is the concentration of the interferent j in the cal gas used to adjust the analyse

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

Combined uncertainty

 $u(C_{,ppm})$

 $\sqrt{u^{2}(corr_{fit}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{s,dr}) + u^{2}(corr_{ep}) + u^{2}(corr_{ep}) + u^{2}(corr_{s,vf}) + u^{2}(corr_{d,oress}) + u^{2}(corr_{ep}) + u^{2}(corr_{odi}) + S_{int}^{-2}}$

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

Uncertainty of NOx measurements

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

Combined uncertainty NOx measurements

 $\sqrt{u^2(corr_{fit}) + u^2(corr_{odt}) + u^2(corr_{sdt}) + u^2(corr_{sof}) + u^2(corr$

Uncertainty of mass concentration at oxygen reference concentration

u(C, O2 ref)

 $\sqrt{u^{2}(corr_{fit}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{s,dr}) + u^{2}(corr_{rep}) + u^{2}(corr_{s,sf}) + u^{2}(corr_{s,sf}) + u^{2}(corr_{semp}) + u^{2}(corr_{temp}) + u^{2}(corr_{odi}) + S_{tat}^{2}} + \left(\frac{u^{2}(O_{2,meas,dry})}{(21 - O_{s,sf})}\right) + \frac{u^{2}(corr_{semp}) + u^{2}(corr_{semp}) + u^{2}(corr_{semp}) + u^{2}(corr_{odi}) + S_{tat}^{2}}{(21 - O_{s,sf})}$

u(C,O_{2,ref)} uncertainty associated with the mass concentration at O₂ ref. concentration mg/m³ C,O_{2,ref} mg/m³ mass concentration at O₂ reference concentration O2 measured concentration % volume

uncertainty associated to the measured O2 concentration % (relative to O_{2 meas}) Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6358, v1

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APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

| Analyser Type/Model | | Sick Maihak 0 | | ction) | |
|---|--------------------------------------|--------------------|-------------------|-------------------|---------------|
| Reference Oxygen % | | J | (0 = No corre | Guoii) | |
| | | Test 1 | Test 2 | Test 3 | |
| imit value | mg/m ³ | 75 | 75 | 75 | |
| Limit value Measured concentration | ppm | 46.7 3.8 | 46.7 0.2 | 46.7 0.3 | |
| Measured concentration | ppm mg/m ³ | 6.0 | 0.2 | 0.5 | |
| Concentration at O ₂ ref. concentration | mg/m ³ | N/A | N/A | N/A | |
| | ,g | | | L | |
| 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 | | | | assumed to be | < 5% u(|
| Zero Drift | % range | 0.00 | 0.00 | 0.00 | |
| Doon Drift | u(Corr, _{Odr}) | 0.00 | 0.00 | 0.00 | |
| Span Drift | % range u(Corr, _{sdr}) | 0.00 | 0.00 | 0.00 | |
| | u(Oon,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 | 0/ | 0.07 | 0.07 | 0.67 | |
| osses in the line | % range u(Corr, _{loss}) | 0.27 | 0.27 0.00 | 0.27 0.00 | |
| Incertainty of calibration gas | % range | 2.0 | 2.0 | 2.0 | |
| Shoertainty of calibration gas | u(Corr, _{cal}) | 0.04 | 0.00 | 0.00 | |
| | e (= c · · · · · cai) | | | | |
| Correction of Influence of Interferents | | | | | |
| N₂O | % range | | | | |
| | u(Corr, _{N2O}) | 0.00 | 0.00 | 0.00 | |
| CO ₂ | % range | | | | |
| | u(Corr, _{CO2}) | 0.00 | 0.00 | 0.00 | |
| CH₄ | % range u(Corr, _{CH4}) | 0.00 | 0.00 | 0.00 | |
| Total of interferent influences | % range | 2.50 | 2.50 | 2.50 | |
| $u(\Sigma Corrint) = \max_{n} [S_{lnt,p}; S_{lnt,n}]$ | u(ΣCorr _{int}) | 0.16 | 0.16 | 0.16 | |
| | , ,,,,, | | | | |
| Correction of Influence Quantities | | | | | |
| Sensitivity to sample volume flow | % range | 1.60 | 1.60 | 1.60 | |
| | u(Corr, _{flow}) | 0.09 | 0.09 | 0.09 | |
| Sensitivity to atmospheric pressure | % range | | | | |
| (Not reported) | u(Corr, _{press}) | 0.00 | 0.00 | 0.00 | |
| Sensitivity to ambient temperature | % range | -2.40 | -2.40 | -2.40 | |
| Sensitivity to electrical voltage | u(Corr, _{temp}) % range | -0.28 0.50 | -0.28 0.50 | -0.28 0.50 | |
| Not reported) | u(Corr, _{volt}) | 0.10 | 0.10 | 0.10 | |
| rect reported) | a(con,voit) | 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 | |
| | | | | | |
| nterferent Concentration Variations | Minimum | Maximum | Value at act | Dorformana | I lock |
| nterferent Concentration Variations CH ₄ range | Minimum 0 | Maximum 10 | Value at cal 0 | Performance 50 | Units mg/m |
| N₂O range | 0 | 0 | 0 | 20 | mg/m |
| CO ₂ range | 8 | 12 | 0 | 15 | mg/m |
| Oxygen effect variations | Minimum | Maximum | Value at cal | | Units |
| Dxygen effect | 0 | 20 | 0 | 2 | mg/m |
| | | | | | |
| nfluence Quantitiy Variations | L MAIL : | Mand | I Malua : : | D-st-ss | 11.00 |
| Consider to comple values - # | Minimum | Maximum | Value at cal | Performance | Units |
| Sensitivity to sample volume flow Sensitivity to atmospheric pressure | 55 99 | 65 100 | 60 99 | 5 1 | l/h kPa |
| Sensitivity to atmospheric pressure | 278 | 313 | 288 | 10 | KPa K |
| Sensitivity to electrical voltage | 187 | 250 | 230 | 5 | V |
| | .57 | | | | • |
| 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 | |
| Type and ad a page trainty average and with a last 1. | ofidence of OFO/ | 0 | | | |
| Expanded uncertainty expressed with a level of cor Overall uncertainty | | | 0.7 | 0.7 | |
| | ppm | 0.7 | 0.7 1.2 | 1.2 | |
| | 3 | | | | |
| Overall uncertainty | mg/m³ | 1.2 19.5 | | | |
| | mg/m ³ % | 1.2 19.5 7.9 | 344.7 7.8 | 246.0 7.8 | |

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

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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







REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303 Company Registration No 03133832



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| Page 4 | Summary Of Results |
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| Page 6 | Operating Information |
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| Page 7 | Part 2: Supporting Information |
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| Page 21 | Appendix 4 |
| Page 22 | Uncertainty Estimates:- TOC |

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Monitoring Objectives

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

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

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

| Sampling Location | Emission | | |
|-------------------|----------------------|--|--|
| 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 |
| тос | TPM/13 | BS EN 12619 : 2013 |
| | | |

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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 | Sampling | | Emission | Authorised | Uncertainty | Detection | Mass | |
|-------------|----------|-------|----------|------------|---------------------|-----------|--------|----------|
| St Ives | Time | | | Result | Limit | +/- | Limit | Emission |
| Labs | Date | Start | End | mg/m³∗ | mg/m ³ * | mg/m³* | mg/m³∗ | g/h |
| тос | 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) 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 | | Sampling Time | | Emission Result | Authorised Limit | Uncertainty +/- | Detection Limit | Mass Emission |
|-----|------------------------|----------|------------------|-------|---------------------|---------------------|--------------------|--------------------|------------------|
| | Labs | Date | Start | End | mg/m ³ * | mg/m³* | mg/m³* | mg/m³* | g/h |
| тос | Test 1 | 04/11/15 | 13:05 | 13:35 | 2.9 | 75 | 1.2 | 0.2 | 9.9 |
| тос | 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 |

| I | * at ref | Stack Gas Weight | 0 °C | Without correction for moisture | |
|---|------------|------------------|-----------|---------------------------------|--|
| | Conditions | 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)

** 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.



Nm³ 273 K, 101.3 kPa



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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 1m².

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 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







1783

REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303

Company Registration No 03133832



Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6359, v1.

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APPENDIX 1

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Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

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

Total organic carbon

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

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Sampling Project Personnel Competency And Expiry Dates

| Report prepared by: | Harpreet Badwal | MCERTS No MM03 149 | Level 1 | Level 2 30/09/2018 | TE1 30/09/2018 | TE2 30/04/2019 | TE3 31/10/2019 | TE4 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 |

Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6359, v1.

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APPENDIX 2

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| 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 | m² |

| Stack Diameter (circular) | 0.30 | m |
|---------------------------|------|---|
| | | |

| Traverse | Traverse | Depth | ΔΡ | Т | Angle | velocity | Traverse | Depth | ΔΡ | T | Angle | velocity |
|----------|----------|-------|--------------------|----|-------|----------|----------|-------|--------------------|----|-------|----------|
| Point | Line | cm | mmH ₂ O | °C | 0 | m/s | Line | cm | mmH ₂ O | °C | 0 | m/s |
| 1 | Α | | | | | | В | | | | | |
| 2 | Α | | | | | | В | | | | | |
| 3 | Α | 5.0 | 18.0 | 22 | <15 | 17.4 | В | | | | | |
| 4 | Α | 5.3 | 15.1 | 22 | <15 | 15.9 | В | | | | | |
| 5 | Α | 7.5 | 10.8 | 22 | <15 | 13.5 | В | | | | | |
| 6 | Α | 10.7 | 10.0 | 22 | <15 | 12.9 | В | | | | | |
| 7 | Α | 19.3 | 16.1 | 22 | <15 | 16.4 | В | | | | | |
| 8 | Α | 22.5 | 12.4 | 22 | <15 | 14.4 | В | | | | | |
| 9 | Α | 24.7 | 9.6 | 22 | <15 | 12.7 | В | | | | | |
| 10 | Α | 25.0 | 9.0 | 22 | <15 | 12.3 | В | | | | | |
| 11 | Α | | | | | | В | | | | | |
| 12 | Α | | | | | | В | | | | | |

| Average Pitot DP | 12.43 | mmH₂O |
|------------------------------|-------|---------------------------------------|
| Average Temperature | 295.2 | К |
| 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

| а | Angel of gas flow less than 15° with regard to duct axis | | YES |
|---|---|------|-----|
| b | No local negative flow | | YES |
| С | 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 | |

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| Date | 04/11/2015 |
|------|------------|
| | |

| From | 13:05 | to | 13:35 | 30 minute mean | | |
|----------------|---------------|----|-----------|----------------|--------|------|
| Volatile organ | ic compounds | | vppm, wet | 1.82 | mg/m³* | 2.93 |
| | | | | | | |
| From | 13:35 | to | 14:05 | 30 minute mean | | |
| Volatile organ | nic compounds | | vppm, wet | 2.80 | mg/m³* | 4.51 |
| _ | | | | | | |
| From | 14:05 | to | 14:35 | 30 minute mean | | |
| Volatile organ | nic compounds | | vppm, wet | 2.42 | mg/m³* | 3.88 |
| | | | | | | |
| | | | | | | |
| Sampling Det | ection Limits | | | | | |
| Volatile organ | ic compounds | | vppm | 0.10 | mg/m³* | 0.16 |
| | | | | | | |
| Reference Ga | as Details | | | | | |
| | | | | | 0 " 1 | |

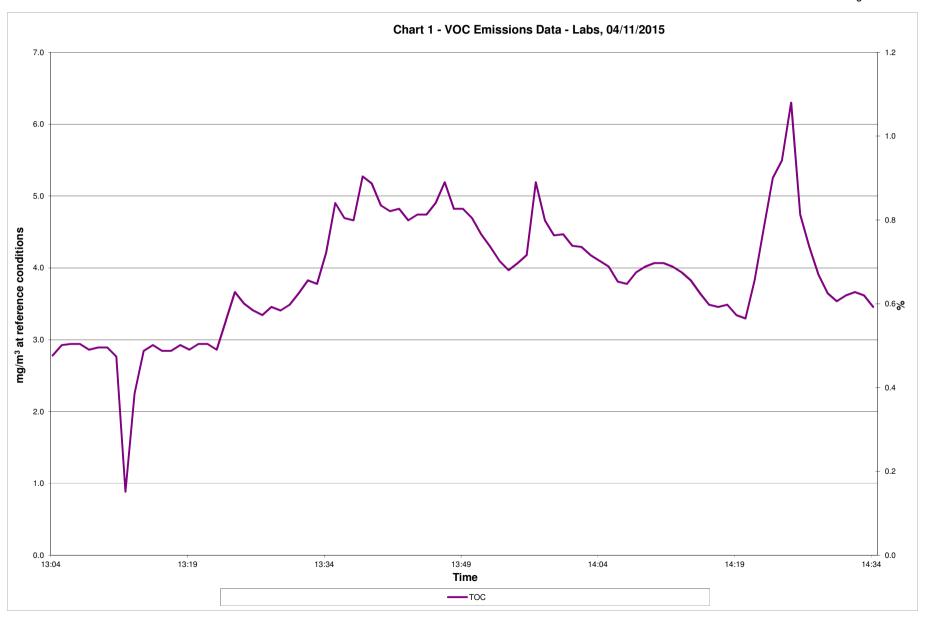
| Species | Units | Value | Cylinder Reference | Analyser Range | Uncertainity $k = 2$ |
|----------------------------|-------|--------|-----------------------|-------------------|----------------------|
| Nitrogen | % | 99.999 | VCK01959 | - | ± 2 |
| Volatile organic compounds | vppm | 74.7 | VC59841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





Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6359, v1.

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APPENDIX 3

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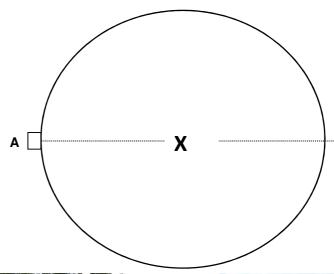
Diagram Of The Sampling Location

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 |





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General Calculations

Stack area:

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

D = Diameter (m) $\pi = 3.142$

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 % (m³ of water vapour in m³ of wet gas)

Vm(std) = Dry gas volume measured, corrected to standard conditions (m³)

mWC = Mass of water collected in the impingers (g)

Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)

Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)

From reference calculations (taken from BS EN 14790):

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

Vm(std) = Dry gas meter volume at standard conditions (m³)

yd = Gas meter calibration coefficient

(V2-V1) = Dry gas meter volume at actual conditions (m³)

Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)

pm = Absolute pressure at the gas meter (kPa) pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):

From reference calculations (taken from EA TGN M2):

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

Estimating Measurment Uncertainty

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

Flow Calculations

Velocity:

From reference calculations (taken from ISO 10780):

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

 $\bar{v} = \text{Average velocity (m/s)}$

 \dot{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 coefficientPe = Absolute gas pressure (kPa)

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

Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m³/s)

v = v Average velocity (m/s)

A =Stack cross-sectional area (m²)

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 (m³/s)

qva = Volume flow rate at actual conditions (m³/s) Ha = Moisture at actual conditions (%volume)

Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure

From reference calculations (taken from BS ISO 9096):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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):

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

qm = Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/s)

O2,m = Actual oxygen concentration (%)

O2,ref = Reference oxygen concentration (%)

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Concentration Calculations

Concentration:

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

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

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

Mass Emission

Mass emission= $c \times q_m$

c = Concentration q = Volume flow rate

Concentration corrected for oxygen:

From reference calculations (taken from BS ISO 9096):

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

cm = Concentration at reference 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 gascdry = Concentration dry gasHa = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m³

From reference calculations (taken from EA TGN M2):

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

molar volume at 273K = 22.4 litres

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Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Corr_{rep} Corr_{adj} Corr_{inf} correction of repeatability of measurement $C_{,ppm}$ concentration in ppm concentration given by analyser C_{NO.reading} correction of adjustment Corr fit correction of lack of fit correction of influence quantities

Corr _{0,dr} correction of zero drift Corr s,dr correction of span drift

Calculation of partial uncertainties

u(Corr_{fit}) $\left(\frac{X_{fit,\max}}{100 \times range}\right)$ Where: $X_{\text{fit,max}}$ is the maximum allowable deviation from linearity

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

u(Corr_{0.dr})

max (S_{0,rep}; S_{srep}) u(Corr_{rep}) Where:

is the standard uncertainty at zero level is the standard uncertainty at span level

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

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

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

is the sensitivity coefficient of the influence quantity

is the minimum value of the influence quantity during monitoring is the maximum value of the influence quantity during monitoring is the value of the influence quantity during adjustment

 $= \frac{c_{j}}{Int_{j,lest}} \sqrt{\frac{Int_{j,max}^{2} + Int_{j,min} \times Int_{j,max} + Int_{j,min}^{2}}{3}}$

 c_{j} Int_{j,test} is the sensitivity coefficient of the interferent i $= \max \left[S_{Int,p}; S_{Int,n} \right]$ $u(\Sigma Corr_{int})$ is the concentration of the interferent j used to determine c is the minimum value of the interferent j quantity during monitoring

is the maximum value of the interferent i quantity during monitoring

 $\mathsf{Int}_{\mathsf{j},\mathsf{adj}}$ is the concentration of the interferent j in the cal gas used to adjust the analyse

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

Combined uncertainty

 $u(C_{,ppm})$

$$\sqrt{u^2(corr_{\mathit{fit}}) + u^2(corr_{\mathit{0,dr}}) + u^2(corr_{\mathit{s,dr}}) + u^2(corr_{\mathit{rep}}) + u^2(corr_{\mathit{rep}}) + u^2(corr_{\mathit{s,yf}}) + u^2(corr_{\mathit{a,press}}) + u^2(corr_{\mathit{emp}}) + u^2(corr_{\mathit{volt}}) + u^2(corr_{\mathit{adj}}) + S_{\mathit{hit}}^{-2}}$$

Overall expanded uncertainty (k = 2)

$$U(C_m) = u(C_m) \times k$$

Uncertainty of NOx measurements

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

Combined uncertainty NOx measurements

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

Uncertainty of mass concentration at oxygen reference concentration

u(C, O2 ref)

$$\sqrt{u^{2}(corr_{fit}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{s,dr}) + u^{2}(corr_{s,dr}) + u^{2}(corr_{s,ef}) + u^{2}(corr_{s,ef}) + u^{2}(corr_{s,ef}) + u^{2}(corr_{temp}) + u^{2}(corr_{temp}) + u^{2}(corr_{odi}) + u^{2}(corr_{od$$

u(C,O_{2,ref)} uncertainty associated with the mass concentration at O₂ ref. concentration mg/m³ C,O_{2,ref} mg/m³ mass concentration at O₂ reference concentration O2 measured concentration % volume uncertainty associated to the measured O2 concentration % (relative to O_{2 meas}) Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6359, v1.

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APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

| | Uncertainty | Estimate | FOI THE | weasureme | iii Oi |
|--|--|--|--|------------------------------------|-------------------|
| Analyser Type/Model | | Maihak | | | |
| Reference Oxygen % | | 0 | (0 = No corre | ction) | |
| | ſ | 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 | |
| nalyser range | mg/m ³ | 15.0 | 15.0 | 15.0 | |
| | | | | | |
| Correction of Lack of Fit | | | • | | |
| ack of fit | % range | 2.0 | 2.0 | 2.0 | |
| | u(Corr, _{fit}) | 0.11 | 0.11 | 0.11 | |
| | | | | | |
| Corrections of Zero and Span Drift | | | | assumed to be | < 5% u(r |
| ero Drift | % range | 0.00 | 0.00 | 0.00 | |
| D D-14 | u(Corr, _{Odr}) | 0.00 | 0.00 | 0.00 | |
| pan Drift | % range | | | | |
| _ | 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 | |
| tot roportou) | a(John,rep) | 0.00 | 0.00 | 0.00 | |
| Correction of adjustment | | | | | |
| osses in the line | % range | 0.27 | 0.27 | 0.27 | |
| assess in the inte | u(Corr, _{loss}) | 0.00 | 0.00 | 0.00 | |
| Incertainty of calibration gas | % range | 2.0 | 2.0 | 2.0 | |
| incertainty of calibration gas | u(Corr, _{cal}) | 0.02 | 0.03 | 0.02 | |
| | u(Oon (cal) | 0.02 | 0.00 | 0.02 | |
| Correction of Influence of Interferents | | | | | |
| I ₂ O | % range | | | | |
| <u>-</u> - | u(Corr, _{N2O}) | 0.00 | 0.00 | 0.00 | |
| O ₂ | % range | 0.00 | 0.00 | 0.00 | |
| | u(Corr, _{CO2}) | 0.00 | 0.00 | 0.00 | |
| CH₄ | % range | 0.00 | 0.00 | 0.00 | |
| 4 | u(Corr, _{CH4}) | 0.00 | 0.00 | 0.00 | |
| otal of interferent influences . | % range | 2.50 | 2.50 | 2.50 | |
| $I(\Sigma Corrint) = \max [S_{int,p}; S_{int,n}]$ | $u(\Sigma Corr_{int})$ | 0.16 | 0.16 | 0.16 | |
| · · · | | | | | |
| Correction of Influence Quantities | | | | | |
| Sensitivity to sample volume flow | % range | 1.60 | 1.60 | 1.60 | |
| | u(Corr,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 | |
| <u> </u> | | | | | |
| Maximum standard uncertainty | u(Corr, _{max}) | 0.11 | 0.11 | 0.11 | |
| % of maximum standard uncertainty | u(Corr,5%) | 0.01 | 0.01 | 0.01 | |
| | | | _ | | |
| | | | | | |
| terferent Concentration Variations | Minimum | Maximum | Value at cal | Performance | Units |
| H ₄ range | 0 | 10 | 0 | 50 | mg/m ³ |
| ₂ O range | 0 | 0 | 0 | 20 | mg/m ³ |
| O ₂ range | 8 | 12 | 0 | 15 | mg/m ³ |
| xygen effect variations | Minimum | Maximum | Value at cal | Performance | Units |
| xygen effect | 0 | 20 | 0 | 2 | mg/m ³ |
| | | | | | |
| nfluence Quantitiy Variations | | | | | |
| | Minimum | Maximum | Value at cal | Performance | Units |
| ensitivity to sample volume flow | 55 | 65 | 60 | 5 | l/h |
| ensitivity to atmospheric pressure | 99 | 100 | 99 | 1 | kPa |
| ensitivity to ambient temperature | 278 | 313 | 288 | 10 | K |
| ensitivity to electrical voltage | 187 | 250 | 230 | 5 | V |
| ensitivity to electrical voltage | | | _ | | |
| - | | _ | Toot 0 | Test 3 | |
| Measurement uncertainty | | Test 1 | Test 2 | | |
| Measurement uncertainty Combined uncertainty | ppm | 0.37 | 0.37 | 0.37 | |
| feasurement uncertainty combined uncertainty combined uncertainty | ppm mg/m³ | 0.37 0.59 | 0.37 0.59 | 0.59 | |
| feasurement uncertainty combined uncertainty combined uncertainty | ppm | 0.37 | 0.37 | | |
| Measurement uncertainty Combined uncertainty Combined uncertainty Combined uncertainty Combined uncertainty at oxygen reference | ppm mg/m³ mg/m³ | 0.37 0.59 0.59 | 0.37 0.59 | 0.59 | |
| fleasurement uncertainty combined uncertainty combined uncertainty combined uncertainty combined uncertainty at oxygen reference expanded uncertainty expressed with a level of con | ppm mg/m³ mg/m³ | 0.37 0.59 0.59 | 0.37 0.59 0.59 | 0.59 0.59 | |
| feasurement uncertainty combined uncertainty combined uncertainty combined uncertainty combined uncertainty at oxygen reference expanded uncertainty expressed with a level of con verall uncertainty | ppm mg/m³ mg/m³ | 0.37 0.59 0.59 0.59 | 0.37 0.59 0.59 | 0.59 0.59 | |
| Measurement uncertainty Combined uncertainty Combined uncertainty Combined uncertainty Combined uncertainty at oxygen reference Expanded uncertainty expressed with a level of con Diversall uncertainty Diversall uncertainty | ppm mg/m³ mg/m³ ffidence of 95%, k- ppm mg/m³ | 0.37 0.59 0.59 =2 0.7 1.2 | 0.37 0.59 0.59 0.7 1.2 | 0.59 0.59 0.7 1.2 | |
| Measurement uncertainty Combined uncertainty Combined uncertainty Combined uncertainty at oxygen reference Expanded uncertainty expressed with a level of con Overall uncertainty Overall uncertainty Overall uncertainty | ppm mg/m³ mg/m³ ifidence of 95%, k ppm mg/m³ | 0.37 0.59 0.59 =2 0.7 1.2 40.1 | 0.37 0.59 0.59 0.7 1.2 26.1 | 0.59 0.59 0.7 1.2 30.3 | |
| Measurement uncertainty Combined uncertainty Combined uncertainty Combined uncertainty Combined uncertainty at oxygen reference Expanded uncertainty expressed with a level of con Diverall uncertainty Diverall uncertainty Diverall uncertainty Diverall uncertainty Diverall uncertainty relative to measured value Diverall uncertainty relative to range Diverall uncertainty relative to ELV | ppm mg/m³ mg/m³ ffidence of 95%, k- ppm mg/m³ | 0.37 0.59 0.59 =2 0.7 1.2 | 0.37 0.59 0.59 0.7 1.2 | 0.59 0.59 0.7 1.2 | |

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

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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







REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303 Company Registration No 03133832



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| Page 7 | Part 2: Supporting Information |
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| Page 13 | Exhaust Gases - Continuous Analysis Data |
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| Page 17 | Generic Calculations |
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| Page 19 | Concentration Calculation |
| Page 20 | Uncertainty Estimate Calculations - Instrumental Techniques |
| Page 21 | Appendix 4 |
| Page 22 | Uncertainty Estimates:- TOC |

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Monitoring Objectives

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

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

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

| Sampling Location | Emission | | |
|-------------------|----------------------|--|--|
| 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 |
| тос | TPM/13 | BS EN 12619 : 2013 |
| | | |

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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 | Sampling | | Emission | Authorised | Uncertainty | Detection | Mass | |
|-------------|----------|-------|----------|------------|---------------------|-----------|----------|-----|
| St Ives | Time | | Result | Limit | +/- | Limit | Emission | |
| RASTA | Date | Start | End | mg/m³* | mg/m ³ * | mg/m³* | mg/m³* | g/h |
| тос | 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 | n 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) 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.

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

| ı | * at ref | Stack Gas Weight | 0 °C | Without correction for moisture |
|---|------------|------------------|-----------|---------------------------------|
| | Conditions | 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)

** 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.



Nm³ 273 K, 101.3 kPa



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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 1m².

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







REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303

Company Registration No 03133832



Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6360, v1

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Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

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

Total organic carbon

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

Sampling Project Personnel Competency And Expiry Dates

| Report prepared by: | Harpreet Badwal | MCERTS No MM03 149 | Level 1 | Level 2 30/09/2018 | TE1 30/09/2018 | TE2 30/04/2019 | TE3 31/10/2019 | TE4 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 |

Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6360, v1

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| 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 | m² |

| Stack Diameter (circular) | 0.13 | m |
|---------------------------|------|---|
| | | |

| Traverse | Traverse | Depth | ΔΡ | T | Angle | velocity | Traverse | Depth | ΔΡ | T | Angle | velocity |
|----------|----------|-------|--------------------|----|-------|----------|----------|-------|--------------------|----|-------|----------|
| Point | Line | cm | mmH ₂ O | °C | 0 | m/s | Line | cm | mmH ₂ O | °C | 0 | m/s |
| 1 | Α | | | | | | В | | | | | |
| 2 | Α | | | | | | В | | | | | |
| 3 | Α | | | | | | В | | | | | |
| 4 | Α | | | | | | В | | | | | |
| 5 | Α | | | | | | В | | | | | |
| 6 | Α | 5.0 | 4.8 | 17 | <15 | 8.9 | В | | | | | |
| 7 | Α | 8.0 | 5.0 | 17 | <15 | 9.1 | В | | | | | |
| 8 | Α | | | | | | В | | | | | |
| 9 | Α | | | | | | В | | | | | |
| 10 | Α | | | | | | В | | | | | |
| 11 | Α | | | | | | В | | | | | |
| 12 | Α | | | | _ | | В | | | | | |

| Average Pitot DP | 4.89 | mmH ₂ O |
|------------------------------|-------|---------------------------------------|
| Average Temperature | 290.2 | К |
| 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

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

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± 2

100

| From | 14:40 | to | 15:10 | 30 minute mean | | | |
|----------------|---------------|----|-----------|----------------|-----------|----------|--------------|
| Volatile organ | ic compounds | | vppm, wet | 1.83 | mg/m³* | 2. | 94 |
| | | | | | | | |
| From | 15:10 | to | 15:40 | 30 minute mean | | | |
| Volatile organ | ic compounds | | vppm, wet | 1.87 | mg/m³* | 3. | 01 |
| <u>=</u> | | | | | | | |
| From | 15:40 | to | 16:10 | 30 minute mean | | | |
| Volatile organ | ic compounds | | vppm, wet | 1.79 | mg/m³* | 2. | 88 |
| _ | | | | | | | |
| | | | | | | | |
| Sampling Det | ection Limits | | | | | | |
| Volatile organ | ic compounds | | vppm | 0.10 | mg/m³* | 0. | 16 |
| | | | | | | | |
| Reference Ga | as Details | | | | | | |
| Species | | | Units | Value | Cylinder | Analyser | Uncertainity |
| | | | | | Reference | Range | k = 2 |

Volatile organic compounds

Nitrogen

| 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 | | |

vppm

99.999

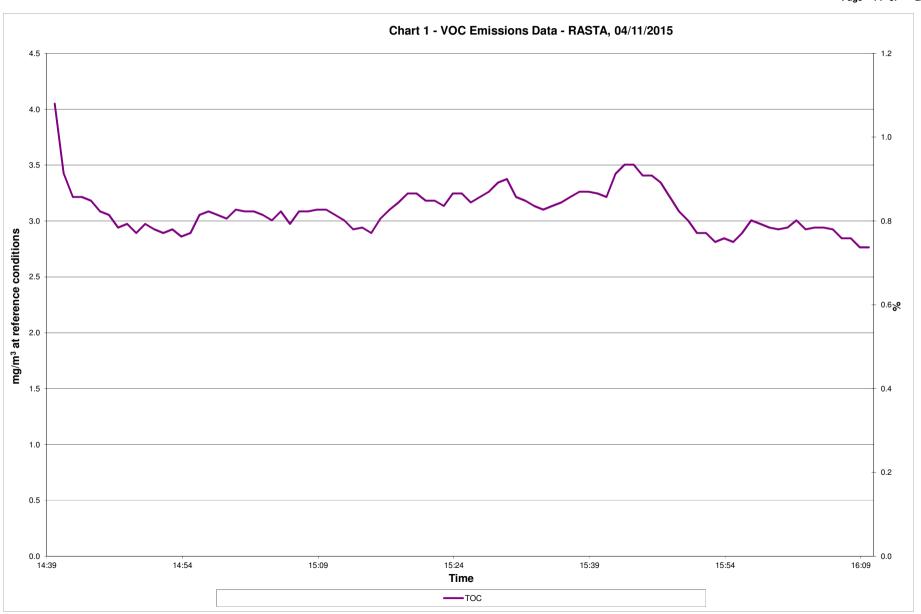
74.7

VCK01959

VC59841

Exhaust Gas Continuous Analysis Data





Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6360, v1

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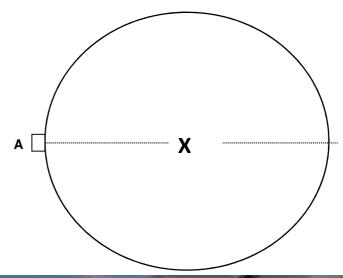
Diagram Of The Sampling Location

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

Traverse length =

| \sim | 4 | 2 | | ~ |
|--------|---|---|-----|---|
| U | ı | 3 | - [| П |

| Point | % of D | Location |
|-------|--------|----------|
| | | cm |
| 1 | 50.0 | 6.5 |





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General Calculations

Stack area:

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

D = Diameter (m) $\pi = 3.142$

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 % (m³ of water vapour in m³ of wet gas)

Vm(std) = Dry gas volume measured, corrected to standard conditions (m³)

mWC = Mass of water collected in the impingers (g)

Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)

Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)

From reference calculations (taken from BS EN 14790):

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

Vm(std) = Dry gas meter volume at standard conditions (m³)

yd = Gas meter calibration coefficient

(V2-V1) = Dry gas meter volume at actual conditions (m³)

Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)

pm = Absolute pressure at the gas meter (kPa)
pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):

From reference calculations (taken from EA TGN M2):

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

Estimating Measurment Uncertainty

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

Flow Calculations

Velocity:

From reference calculations (taken from ISO 10780):

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

 $\frac{1}{v}$ = Average velocity (m/s)

 \dot{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 coefficientPe = Absolute gas pressure (kPa)

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

Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m³/s)

v = v Average velocity (m/s)

A =Stack cross-sectional area (m²)

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 (m³/s)

qva = Volume flow rate at actual conditions (m³/s) Ha = Moisture at actual conditions (%volume)

Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure

From reference calculations (taken from BS ISO 9096):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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 gascdry = Concentration dry gasHa = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m³

From reference calculations (taken from EA TGN M2):

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

correction of repeatability of measurement $C_{,ppm}$ concentration in ppm

Corr_{rep} Corr_{adj} Corr_{inf} concentration given by analyser C_{NO.reading} correction of adjustment Corr fit correction of lack of fit correction of influence quantities Corr _{0,dr} correction of zero drift

Corr s,dr correction of span drift

Calculation of partial uncertainties

u(Corr_{fit}) $\left(\frac{X_{fit,\max}}{100 \times range}\right)$ Where: $X_{\text{fit,max}}$ is the maximum allowable deviation from linearity

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

$$u(Corr_{rep}) \hspace{1.5cm} = \hspace{1.5cm} max \ (S_{0,rep} \ ; S_{srep}) \hspace{1.5cm} = \hspace{1.5cm} S_{rep} \\ \hspace{1.5cm} Where: \hspace{1.5cm} \\$$

is the standard uncertainty at zero level is the standard uncertainty at span level

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

is the sensitivity coefficient of the influence quantity is the minimum value of the influence quantity during monitoring is the maximum value of the influence quantity during monitoring is the value of the influence quantity during adjustment

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

 $= \max \left[S_{Int,p}; S_{Int,n} \right]$

 c_{j} $Int_{j,test}$ is the sensitivity coefficient of the interferent i is the concentration of the interferent j used to determine c is the minimum value of the interferent j quantity during monitoring is the maximum value of the interferent i quantity during monitoring

 $\mathsf{Int}_{\mathsf{j},\mathsf{adj}}$ 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 is the sum of interferents with negative impact

Combined uncertainty

 $u(\Sigma Corr_{int})$

$$u(C_{ppm}) =$$

$$\sqrt{u^2 (corr_{\mathit{fit}}) + u^2 (corr_{\mathit{o,dr}}) + u^2 (corr_{\mathit{s,dr}}) + u^2 (corr_{\mathit{rep}}) + u^2 (corr_{\mathit{s,yf}}) + u^2 (corr_{\mathit{a,press}}) + u^2 (corr_{\mathit{temp}}) + u^2 (corr_{\mathit{volt}}) + u^2 (corr_{\mathit{adj}}) + S_{\mathit{hit}}^{-2}}$$

Overall expanded uncertainty (k = 2)

$$U(C_m) = u(C_m) \times k$$

Uncertainty of NOx measurements

$$u(C_{NOx},_{conv}) = \frac{C_{NOx} \times R \times \eta}{\sqrt{3}}$$
 Where:
$$C_{NOx}$$
 is the concentration of NOx measured by the analyser is the ratio of NO:Nox in the stack gas is the NOx converter efficiency

Combined uncertainty NOx measurements

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

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

Uncertainty of mass concentration at oxygen reference concentration

$$u(C, O2 ref) =$$

$$\sqrt{u^{2}(corr_{\mathit{fit}}) + u^{2}(corr_{\mathit{o,dr}}) + u^{2}(corr_{\mathit{s,dr}}) + u^{2}(corr_{\mathit{rep}}) + u^{2}(corr_{\mathit{s,vf}}) + u^{2}(corr_{\mathit{s,vf}}) + u^{2}(corr_{\mathit{s,otr}}) + u^{2}(corr_{\mathit{sott}}) + u^{2}(corr_{\mathit{odd}}) + S_{\mathit{Int}}^{2} + \left(\frac{u^{2}(O_{2,\mathit{meas,dry}})}{(21 - O_{2,\mathit{meas,dry}})^{2}}\right)}$$

u(C,O_{2,ref)} uncertainty associated with the mass concentration at O₂ ref. concentration mg/m³ C,O_{2,ref} mg/m³ mass concentration at O₂ reference concentration O2 measured concentration % volume uncertainty associated to the measured O2 concentration % (relative to O_{2 meas}) Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6360, v1

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Uncertainty Estimate For The Measurement Of Total Organic Carbon

| Analyser Type/Model | | Maihak | (0 = No corre | ation) | |
|--|--|---------------|-------------------|-------------------|---------------|
| Reference Oxygen % | | 0 | | ction) | |
| | | Test 1 | Test 2 | Test 3 | |
| imit value | mg/m ³ | 75 | 75 | 75 | |
| imit value | ppm | 46.7 | 46.7 | 46.7 | |
| Measured concentration | ppm | 1.8 | 1.9 | 1.8 | |
| Measured concentration Concentration at O ₂ ref. concentration | mg/m ³ mg/m ³ | 2.9 N/A | 3.0 N/A | 2.9 N/A | |
| Doncentration at O2 fer. concentration | mg/m | IV/A | IVA | IN/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 | |
| Damas 4 2 2 5 5 5 5 5 5 5 5 | | | | | |
| Correction of Lack of Fit Lack of fit | % range | 2.0 | 2.0 | 2.0 | |
| Lack of the | u(Corr, _{fit}) | 0.11 | 0.11 | 0.11 | |
| | -(| | | | |
| Corrections of Zero and Span Drift | (*All drift is ca | alculated for | . the residual is | assumed to be | e < 5% u(|
| 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 Depostability of Massurement | | | | | |
| Correction of Repeatability of Measurement Repeatability SD at span level | % range | 0.0 | 0.0 | 0.0 | |
| Not reported) | u(Corr, _{reo}) | 0.00 | 0.00 | 0.00 | |
| | - (· · iep / | 2.00 | | 2.30 | |
| Correction of adjustment | | | | | |
| osses in the line | % range | 0.27 | 0.27 | 0.27 | |
| | u(Corr, _{loss}) | 0.00 | 0.00 | 0.00 | |
| Incertainty 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 ₂ O | % range | | | 1 | |
| -2- | u(Corr, _{N2O}) | 0.00 | 0.00 | 0.00 | |
| CO_2 | % range | | | | |
| | u(Corr, _{CO2}) | 0.00 | 0.00 | 0.00 | |
| CH₄ | % range | | | | |
| | u(Corr, _{CH4}) | 0.00 | 0.00 | 0.00 | |
| Total of interferent influences $\mu(\Sigma Corrint) = \max_{s} [S_{lnt,p}; S_{lnt,n}]$ | % range $u(\Sigma Corr_{int})$ | 2.50 | 2.50 | 2.50 | |
| $J(ZOOTTIR) = IMM[O_{Int,p}, O_{Int,n}]$ | u(ZOOII 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 | |
| • | 107 | | • | | |
| | | | | | |
| nterferent Concentration Variations | Minimum | Maximum | Value at cal | | Units |
| CH ₄ range | 0 | 10 | 0 | 50 | mg/m |
| N ₂ O range | 0 | 12 | 0 | 20 | mg/m |
| CO ₂ range Dxygen effect variations | 8 Minimum | 12 Maximum | 0 Value at cal | 15 Performance | mg/m |
| Dxygen effect variations Dxygen effect | Minimum 0 | Maximum 20 | value at cal | Performance 2 | Units mg/m |
| saygon ondot | 1 0 | 20 | | | mg/m |
| nfluence 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 |
| Accourament uncertainty | i | Toot 4 | Toot 0 | Toot 0 | |
| Measurement uncertainty Combined uncertainty | ppm | 0.37 | Test 2 0.37 | Test 3 0.37 | |
| Combined uncertainty | mg/m ³ | 0.57 | 0.57 | 0.59 | |
| Combined uncertainty Combined uncertainty at oxygen reference | mg/m³ | 0.59 | 0.59 | 0.59 | |
| and the second s | mg/m | 2.00 | 2.00 | 2.30 | |
| 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.

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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





REC Ltd Environmental Monitoring Unit 19 Bordesley Green Trading Estate Bordesley Green Road

Birmingham B8 1BZ

Tel: 0845 676 9303 Company Registration No 03133832



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| Page 22 | Uncertainty Estimates:- TOC |

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Monitoring Objectives

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

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

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

| Sampling Location | Emission |
|------------------------------|----------------------|
| 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 |
| тос | TPM/13 | BS EN 12619 : 2013 |
| | | |

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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 | Sampling | | Emission | Authorised | Uncertainty | Detection | Mass | |
|------------------------------|----------|-------|----------|------------|---------------------|-----------|----------|-----|
| St Ives | Time | | Result | Limit | +/- | Limit | Emission | |
| Environmental Chamber Room 1 | Date | Start | End | mg/m³* | mg/m ³ * | mg/m³* | mg/m³* | g/h |
| тос | 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) 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.

| Emiss St I | | Sampling Time | | Emission Result | Authorised Limit | Uncertainty +/- | Detection Limit | Mass Emission | |
|-----------------|----------------|------------------|-------|--------------------|---------------------|---------------------|--------------------|------------------|-----|
| Environmental C | Chamber Room 1 | Date | Start | End | mg/m³∗ | mg/m ³ * | mg/m³* | mg/m³* | g/h |
| тос | Test 1 | 04/11/15 | 16:15 | 16:45 | 8.3 | 75 | 1.2 | 0.2 | 3.5 |
| тос | Test 2 | 04/11/15 | 16:45 | 17:15 | 11.1 | 75 | 1.2 | 0.2 | 4.7 |
| тос | Test 3 | 04/11/15 | 17:15 | 17:45 | 3.4 | 75 | 1.2 | 0.2 | 1.5 |

| ı | * at ref | Stack Gas Weight | 0 °C | Without correction for moisture | |
|---|------------|------------------|-----------|---------------------------------|--|
| | Conditions | 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)

** 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.



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Nm³ 273 K, 101.3 kPa



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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 1m².

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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REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303

Company Registration No 03133832



Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6361, v1

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Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

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

Total organic carbon

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

Sampling Project Personnel Competency And Expiry Dates

| Report prepared by: | Harpreet Badwal | MCERTS No MM03 149 | Level 1 - | Level 2 30/09/2018 | TE1 30/09/2018 | TE2 30/04/2019 | TE3 31/10/2019 | TE4 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 |

Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6361, v1

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| 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 | Traverse | Depth | ΔΡ | Т | Angle | velocity | Traverse | Depth | ΔΡ | Т | Angle | velocity |
|----------|----------|-------|--------------------|----|-------|----------|----------|-------|--------------------|----|-------|----------|
| Point | Line | cm | mmH ₂ O | °C | 0 | m/s | Line | cm | mmH ₂ O | °C | 0 | m/s |
| 1 | Α | | | | | | В | | | | | |
| 2 | Α | | | | | | В | | | | | |
| 3 | Α | | | | | | В | | | | | |
| 4 | Α | | | | | | В | | | | | |
| 5 | Α | 5.0 | 1.0 | 7 | <15 | 4.0 | В | | | | | |
| 6 | Α | 7.1 | 0.7 | 7 | <15 | 3.4 | В | | | | | |
| 7 | Α | 12.9 | 0.8 | 7 | <15 | 3.6 | В | | | | | |
| 8 | Α | 15.0 | 1.2 | 7 | <15 | 4.4 | В | | | | | |
| 9 | Α | | | | | | В | | | | | |
| 10 | Α | | | | | | В | | | | | |
| 11 | Α | | | | | | В | | | | | |
| 12 | Α | | | | | | В | | | | | |

| Average Pitot DP | 0.93 | mmH ₂ O |
|------------------------------|-------|---------------------------------------|
| Average Temperature | 280.2 | К |
| 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 | a Angel of gas flow less than 15° with regard to duct axis | | | |
| b | No local negative flow | | YES | |
| С | Minimum pitot greater than 5Pa | | YES | |
| d | Ratio of highest to lowest local gas velocity less than 3:1 | | | |
| | Minimum local gas velocity | 3.4 | | |
| Maximum local gas velocity 4.4 | | | | |
| Ratio of highest to lowest local gas velocity 1.31 | | | | |
| | | | | |

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± 2

100

| Date | 04/11/2015 |
|------|------------|
| | |

| From | 16:15 | to | 16:45 | 30 minute mean | | | |
|----------------|----------------|----|-----------|----------------|-----------------------|-------------------|----------------------|
| Volatile orgar | nic compounds | | vppm, wet | 5.14 | mg/m³* | 8. | 26 |
| \ <u></u> | | | | | | | |
| From | 16:45 | to | 17:15 | 30 minute mean | l | | |
| Volatile organ | nic compounds | | vppm, wet | 6.89 | mg/m³* | 11 | .07 |
| _ | | | | - | | | |
| From | 17:15 | to | 17:45 | 30 minute mean | l | | |
| Volatile organ | nic compounds | | vppm, wet | 2.14 | mg/m³* | 3. | 45 |
| _ | | | | | | | |
| | | | | | | | |
| Sampling De | tection Limits | | | | | | |
| Volatile organ | nic compounds | | vppm | 0.10 | mg/m³* | 0. | 16 |
| | | | | | | | |
| Reference Ga | as Details | | | | | | |
| Species | | | Units | Value | Cylinder Reference | Analyser Range | Uncertainity $k = 2$ |

Zero And Span Gas Details

Volatile organic compounds

Nitrogen

| 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 |

vppm

99.999

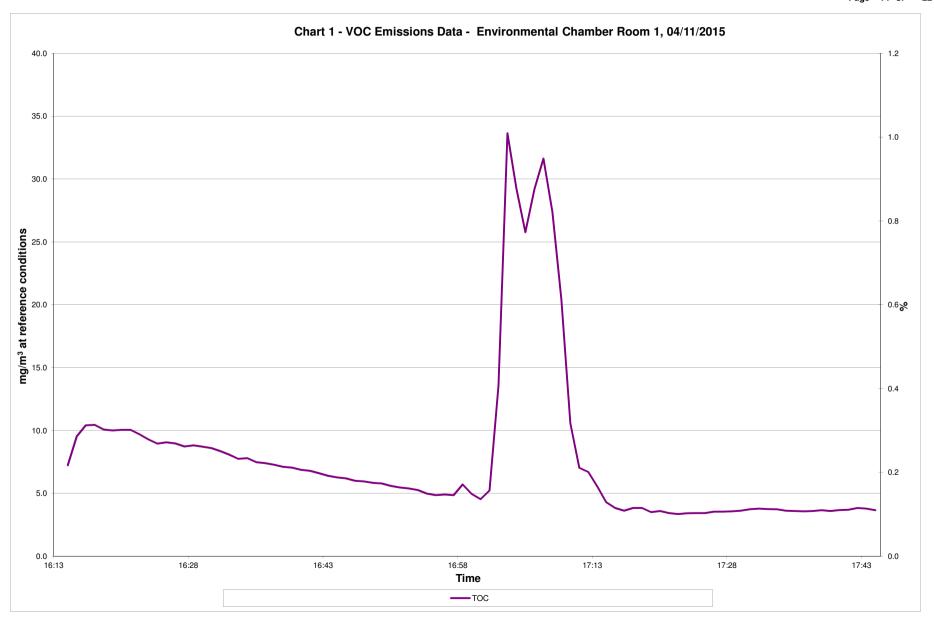
74.7

VCK01959

VC59841

Exhaust Gas Continuous Analysis Data

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Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6361, v1

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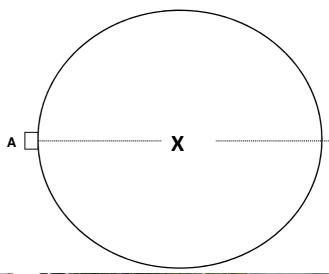
Diagram Of The Sampling Location

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 |





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General Calculations

Stack area:

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

D = Diameter (m) $\pi = 3.142$

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 % (m³ of water vapour in m³ of wet gas)

Vm(std) = Dry gas volume measured, corrected to standard conditions (m³)

mWC = Mass of water collected in the impingers (g)

Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)

Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)

From reference calculations (taken from BS EN 14790):

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

Vm(std) = Dry gas meter volume at standard conditions (m³)

yd = Gas meter calibration coefficient

(V2-V1) = Dry gas meter volume at actual conditions (m³)

Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)

pm = Absolute pressure at the gas meter (kPa) pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):

From reference calculations (taken from EA TGN M2):

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

Estimating Measurment Uncertainty

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

Flow Calculations

Velocity:

From reference calculations (taken from ISO 10780):

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

 $\frac{1}{v}$ = Average velocity (m/s)

 \dot{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 coefficientPe = Absolute gas pressure (kPa)

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

Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m³/s)

v = v Average velocity (m/s)

A =Stack cross-sectional area (m²)

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 (m³/s)

qva = Volume flow rate at actual conditions (m³/s) Ha = Moisture at actual conditions (%volume)

Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure

From reference calculations (taken from BS ISO 9096):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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 gascdry = Concentration dry gasHa = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m³

From reference calculations (taken from EA TGN M2):

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Corr_{rep} Corr_{adj} Corr_{inf} correction of repeatability of measurement $C_{,ppm}$ concentration in ppm concentration given by analyser C_{NO.reading} correction of adjustment Corr fit correction of lack of fit correction of influence quantities

Corr _{0,dr} correction of zero drift Corr s,dr correction of span drift

Calculation of partial uncertainties

u(Corr_{fit}) $\left(\frac{X_{fit,\max}}{100 \times range}\right)$ Where:

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

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

max (S_{0,rep}; S_{srep}) u(Corr_{rep}) Where:

is the standard uncertainty at zero level is the standard uncertainty at span level

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

is the sensitivity coefficient of the influence quantity is the minimum value of the influence quantity during monitoring is the maximum value of the influence quantity during monitoring is the value of the influence quantity during adjustment

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

 c_{j} $Int_{j,test}$ is the sensitivity coefficient of the interferent i $= \max \left[S_{Int,p}; S_{Int,n} \right]$ $u(\Sigma Corr_{int})$ is the concentration of the interferent j used to determine c is the minimum value of the interferent j quantity during monitoring is the maximum value of the interferent i quantity during monitoring

 $\mathsf{Int}_{\mathsf{j},\mathsf{adj}}$ 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 is the sum of interferents with negative impact

Combined uncertainty

$$u(C, ppm) =$$

$$\sqrt{u^2 (corr_{\mathit{fit}}) + u^2 (corr_{\mathit{o,dr}}) + u^2 (corr_{\mathit{s,dr}}) + u^2 (corr_{\mathit{rep}}) + u^2 (corr_{\mathit{s,yf}}) + u^2 (corr_{\mathit{a,press}}) + u^2 (corr_{\mathit{temp}}) + u^2 (corr_{\mathit{volt}}) + u^2 (corr_{\mathit{adj}}) + S_{\mathit{hit}}^{-2}}$$

Overall expanded uncertainty (k = 2)

$$U(C_m) = u(C_m) \times k$$

Uncertainty of NOx measurements

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

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

Combined uncertainty NOx measurements

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

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

Uncertainty of mass concentration at oxygen reference concentration

$$u(C, O2 ref) =$$

$$\sqrt{u^{2}(corr_{\mathit{fit}}) + u^{2}(corr_{\mathit{o,dr}}) + u^{2}(corr_{\mathit{s,dr}}) + u^{2}(corr_{\mathit{rep}}) + u^{2}(corr_{\mathit{s,vf}}) + u^{2}(corr_{\mathit{s,vf}}) + u^{2}(corr_{\mathit{s,otr}}) + u^{2}(corr_{\mathit{sott}}) + u^{2}(corr_{\mathit{odd}}) + S_{\mathit{Int}}^{2} + \left(\frac{u^{2}(O_{2,\mathit{meas,dry}})}{(21 - O_{2,\mathit{meas,dry}})^{2}}\right)}$$

u(C,O_{2,ref)} uncertainty associated with the mass concentration at O₂ ref. concentration mg/m³ C,O_{2,ref} mg/m³ mass concentration at O₂ reference concentration O2 measured concentration % volume uncertainty associated to the measured O2 concentration % (relative to O_{2 meas}) Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6361, v1

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APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

| | Uncertainty | Estimate | For The I | Measureme | ent Of I |
|--|--|------------------|-----------------|---------------|-------------------|
| Analyser Type/Model | Sick I | Maihak | | | |
| Reference Oxygen % | | 0 | (0 = No corre | ction) | |
| | İ | Test 1 | Test 2 | Test 3 | |
| imit value | mg/m ³ | 75 | 75 | 75 | |
| imit 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/m³ | 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 | | | | | |
| ack 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 in a | alaulatad far | the regidual is | annumed to be | . F0//m |
| Zero Drift | % range | 0.00 | 0.00 | 0.00 |) < 5% u(III |
| 2010 21111 | u(Corr, _{Odr}) | 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 | 1 0/ | | | | |
| 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 | | | | | |
| osses in the line | % range | 0.27 | 0.27 | 0.27 | |
| | u(Corr, _{loss}) | 0.01 | 0.01 | 0.00 | |
| Incertainty of calibration gas | % range | 2.0 | 2.0 | 2.0 | |
| | u(Corr, _{cal}) | 0.05 | 0.07 | 0.02 | |
| | | | | | |
| Correction of Influence of Interferents | | | 1 | | |
| N₂O | % range u(Corr, _{N2O}) | 0.00 | 0.00 | 0.00 | |
| CO ₂ | % range | 0.00 | 0.00 | 0.00 | |
| 502 | u(Corr, _{CO2}) | 0.00 | 0.00 | 0.00 | |
| CH ₄ | % range | 0.00 | 0.00 | 0.00 | |
| • | u(Corr, _{CH4}) | 0.00 | 0.00 | 0.00 | |
| Total of interferent influences | % range | 2.50 | 2.50 | 2.50 | |
| $u(\Sigma Corrint) = \max[S_{Int,p}; S_{Int,n}]$ | $u(\Sigma Corr_{int})$ | 0.16 | 0.16 | 0.16 | |
| | | | | | |
| Correction of Influence Quantities | 0/ 20000 | 1.00 | 1.00 | 1.00 | |
| Sensitivity to sample volume flow | % range u(Corr, _{flow}) | 1.60 0.09 | 1.60 0.09 | 1.60 0.09 | |
| Sensitivity to atmospheric pressure | % range | 0.03 | 0.03 | 0.03 | |
| (Not reported) | u(Corr, _{press}) | 0.00 | 0.00 | 0.00 | |
| Sensitivity to ambient temperature | % range | -2.40 | -2.40 | -2.40 | |
| , | 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 | |
| | 1 (0) | | | | |
| 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 | |
| | | | | | |
| nterferent Concentration Variations | Minimum | Maximum | Value at cal | Performance | Units |
| CH ₄ range | 0 | 10 | 0 | 50 | mg/m ³ |
| N ₂ O range | 0 | 0 | 0 | 20 | mg/m ³ |
| CO₂ 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 |
| nfluence Quantitiv Variations | | | | | |
| nfluence Quantitiy Variations | Minimum | Maximum | Value at cal | Performance | Units |
| Sensitivity to sample volume flow | 55 | 65 | 60 | 5 | I/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 | |
| | ma/m ³ | 0.59 | 0.60 | 0.59 | |
| | | | 0.60 | 0.59 | |
| | mg/m ³ | 0.59 | | | |
| Combined uncertainty at oxygen reference | mg/m ³ | | | | |
| Combined uncertainty at oxygen reference Expanded uncertainty expressed with a level of con | mg/m ³ fidence of 95%, k | =2 | | 0.7 | |
| Combined uncertainty at oxygen reference Expanded uncertainty expressed with a level of con Overall uncertainty | mg/m ³ fidence of 95%, k | | 0.7 | 0.7 | |
| Combined uncertainty Combined uncertainty at oxygen reference Expanded uncertainty expressed with a level of con Overall uncertainty Overall uncertainty Overall uncertainty relative to measured value | mg/m ³ fidence of 95%, k | =2 0.7 | 0.7 | | |
| Combined uncertainty at oxygen reference Expanded uncertainty expressed with a level of con Overall uncertainty Overall uncertainty | fidence of 95%, k ppm mg/m³ | =2 0.7 1.2 | 0.7 | 1.2 | |

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

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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







REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

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| Page 18 | Diagram of Sampling Location | | | | | |
| Page 19 | Generic Calculations | | | | | |
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| Page 25 | Uncertainty Estimates:- TOC | | | | | |

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Monitoring Objectives

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

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

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

| Sampling Location | Emission |
|---------------------------------|----------------------|
| 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 |
| тос | TPM/13 | BS EN 12619 : 2013 |
| | | |

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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 | Sampling | | | Emission | Authorised | Uncertainty | Detection | Mass |
|---------------------------------|----------|-------|--------|----------|------------|-------------|-----------|-------|
| St Ives | Time | | Result | Limit | +/- | Limit | Emission | |
| Wet Test Stack 1 (Room Extract) | Date | Start | End | mg/m³∗ | mg/m³* | mg/m³∗ | mg/m³∗ | g/h |
| тос | 02/11/15 | 16:50 | 17:50 | 30.8 | 75 | 1.3 | 0.2 | 131.7 |
| тос | 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)

** 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.



Nm³ 273 K, 101.3 kPa



1783

Nm³ 273 K, 101.3 kPa

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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.

| Emiss | sion at | Sampling | | Emission | Authorised | Uncertainty | Detection | Mass | |
|----------------|------------------|----------|-------|----------|------------|---------------------|-----------|---------------------|-------|
| St I | lves | Time | | Result | Limit | +/- | Limit | Emission | |
| Wet Test Stack | 1 (Room Extract) | Date | Start | End | mg/m³* | mg/m ³ * | mg/m³* | mg/m ³ * | g/h |
| TOC | Test 1 | 02/11/15 | 16:50 | 17:20 | 41.5 | 75 | 1.4 | 0.2 | 177.5 |
| тос | Test 2 | 02/11/15 | 17:20 | 17:50 | 20.1 | 75 | 1.2 | 0.2 | 85.9 |
| тос | Test 3 | 03/11/15 | 08:30 | 09:00 | 17.5 | 75 | 1.2 | 0.2 | 74.9 |

| * at ref | Stack Gas Weight | 0 °C | Without correction for moisture | | |
|------------|------------------|-----------|---------------------------------|--|--|
| Conditions | 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)

** 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 1m².

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.

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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 1 (Room Extract)

Sampling Date 2nd & 3rd November 2015
Report Date 7th December 2015

Report Date 7th December 500 Number EM-2112

Job Number EM-211 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







REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303

Company Registration No 03133832



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APPENDIX 1

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Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

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

Total organic carbon

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

Sampling Project Personnel Competency And Expiry Dates

| Report prepared by: | Harpreet Badwal | MCERTS No MM03 149 | Level 1 - | Level 2 30/09/2018 | TE1 30/09/2018 | TE2 30/04/2019 | TE3 31/10/2019 | TE4 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 |

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APPENDIX 2

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| 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 | m² |

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

| Traverse | Traverse | Depth | ΔΡ | T | Angle | velocity | Traverse | Depth | ΔΡ | Т | Angle | velocity |
|----------|----------|-------|--------------------|----|-------|----------|----------|-------|--------------------|----|-------|----------|
| Point | Line | cm | mmH ₂ O | °C | 0 | m/s | Line | cm | mmH ₂ O | °C | 0 | m/s |
| 1 | Α | | | | | | В | | | | | |
| 2 | Α | 5.0 | 0.1 | 14 | <15 | 1.3 | В | | | | | |
| 3 | Α | 10.5 | 0.1 | 14 | <15 | 1.3 | В | | | | | |
| 4 | Α | 17.5 | 0.1 | 14 | <15 | 1.3 | В | | | | | |
| 5 | Α | 24.5 | 0.3 | 14 | <15 | 2.2 | В | | | | | |
| 6 | Α | 31.5 | 0.2 | 14 | <15 | 1.8 | В | | | | | |
| 7 | Α | 38.5 | 0.2 | 14 | <15 | 1.8 | В | | | | | |
| 8 | Α | 45.5 | 0.1 | 14 | <15 | 1.3 | В | | | | | |
| 9 | Α | 52.5 | 0.3 | 14 | <15 | 2.2 | В | | | | | |
| 10 | Α | 59.5 | 0.5 | 14 | <15 | 2.9 | В | | | | | |
| 11 | Α | 65.0 | 0.4 | 14 | <15 | 2.6 | В | | | | | |
| 12 | Α | | | | _ | | В | | | | | |

| Average Pitot DP | 0.22 | mmH₂O |
|------------------------------|-------|---------------------------------------|
| Average Temperature | 287.2 | К |
| 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

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

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Date 02/11/2015

| From | 16:50 | to | 17:20 | 30 minute mean | | |
|----------------|---------------|----|-----------|----------------|----------|-------|
| Volatile organ | ic compounds | | vppm, wet | 25.80 | mg/m³* | 41.46 |
| | • | | | | <u> </u> | |
| _ | | | | | | |
| From | 17:20 | to | 17:50 | 30 minute mean | | |
| Volatile organ | ic compounds | | vppm, wet | 12.48 | mg/m³* | 20.06 |
| _ | | | | | | |
| | | | | | | |
| | | | | | | |
| Sampling Dot | action Limite | | | | | |

Sampling Detection Limits

| 1 0 | | | | |
|----------------------------|------|------|--------|------|
| 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

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Date 03/11/2015

| From | 08:30 | to | 09:00 | 30 minute mean | l | |
|------------------|-------------|----|-----------|----------------|--------|-------|
| Volatile organic | c 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

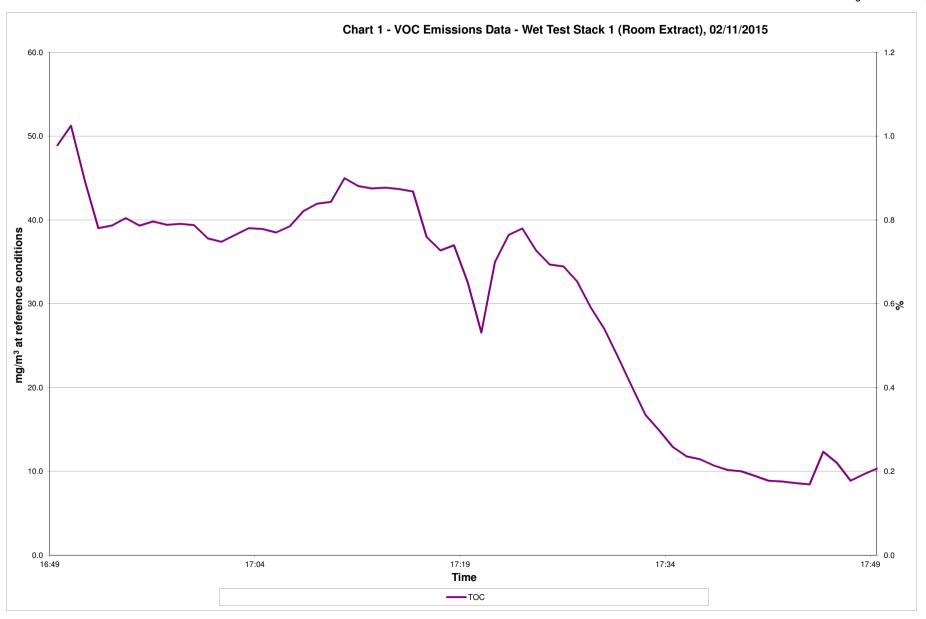
| Species | Units | Value | Cylinder Reference | Analyser Range | Uncertainity $k = 2$ |
|----------------------------|-------|--------|-----------------------|-------------------|----------------------|
| Nitrogen | % | 99.999 | VCK01959 | - | ± 2 |
| Volatile organic compounds | vppm | 74.7 | VC59841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

Zero And Span Gas Details

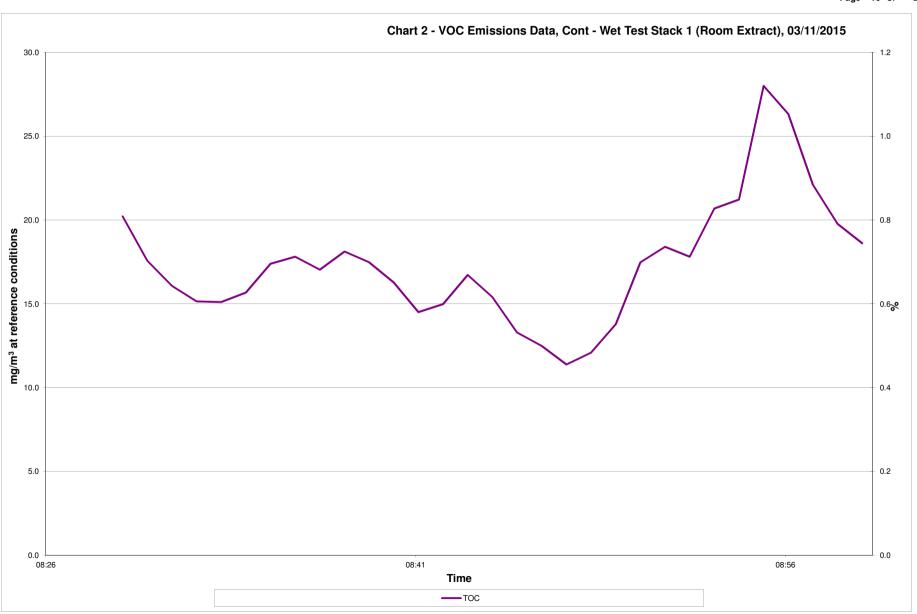
| Species | units | Initial Time | 08:19 | Final Time | 10:10 |
|----------------------------|-------|--------------|--------------|------------|------------|
| | | Initial Zero | Initial Span | Final Zero | Final Span |
| Volatile organic compounds | vppm | 0.00 | 74.70 | -0.21 | 74.14 |

Exhaust Gases Continuous Analysis Data, Continued





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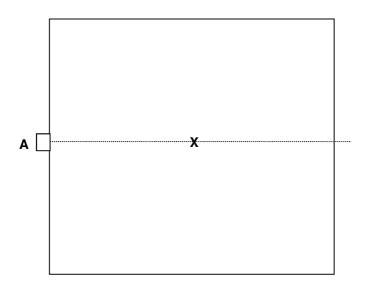
APPENDIX 3

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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





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General Calculations

Stack area:

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

D = Diameter (m) $\pi = 3.142$

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 % (m³ of water vapour in m³ of wet gas)

Vm(std) = Dry gas volume measured, corrected to standard conditions (m³)

mWC = Mass of water collected in the impingers (g)

Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)

Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)

From reference calculations (taken from BS EN 14790):

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

Vm(std) = Dry gas meter volume at standard conditions (m³)

yd = Gas meter calibration coefficient

(V2-V1) = Dry gas meter volume at actual conditions (m³)

Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)

pm = Absolute pressure at the gas meter (kPa) pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):

From reference calculations (taken from EA TGN M2):

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

Estimating Measurment Uncertainty

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

Flow Calculations

Velocity:

From reference calculations (taken from ISO 10780):

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

 $\frac{1}{v}$ = Average velocity (m/s)

 \dot{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 coefficientPe = Absolute gas pressure (kPa)

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

Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m³/s)

v = v Average velocity (m/s)

A =Stack cross-sectional area (m²)

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 (m³/s)

qva = Volume flow rate at actual conditions (m³/s) Ha = Moisture at actual conditions (%volume)

Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure

From reference calculations (taken from BS ISO 9096):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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 gascdry = Concentration dry gasHa = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m³

From reference calculations (taken from EA TGN M2):

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

Corr_{rep} Corr_{adj} Corr_{inf} correction of repeatability of measurement $C_{,ppm}$ concentration in ppm concentration given by analyser C_{NO.reading} correction of adjustment correction of lack of fit correction of influence quantities

Corr fit Corr _{0,dr} correction of zero drift

Corr s,dr correction of span drift

Calculation of partial uncertainties

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

Where:

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

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

u(Corr_{0.dr})

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

Where:

is the standard uncertainty at zero level is the standard uncertainty at span level

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

 $u(Corr_{loss})$ is the uncertainty due to losses in sample line is the uncertainty due to losses in sample line is the concentration of sample loss at span level

 $u(Corr_{cal})$ is the expanded uncertainty of the calibration gas

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

is the sensitivity coefficient of the influence quantity

is the minimum value of the influence quantity during monitoring is the maximum value of the influence quantity during monitoring is the value of the influence quantity during adjustment

 $= \frac{c_{j}}{Int_{j,lest}} \sqrt{\frac{Int_{j,max}^{2} + Int_{j,min} \times Int_{j,max} + Int_{j,min}^{2}}{3}}$

 $= \max \left[S_{Int,p}; S_{Int,n} \right]$

is the sensitivity coefficient of the interferent i

 c_{j} Int_{j,test} is the concentration of the interferent j used to determine c is the minimum value of the interferent j quantity during monitoring is the maximum value of the interferent i quantity during monitoring

 $\mathsf{Int}_{\mathsf{j},\mathsf{adj}}$ is the concentration of the interferent j in the cal gas used to adjust the analyse

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

Combined uncertainty

 $u(\Sigma Corr_{int})$

 $u(C_{,ppm})$

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{o,dr}) + u^2(corr_{s,dr}) + u^2(corr_{ep}) + u^2(corr_{s,yf}) + u^2(corr_{d,press}) + u^2(corr_{epp}) + u^2(corr_{odi}) + S_{hit}^{-2}} + u^2(corr_{epp}) + u^2(corr_{odi}) + S_{hit}^{-2}$$

Overall expanded uncertainty (k = 2)

 $U(C_m) = u(C_m) \times k$

Uncertainty of NOx measurements

is the concentration of NOx measured by the analyser is the ratio of NO:Nox in the stack gas

C_{NOx} is the NOx converter efficiency

Combined uncertainty NOx measurements

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

Uncertainty of mass concentration at oxygen reference concentration

u(C, O2 ref)

$$\sqrt{u^{2}(corr_{fit}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{s,dr}) + u^{2}(corr_{rep}) + u^{2}(corr_{s,vf}) + u^{2}(corr_{s,vf}) + u^{2}(corr_{temp}) + u^{2}(corr_{temp}) + u^{2}(corr_{o,dt}) + u^{2}(corr_{odt}) + S_{lnt}^{2}} + \left(\frac{u^{2}(O_{2,meas,dry})}{(21 - O_{2,meas,dry})^{2}}\right) + u^{2}(corr_{temp}) + u^{2}(corr_{temp}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{temp}) $

u(C,O_{2,ref)} uncertainty associated with the mass concentration at O₂ ref. concentration mg/m³ C,O_{2,ref} mg/m³ mass concentration at O₂ reference concentration O2 measured concentration % volume

uncertainty associated to the measured O2 concentration

% (relative to O_{2 meas})

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APPENDIX 4

Uncertainty Estimate For The Measurement Of Total Organic Carbon

| U | ncertainty | Estimate | For The N | <i>l</i> leasureme | ent Of Tota |
|--|---------------------------|---------------|-------------------|--------------------|----------------------------|
| Analyser Type/Model | Sick I | Maihak | 1 | | |
| Reference Oxygen % | | 0 | (0 = No corre | ction) | |
| | | | | | |
| | | Test 1 | Test 2 |] | |
| Limit value | mg/m ³ | 75 | 75 | | |
| Limit value | ppm | 46.7 | 46.7 | | |
| Measured concentration Measured concentration | ppm mg/m ³ | 25.8 41.5 | 12.5 20.1 | 1 | |
| Concentration at O ₂ ref. concentration | mg/m ³ | N/A | N/A | 1 | |
| 2 | mg/m | | | 1 | |
| Calibration gas | ppm | 74.7 | 74.7 | Ì | |
| 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 | 1 | |
| O-marking of Lock of Eit | | | | | |
| Correction of Lack of Fit Lack of fit | % range | 2.0 | 2.0 | 1 | |
| Lack of lit | u(Corr, _{fit}) | 0.11 | 0.11 | † | |
| | G(GG.1,111) | 0 | 0 | 1 | |
| Corrections of Zero and Span Drift | (*All drift is c | alculated for | the residual is | s assumed to be | e < 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 Popostobility of Massacrament | | | | | |
| Correction of Repeatability of Measurement Repeatability SD at span level | % range | 0.0 | 0.0 | ì | |
| (Not reported) | u(Corr,ren) | 0.00 | 0.00 | 1 | |
| (spanner) | . (= - · · rep/ | 5.00 | 0.00 | 1 | |
| 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 ₂ O | % range | | | 1 | |
| 1420 | u(Corr, _{N2O}) | 0.00 | 0.00 | | |
| CO ₂ | % range | 0.00 | 0.00 | 1 | |
| | u(Corr, _{CO2}) | 0.00 | 0.00 | 1 | |
| CH ₄ | % range | | | 1 | |
| | u(Corr, _{CH4}) | 0.00 | 0.00 |] | |
| Total of interferent influences | % range | 2.50 | 2.50 | | |
| $u(\Sigma Corrint) = \max[S_{lnt,p}; S_{lnt,n}]$ | u(ΣCorr _{int}) | 0.16 | 0.16 | J | |
| Correction of Influence Quantities | | | | | |
| Sensitivity to sample volume flow | % range | 1.60 | 1.60 | 1 | |
| constantly to cample volume now | u(Corr, _{flow}) | 0.09 | 0.09 | 1 | |
| Sensitivity to atmospheric pressure | % range | | | 1 | |
| (Not reported) | u(Corr,press) | 0.00 | 0.00 | 1 | |
| Sensitivity to ambient temperature | % range | -2.40 | -2.40 | 1 | |
| | 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 | 1 | 0.00 | 0.00 | 1 | |
| riido | | 0.00 | 0.00 | 1 | |
| Maximum standard uncertainty | u(Corr,max) | 0.26 | 0.12 | 1 | |
| 5% of maximum standard uncertainty | u(Corr,5%) | 0.01 | 0.01 |] | |
| | | | | | |
| Interferent Concentration Variations | Minimum | Maximum | Value of ool | Performance | Unito |
| CH ₄ range | Minimum 0 | Maximum 10 | Value at cal 0 | Performance 50 | Units ma/m ³ |
| N ₂ O 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 | 1 841 1 | Mari | 1 V-1. · · | Dowl | 11.5 |
| Consitivity to comple volume flow | Minimum | Maximum | Value at cal | Performance | Units |
| Sensitivity to sample volume flow Sensitivity to atmospheric pressure | 55 99 | 65 100 | 60 99 | 5 1 | l/h kPa |
| Sensitivity to atmospheric pressure Sensitivity to ambient temperature | 278 | 313 | 288 | 10 | KFa |
| Sensitivity to electrical voltage | 187 | 250 | 230 | 5 | V |
| , | | | | | |
| Measurement uncertainty | | Test 1 | Test 2 |] | |
| Combined uncertainty | ppm | 0.45 | 0.39 | 1 | |
| Combined uncertainty | mg/m ³ | 0.72 | 0.62 | 1 | |
| Combined uncertainty at oxygen reference | mg/m ³ | 0.72 | 0.62 | J | |
| Evnanded uncertainty evarenced with a level of a cold | longo of OE9/ | -0 | | | |
| Expanded uncertainty expressed with a level of confid | | | 0.0 | 1 | |
| Overall uncertainty Overall uncertainty | ppm mg/m ³ | 0.9 1.4 | 0.8 1.2 | 1 | |
| Overall uncertainty Overall uncertainty relative to measured value | mg/m | 3.5 | 6.2 | 1 | |
| | | | | | |
| | % | 9.6 | 8.3 | 1 | |
| Overall uncertainty relative to measured value Overall uncertainty relative to range Overall uncertainty relative to ELV | | | | 1 | |

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 | |

| 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 |
| | | |

| 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 o | alculated for |
|------------------------------------|--------------------------|---------------|
| Zero Drift | % range | 0.00 |
| | u(Corr, _{0dr}) | 0.00 |
| Span Drift | % range | 0.00 |
| | u(Corr.cdr) | 0.00 |

or ∴ the residual is assumed to be < 5% u(max))

| Zero Driit | % range | 0.00 |
|--|--------------------------|------|
| | u(Corr, _{0dr}) | 0.00 |
| Span Drift | % range | 0.00 |
| | u(Corr, _{sdr}) | 0.00 |
| Correction of Repeatability of Measurement | | |

| Correction of repeatability of weasurement | | |
|--|--------------------------|------|
| 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 ₂ O | % range | |
|--|--------------------------|------|
| | u(Corr, _{N2O}) | 0.00 |
| CO ₂ | % range | |
| | u(Corr, _{CO2}) | 0.00 |
| CH₄ | % range | |
| | u(Corr, _{CH4}) | 0.00 |
| Total of interferent influences | % range | 2.50 |
| $u(\Sigma Corrint) = \max[S_{Int,p}; S_{Int,n}]$ | $u(\Sigma Corr_{int})$ | 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 |
|--------------------------------------|---------|---------|--------------|-------------|-------------------|
| CH₄ range | 0 | 10 | 0 | 50 | mg/m ³ |
| N ₂ O 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 | ma/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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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







REC Ltd Environmental Monitoring

Unit 19 Bordesley Green Trading Estate Bordesley Green Road Birmingham B8 1BZ

Tel: 0845 676 9303 Company Registration No 03133832



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| Page 3 | Special Monitoring Requirements |
| Page 3 | Summary Of Methods |
| Page 4 | Summary Of Results |
| Page 5 | Summary Of Results, Exhaust Gases |
| Page 6 | Operating Information |
| Page 6 | Comments On Monitoring Procedures |
| Page 7 | Part 2: Supporting Information |
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| Page 9 | Emission Monitoring Procedures and Instrumentation |
| Page 10 | Sampling Personnel |
| Page 10 | Equipment References |
| Page 11 | Appendix 2 |
| Page 12 | Preliminary Velocity Traverse Data |
| Page 13 | Exhaust Gases - Continuous Analysis Data |
| Page 14 | Exhaust Gases - Continuous Analysis Data, Continued |
| Page 15 | Chart 1 - VOCs Emissions Data, 02/11/2015 |
| Page 16 | Chart 2 - VOCs Emissions Data Cont, 03/11/2015 |
| Page 17 | Appendix 3 |
| Page 18 | Diagram of Sampling Location |
| Page 19 | Generic Calculations |
| Page 20 | Flow Calculations |
| Page 21 | Concentration Calculation |
| Page 22 | Uncertainty Estimate Calculations - Instrumental Techniques |
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| Page 24 | Uncertainty Estimates:- TOC |
| Page 25 | Uncertainty Estimates:- TOC |

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Monitoring Objectives

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

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

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

| Sampling Location | Emission |
|--|----------------------|
| 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 |
| тос | TPM/13 | BS EN 12619 : 2013 |
| | | |

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Summary Of Results

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

Linx Printing Technologies Limited

| Emission at | Sampling | | Emission | Authorised | Uncertainty | Detection | Mass | |
|--|----------|-------|----------|------------|-------------|-----------|----------|--------|
| St Ives | Time | | Result | Limit | +/- | Limit | Emission | |
| Wet Test Stack 2 (Individual Test Rig Extract) | Date | Start | End | mg/m³* | mg/m³* | mg/m³* | mg/m³* | g/h |
| тос | 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) 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 The results were measured from the sample positions downstream of the arrestment plant.

Linx Printing Technologies Limited

| | Emission at | | Sampling | | Emission | Authorised | Uncertainty | Detection | Mass |
|----------------|-----------------------------------|----------|----------|-------|---------------------|---------------------|-------------|-----------|----------|
| | St Ives | | Time | | Result | Limit | +/- | Limit | Emission |
| Wet Test Stack | c 2 (Individual Test Rig Extract) | Date | Start | End | mg/m ³ * | mg/m ³ * | mg/m³* | mg/m³* | 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 | Stack Gas Weight | 0 °C | Without correction for moisture |
|------------|------------------|-----------|---------------------------------|
| Conditions | 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) 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

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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 | Ink Printer Testing | Continuous | N/A | Methyl - Ethyl | None | Normal |
| November 2015 | Individual Rig Extraction | | | Ketone & Acetone | | 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 1m².

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.



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







1783

REC Ltd Environmental Monitoring

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Tel: 0845 676 9303

Company Registration No 03133832



Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6363, v1

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APPENDIX 1

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Emission Monitoring Procedures And Instrumentation

Gas velocity and temperature

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

Total organic carbon

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

Sampling Project Personnel Competency And Expiry Dates

| Report prepared by: | Harpreet Badwal | MCERTS No MM03 149 | Level 1 | Level 2 30/09/2018 | TE1 30/09/2018 | TE2 30/04/2019 | TE3 31/10/2019 | TE4 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 |

Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6363, v1

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APPENDIX 2

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| - | 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 | m² |

| Stack Diameter (circular) | 0.30 | m |
|---------------------------|------|---|
| | | _ |

| Traverse | Traverse | Depth | ΔΡ | Т | Angle | velocity | Traverse | Depth | ΔΡ | Т | Angle | velocity |
|----------|----------|-------|--------------------|----|-------|----------|----------|-------|--------------------|----|-------|----------|
| Point | Line | cm | mmH ₂ O | °C | 0 | m/s | Line | cm | mmH ₂ O | °C | 0 | m/s |
| 1 | Α | | | | | | В | | | | | |
| 2 | Α | | | | | | В | | | | | |
| 3 | Α | 5.0 | 8.8 | 17 | <15 | 12.0 | В | 5.0 | 7.4 | 17 | <15 | 11.1 |
| 4 | Α | 5.3 | 12.2 | 17 | <15 | 14.2 | В | 5.3 | 8.3 | 17 | <15 | 11.7 |
| 5 | Α | 7.5 | 12.4 | 17 | <15 | 14.3 | В | 7.5 | 8.1 | 17 | <15 | 11.5 |
| 6 | Α | 10.7 | 11.0 | 17 | <15 | 13.5 | В | 10.7 | 8.9 | 17 | <15 | 12.1 |
| 7 | Α | 19.3 | 10.1 | 17 | <15 | 12.9 | В | 19.3 | 10.5 | 17 | <15 | 13.1 |
| 8 | Α | 22.5 | 8.8 | 17 | <15 | 12.0 | В | 22.5 | 12.1 | 17 | <15 | 14.1 |
| 9 | Α | 24.7 | 8.1 | 17 | <15 | 11.5 | В | 24.7 | 13.5 | 17 | <15 | 14.9 |
| 10 | Α | 25.0 | 7.3 | 17 | <15 | 11.0 | В | 25.0 | 11.6 | 17 | <15 | 13.8 |
| 11 | Α | | | | | | В | | | | | |
| 12 | Α | | | | | | В | | | | | |

| Average Pitot DP | 9.85 | mmH ₂ O |
|------------------------------|-------|---------------------------------------|
| Average Temperature | 290.2 | К |
| 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

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

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Date 02/11/2015

| From | 16:00 | to | 16:30 | 30 minute mean | | |
|-----------------|-------------|----|-----------|----------------|--------|--------|
| Volatile organi | c 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

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Date 03/11/2015

| From | 09:05 | to | 09:35 | 30 minute mean | | |
|-----------------|-------------|----|-----------|----------------|--------|--------|
| Volatile organi | c compounds | | vppm, wet | 313.73 | mg/m³* | 504.21 |
| | | | | | | |
| From | 09:35 | to | 10:05 | 30 minute mean | | |
| Volatile organi | c compounds | | vppm, wet | 335.28 | mg/m³* | 538.84 |
| _ | | | | | | |

Sampling Detection Limits

| - Camping 2 steetier 2 mile | | | | |
|-----------------------------|------|------|--------|------|
| Volatile organic compounds | vppm | 0.10 | mg/m³* | 0.16 |

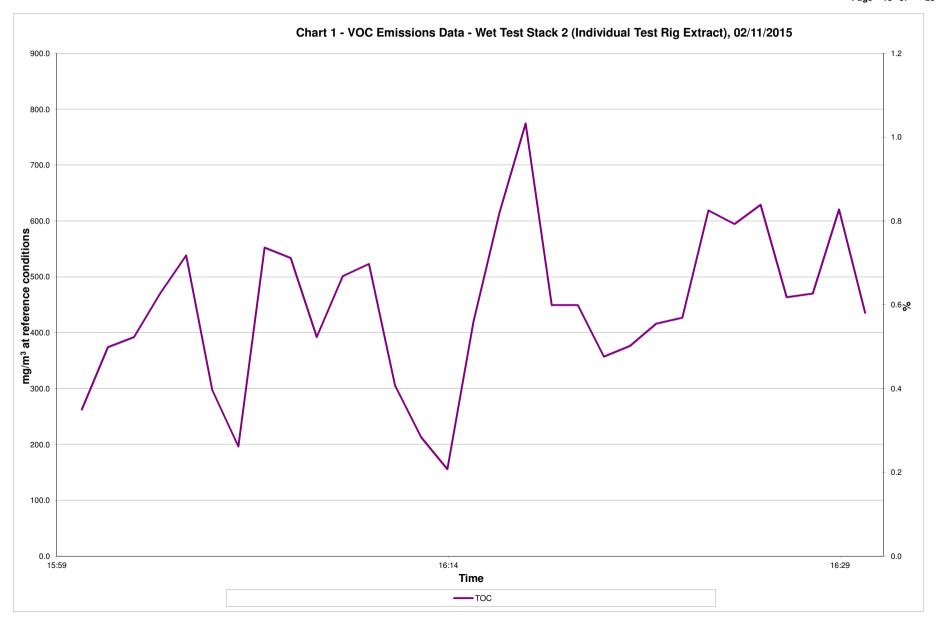
Reference Gas Details

| Species | Units | Value | Cylinder Reference | Analyser Range | Uncertainity $k = 2$ |
|----------------------------|-------|--------|-----------------------|-------------------|----------------------|
| Nitrogen | % | 99.999 | VCK01959 | 1 | ± 2 |
| Volatile organic compounds | vppm | 74.7 | VC59841 | 10 | ± 2 |

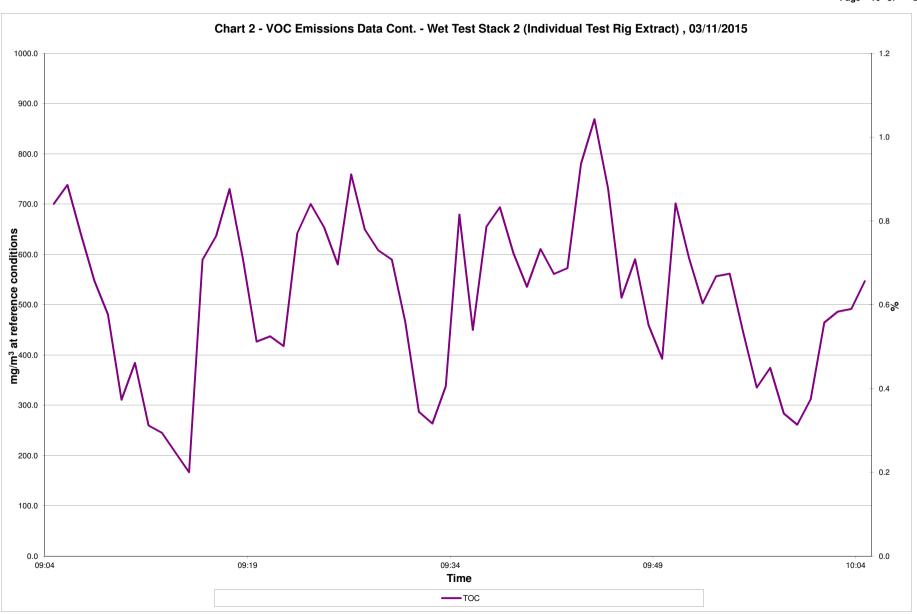
Zero And Span Gas Details

| 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



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APPENDIX 3

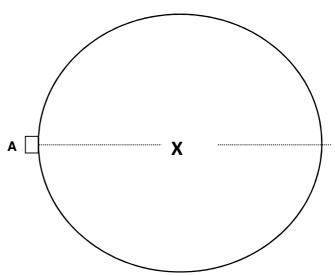
Diagram Of The Sampling Location

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

Traverse length =

| | m |
|--|---|
| | |

| Point | % of D | Location |
|-------|--------|----------|
| | | cm |
| 1 | 50.0 | 15.0 |







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General Calculations

Stack area:

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

D = Diameter (m) $\pi = 3.142$

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 % (m³ of water vapour in m³ of wet gas)

Vm(std) = Dry gas volume measured, corrected to standard conditions (m³)

mWC = Mass of water collected in the impingers (g)

Mw = Molecular weight of water, 18.01534 rounded to 18 (g/mol)

Vmol(std) = Molar volume of water at standard conditions = 0.0224 (m3/mol)

Gas meter volume at standard conditions (STP)

From reference calculations (taken from BS EN 14790):

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

Vm(std) = Dry gas meter volume at standard conditions (m³)

yd = Gas meter calibration coefficient

(V2-V1) = Dry gas meter volume at actual conditions (m³)

Tm = Actual Temperature (K)
Tstd = Standard temperature (273 K)

pm = Absolute pressure at the gas meter (kPa) pstd = Standard gas pressure (101.3 kPa)

Isokenetic Ratio (%):

From reference calculations (taken from EA TGN M2):

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

Estimating Measurment Uncertainty

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

Flow Calculations

Velocity:

From reference calculations (taken from ISO 10780):

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

 $\frac{1}{v}$ = 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 coefficientPe = Absolute gas pressure (kPa)

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

Volume flow rate

From reference calculations (taken from ISO 10780):

$$q_{va} = vA$$

qva = Average flow rate (m³/s)

v = v Average velocity (m/s)

A =Stack cross-sectional area (m²)

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 (m³/s)

qva = Volume flow rate at actual conditions (m³/s) Ha = Moisture at actual conditions (%volume)

Hm = Reference moisture (%volume)

Volume flow rate corrected for temperature and pressure

From reference calculations (taken from BS ISO 9096):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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):

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

qm =Corrected volume flowrate (m³/s)

qva = Volume flow rate at actual conditions (m³/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 gascdry = Concentration dry gasHa = Water vapour content (%vol)

Conversion of parts per million (ppm) to mg/m³

From reference calculations (taken from EA TGN M2):

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

molar volume at 273K = 22.4 litres

When Converting TOC

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

Calculation of Uncertainty Estimates - Instrumental Monitoring Techniques

Model equation

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

correction of repeatability of measurement $C_{,ppm}$ concentration in ppm

Corr_{rep} Corr_{adj} Corr_{inf} concentration given by analyser C_{NO.reading} correction of adjustment Corr fit correction of lack of fit correction of influence quantities Corr _{0,dr} correction of zero drift Corr s,dr correction of span drift

Calculation of partial uncertainties

u(Corr_{fit}) $\left(\frac{X_{fit,\max}}{100 \times range}\right)$ Where:

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

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

u(Corr_{0.dr})

max (S_{0,rep}; S_{srep}) u(Corr_{rep}) Where:

is the standard uncertainty at zero level is the standard uncertainty at span level

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

is the concentration of sample loss at span level $u(Corr_{cal})$ is the expanded uncertainty of the calibration gas

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

is the sensitivity coefficient of the influence quantity

is the minimum value of the influence quantity during monitoring is the maximum value of the influence quantity during monitoring is the value of the influence quantity during adjustment

 $= \frac{c_{j}}{Int_{j,lest}} \sqrt{\frac{Int_{j,max}^{2} + Int_{j,min} \times Int_{j,max} + Int_{j,min}^{2}}{3}}$

 c_{j} $Int_{j,test}$ is the sensitivity coefficient of the interferent i $= \max \left[S_{Int,p}; S_{Int,n} \right]$ $u(\Sigma Corr_{int})$ is the concentration of the interferent j used to determine c

is the minimum value of the interferent j quantity during monitoring is the maximum value of the interferent i quantity during monitoring

 $\mathsf{Int}_{\mathsf{j},\mathsf{adj}}$ is the concentration of the interferent j in the cal gas used to adjust the analyse $S_{int,p}$

is the sum of interferents with positive impact is the sum of interferents with negative impact

Combined uncertainty

 $u(C_{,ppm})$

$$\sqrt{u^2(corr_{fit}) + u^2(corr_{o,dr}) + u^2(corr_{s,dr}) + u^2(corr_{ep}) + u^2(corr_{s,yf}) + u^2(corr_{a,press}) + u^2(corr_{temp}) + u^2(corr_{volt}) + u^2(corr_{adj}) + S_{hit}}$$

Overall expanded uncertainty (k = 2)

 $U(C_m) = u(C_m) \times k$

Uncertainty of NOx measurements

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

is the NOx converter efficiency

Combined uncertainty NOx measurements

$$\sqrt{u^{2}(corr_{fit}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{s,dr}) + u^{2}(corr_{rep}) + u^{2}(corr_{rep}) + u^{2}(corr_{s,vf}) + u^{2}(corr_{a,press}) + u^{2}(corr_{temp}) + u^{2}(corr_{volt}) + u^{2}(corr_{odj}) + S_{lnt}^{2} + u^{2}(corr_{NOx,comv}) + u^{2}(corr_{temp}) + u^{2}(cor$$

Uncertainty of mass concentration at oxygen reference concentration

u(C, O2 ref)

$$\sqrt{u^{2}(corr_{fit}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{s,dr}) + u^{2}(corr_{rep}) + u^{2}(corr_{s,vf}) + u^{2}(corr_{s,vf}) + u^{2}(corr_{temp}) + u^{2}(corr_{temp}) + u^{2}(corr_{o,dt}) + u^{2}(corr_{odt}) + S_{lnt}^{2}} + \left(\frac{u^{2}(O_{2,meas,dry})}{(21 - O_{2,meas,dry})^{2}}\right) + u^{2}(corr_{temp}) + u^{2}(corr_{temp}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{o,dr}) + u^{2}(corr_{temp}) $

u(C,O_{2,ref)} uncertainty associated with the mass concentration at O₂ ref. concentration mg/m³ C,O_{2,ref} mg/m³ mass concentration at O₂ reference concentration O2 measured concentration % volume uncertainty associated to the measured O2 concentration % (relative to O_{2 meas}) Linx Printing Technologies Limited, St Ives, Permit No: B18/14, R/15-6363, v1

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APPENDIX 4

Uncertainty Estimate For The Me nt Of Total Organic Carbon

| | Uncertaint | / Estimate | For The I | Measurem | ent Of T |
|--|----------------------------|--------------|-----------------|--------------|-------------------|
| Analyser Type/Model | Sick | Maihak | 1 | | |
| Reference Oxygen % | | 0 | (0 = No corre | ction) | |
| | | Toot 1 | 1 | | |
| Limit value | mg/m ³ | Test 1 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/m³ | N/A | | | |
| - | ı | | | | |
| 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 | 1 | | |
| | u(Corr, _{fit}) | 0.11 | 1 | | |
| | | | | | |
| Corrections of Zero and Span Drift | | | the residual is | assumed to b | e < 5% u(ma |
| Zero Drift | % range | 0.00 | | | |
| | u(Corr, _{0dr}) | 0.00 | 4 | | |
| Span Drift | % range | 0.00 | 1 | | |
| | u(Corr, _{sdr}) | 0.00 |] | | |
| Correction of Repeatability of Measurement | | | | | |
| Repeatability SD at span level | % range | 0.0 | 1 | | |
| Not reported) | u(Corr, _{rep}) | 0.00 | | | |
| Correction of adjustment | | | | | |
| losses in the line | % range | 0.09 | 1 | | |
| | u(Corr, _{loss}) | 0.15 | | | |
| Uncertainty of calibration gas | % range | 2.0 | | | |
| | u(Corr, _{cal}) | 2.78 | | | |
| | | | - " | | |
| Correction of Influence of Interferents | 0/ 10000 | 1 | 1 | | |
| N₂O | % range | 0.00 | _ | | |
| 20 | u(Corr, _{N2O}) | 0.00 | _ | | |
| CO ₂ | % range | 0.00 | | | |
| 211 | u(Corr, _{CO2}) | 0.00 | 4 | | |
| CH₄ | % range | 0.00 | 4 | | |
| T | u(Corr, _{CH4}) | 0.00 | 4 | | |
| Total of interferent influences | % range | 2.50 | 4 | | |
| $u(\Sigma Corrint) = \max[S_{Int,p}; S_{Int,n}]$ | $u(\Sigma Corr_{int})$ | 0.16 | J | | |
| Correction of Influence Quantities | | | | | |
| Sensitivity to sample volume flow | % range | 1.60 | 1 | | |
| • • | u(Corr, _{flow}) | 0.09 | 1 | | |
| Sensitivity to atmospheric pressure | % range | | 1 | | |
| (Not reported) | u(Corr, _{press}) | 0.00 | 1 | | |
| Sensitivity to ambient temperature | % range | -2.40 | 1 | | |
| | u(Corr, _{temp}) | -0.28 | 1 | | |
| Sensitivity to electrical voltage | % range | 0.50 | 1 | | |
| (Not reported) | u(Corr, _{volt}) | 0.10 |] | | |
| | L (O) | 0.70 | 1 | | |
| Maximum standard uncertainty | u(Corr, _{max}) | 2.78 | 4 | | |
| 5% of maximum standard uncertainty | u(Corr, _{5%}) | 0.14 | J | | |
| | | | | | |
| nterferent Concentration Variations | Minimum | Maximum | Value at cal | Performance | Units |
| CH ₄ range | 0 | 10 | 0 | 50 | mg/m ³ |
| N ₂ O range | 0 | 0 | 0 | 20 | mg/m ³ |

| Interferent Concentration Variations | Minimum | Maximum | Value at cal | Performance | Units |
|--------------------------------------|---------|---------|--------------|-------------|-------------------|
| CH ₄ range | 0 | 10 | 0 | 50 | mg/m ³ |
| N ₂ O 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 | ma/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

| | Uncertainty | | ; FOI THE ! | vicasureiii | ent Or 10 |
|--|---|--------------------|----------------------|-------------------|--|
| Analyser Type/Model Reference Oxygen % | | Maihak 0 | (0 = No corre | ection) | |
| | Í | Test 1 | Test 2 | 1 | |
| Limit value | mg/m ³ | 75 | 75 | 1 | |
| Limit value | ppm | 46.7 | 46.7 |] | |
| Measured concentration | ppm | 313.7 | 335.3 | | |
| Measured concentration Concentration at O ₂ ref. concentration | mg/m ³ | 504.2 N/A | 538.8 N/A | | |
| Concentration at O ₂ ref. concentration | mg/m ³ | IV/A | IN/A | 1 | |
| Calibration gas | ppm | 74.7 | 74.7 | 1 | |
| 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 | 1 | |
| | u(Corr, _{fit}) | 0.11 | 0.11 |] | |
| | | | | | |
| Corrections of Zero and Span Drift Zero Drift | (*All drift is c | alculated for 0.00 | the residual is 0.00 | assumed to be | e < 5% u(ma) |
| Zelo Dint | u(Corr, _{Odr}) | 0.00 | 0.00 | | |
| Span Drift | % range | 0.00 | 0.00 | 1 | |
| | u(Corr, _{sdr}) | 0.00 | 0.00 |] | |
| | | | | | |
| Correction of Repeatability of Measurement Repeatability SD at span level | 0/ range | 0.0 | 0.0 | 1 | |
| (Not reported) | % range u(Corr, _{rep}) | 0.00 | 0.00 | 1 | |
| 7P | - (· · iep / | 2.00 | | 1 | |
| Correction of adjustment | | | | • | |
| losses in the line | % range | 0.15 | 0.15 | 1 | |
| Uncertainty of calibration gas | u(Corr, _{loss}) % range | 0.27 2.0 | 0.29 2.0 | + | |
| Officertainty of Calibration gas | u(Corr, _{cal}) | 3.14 | 3.35 | • | |
| | - (/Gai/ | | | 1 | |
| Correction of Influence of Interferents | | | | = | |
| N ₂ O | % range | | | | |
| CO ₂ | u(Corr, _{N2O}) % range | 0.00 | 0.00 | | |
| 002 | u(Corr, _{CO2}) | 0.00 | 0.00 | • | |
| CH ₄ | % range | 0.00 | 0.00 | 1 | |
| | u(Corr, _{CH4}) | 0.00 | 0.00 | | |
| Total of interferent influences $u(\Sigma Corrint) = \max_{l} [S_{lnt,p}; S_{lnt,n}]$ | $\frac{\% \text{ range}}{u(\Sigma Corr_{int})}$ | 2.50 | 2.50 | 1 | |
| $u(2COTITI() \equiv \max[S_{lnt,p}, S_{lnt,n}]$ | u(20011 int) | 0.16 | 0.16 | J | |
| Correction of Influence Quantities | | | | | |
| Sensitivity to sample volume flow | % range | 1.60 | 1.60 |] | |
| | u(Corr, _{flow}) | 0.09 | 0.09 | 1 | |
| Sensitivity to atmospheric pressure | % range | 0.00 | 0.00 | 4 | |
| (Not reported) Sensitivity to ambient temperature | u(Corr, _{press}) % range | 0.00 -2.40 | 0.00 -2.40 | 1 | |
| constantly to ambient temperature | u(Corr, _{temp}) | -0.28 | -0.28 | 1 | |
| Sensitivity to electrical voltage | % range | 0.50 | 0.50 | 1 | |
| (Not reported) | u(Corr, _{volt}) | 0.10 | 0.10 |] | |
| | | | | _ | |
| Maximum standard uncertainty | u(Corr, _{max}) | 3.14 | 3.35 | 1 | |
| 5% of maximum standard uncertainty | u(Corr, _{5%}) | 0.16 | 0.17 | 1 | |
| *************************************** | 0/0/ | | | • | |
| | | | T | In (| 11.5 |
| Interferent Concentration Variations | Minimum 0 | Maximum 10 | Value at cal | Performance 50 | Units ma/m ³ |
| CH₄ range N₂O range | 0 | 0 | 0 | 50 20 | mg/m ³ 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 | | | | | |
| minuence Quantity variations | Minimum | Maximum | Value at cal | Performance | Units |
| Sensitivity to sample volume flow | 55 | 65 | 60 | 5 | I/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 | ĺ | Test 1 | Test 2 | 1 | |
| Combined uncertainty | ppm | 3.16 | 3.38 | 1 | |
| Combined uncertainty | mg/m ³ | 5.08 | 5.43 |] | |
| Combined uncertainty at oxygen reference | mg/m ³ | 5.08 | 5.43 |] | |
| | | . 0 | | | |
| Evpanded upportainty overseased with a level of | confidence of OEC/ | | | | |
| Expanded uncertainty expressed with a level of Overall uncertainty | | | 6.8 | 1 | |
| | ppm | 6.3 10.2 | 6.8 10.9 | | |
| Overall uncertainty | ppm mg/m³ % | 6.3 | 10.9 2.0 |] | |
| Overall uncertainty Overall uncertainty | ppm mg/m ³ | 6.3 10.2 | 10.9 | | |

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