7th October 2016

Kevin Ashcroft
Senior Permitting Officer
Natural Resources Wales
Cambria House
29 Newport Road
Cardiff
CF24 0TP

CRM 083 002 PE L 041

Dear Kevin

Re: Schedule 5 dated 16/08/2016
Permit Reference Number: EPR/GB3490HG/A001
Facility: Nine Mile Point Waste Processing Facility
Operator: Hazrem Environmental Limited

We have reviewed the Schedule 5 Request for Information dated 16th August 2016 and provide responses below to each question. Where referenced, supporting information has also been supplied in the attached documents. The equipment suppliers have indicated that they are not able to provide any further technical information about the plant in addition to what we have provided in this response as it is simply not available.

Table 1: Responses to Schedule 5 Request for Information

Ref	Question	Response
1	**Predicted concentrations of ammonia (and other nitrogen containing gases) in the air extracted from the waste reception area.**	This question has been responded to in a note prepared by our specialist Air Quality Consultants, AQC titled **Emissions Note: Nine Mile Point RTO** which is attached below. The information within this note seeks to address the questions posed by NRW in relation to the initial assumptions made about the emissions from the site. The letter obtained from Andritz should be used to assesses the NOX emissions from the dryer. This letter is attached and provides answers to question 5 below.
2	**The volumetric flow rate of the air being extracted from the waste reception area through the RTO**	This has been calculated at 9100Nm3/h of combustion air from the tipping area. This air will be passed through the dryer then RTO when the dryer is operational. When the dryer it not operational this air will be directed to the RTO. Andritz have provided a document titled **Andritz Drum Drying** which is attached below and the description below with regards to the calculation of the combustion air from the tipping area; 1. The dryer has a heat demand to evaporate the water plus heat losses. 2. To cover this requirement in terms of thermal energy you need a certain amount of natural gas, depending on the calorific value of the gas

		3. Burning natural gas needs oxygen or air, carrying enough oxygen 4. Providing the exact amount of oxygen it is called stoichiometric combustion. 5. In this case for every carbon, hydrogen atom, etc. there is exactly enough oxygen atoms around to produce water and carbon dioxide etc. 6. In practice burners operate in a certain range or excess air 7. For this calculation Andritz used 40% of excess oxygen which is quite a common figure.
3	**A written assessment of the fate of ammonia and other nitrogen containing gases as they are treated in the RTO and their impact on the overall NOx emissions from the site.**	This question has been responded to in the note prepared by AQC titled **Emissions Note: Nine Mile Point RTO** and is attached.
4	**Prediction of the concentration of NOx resulting from the burning of natural gas in the RTO and the gas flow rate exiting the RTO both as maximum and operating capacity.**	This question has been responded to in a note prepared by AQC titled **Emissions Note: Nine Mile Point RTO** and is attached.
5	**The manufacturer's specification for the dryer. The specification shall state the concentration of NOx produced by the dryer and the flow rate of emissions from the dryer operating at maximum rate.**	The **specification for the dryer** is attached below. It does not state the concentration of NOx as this is not a requirement in Austria. However, a letter has been obtained from Andritz Separation which states the predicted level of NOx emissions from the dryer (i.e. average of 50mg/Nm3). This **letter, dated 26th September 2016** is also attached below. This letter refers to the dryer and RTO used in the Swindon Plant. The predicted level of emissions at Nine Mile Point are based on the emissions monitoring undertaken at the Swindon Plant. This monitoring included emissions from both the Dryer and RTO. This plant takes 90% of its feedstock from municipal waste include a food waste element. This waste is a much higher moisture content than the waste to be received at Nine Mile Point which is predominately commercial and Industrial waste. **A waste analysis, undertaken by Marchwood Scientific Services**, is also attached below. This shows the moisture content of the waste to be received by Hazrem.

We trust that you will now proceed with the permit determination process as a matter of priority, however please contact me on 01454 269237 or via steph.charnaud@enzygo.com should you have any queries.

Yours sincerely

Steph Charnaud
Principal Consultant

Emissions Note:
Nine Mile Point Waste Processing Facility

October 2016

Experts in air quality management & assessment

Document Control

Client	Enzygo	**Principal Contact**	Steph Charnaud

Job Number	J2282

Report Prepared By:	Laurence Caird

Document Status and Review Schedule

Report No.	Date	Status	Reviewed by
J2282/4/F2	5 October 2016	Final	Penny Wilson (Principal Consultant)

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Air Emissions Response

1. Natural Resources Wales (NRW) have provided a notice of further information, required to verify the assumption used in the air quality assessment for the Nine Mile Point Waste Processing Facility that NOx emissions from the site will be 300 mg/Nm^3 and appropriately account for emissions from both the gas-fired burners, and Regenerative Thermal Oxidiser (RTO) used in the production of Solid Recovered Fuel (SRF) at the facility.

2. The emission rate used in the modelling was based on a NOx emission from the gas-fired burner of 150 mg/Nm^3 combined with additional NOx emissions of 150 mg/Nm^3 formed by gas combustion in the RTO. Emissions estimates were provided by an RTO provider (Vandenbroek Thermal Processing B.V. (VDB)).

3. The assumed emission rate is deliberately conservative, as the information provided by VDB made it clear that the exhaust gas from the burners (at 150 mgNOx/Nm^3) would be combined with a very high volume of low-NOx process air from the dryers, thus reducing the NOx concentration in the released air. The additional NOx from gas combustion in the RTO (at 150 mgNOx/Nm^3) also excludes the process air, thus resulting in a much lower NOx emission per m^3 of released air than has been modelled.

Ammonia and Nitrogen Gases in Waste Reception Area

4. In the notice of further information, NRW has requested information regarding:

"1) Predicted concentrations of ammonia (and other nitrogen containing gases) in the air extracted from the waste reception area."

5. It is not possible to accurately quantify the concentrations of ammonia and other nitrogen containing gases in the waste reception area, but it highly likely that concentrations of these gases will be very low. The waste processed at the Nine Mile Point Waste Processing Facility will be stored at ambient temperatures and will contain very little organic material (predominantly paper, card, textiles and plastics), therefore ammonia formation is likely to be negligible.

Fate of Ammonia and Nitrogen Gases in the RTO

6. The NRW notice of further information also requests information regarding:

"3) A written assessment of the fate of ammonia and other nitrogen containing gases as they are treated in the RTO and their impact on the overall NOx emissions from the site."

7. It is unlikely that the input air stream to the RTO will contain a significant ammonia concentration, but any ammonia entering the RTO will not convert to NOx as thermal dissociation of ammonia

requires a nickel catalyst, and direct oxidation of ammonia requires a platinum catalyst, neither of which are present in the RTO.

8. In terms of other nitrogen containing gases, the key gases are elemental nitrogen (N_2), oxides of nitrogen (NOx) and nitrous oxide N_2O.

9. The RTO operates at temperatures too low for thermal NOx formation from N_2. This reaction typically requires temperatures in excess of 1600 degrees C, whereas the RTO operates at around 850 degrees C.

10. The exception to this is within the combustion chamber of the RTO, where gas is combusted, which will lead to the formation of both thermal NOx and potentially some prompt NOx. The NOx formed from gas combustion in the RTO has been accounted for in the emissions used in the air quality modelling.

11. In terms of N_2O, this is unlikely to be present in the RTO in significant concentrations, and conversion to NOx can only occur via exothermic decomposition to N_2 and O_2, and subsequent coupling under combustion conditions in the combustion chamber, as has been accounted for in the emission rates used in the modelling.

NOx Emissions from the RTO and Burner

12. The NRW notice of further information additionally requests that information is provided regarding:

"4) Prediction of the concentration of NOx resulting from the burning of natural gas in the RTO and the gas flow rate exiting the RTO both as maximum operating capacity."

13. The concentration of NOx emissions from gas combustion in the RTO has been assumed to be 150 mg/Nm^3 as described earlier in this note. The total assumed volume flow rate of gas is 30,000 Am^3/h.

14. Recent testing (March 2015) of a similar RTO and rotary drum dryer at a facility in Swindon measured NOx concentrations in the RTO exhaust of only 40.1 mg/Nm^3 (well below the concentration of 300 mg/Nm^3 assumed in the Nine Mile Point modelling). The RTO exhaust gas volume was also lower, at 17,000 Am^3/h, although the facility is slightly smaller in scale than the facility proposed at Nine Mile Point.

Summary Statement

15. Dispersion modelling carried out for the proposed Nine Mile Point Waste Processing Facility was based on a conservative assumption regarding NOx emission rates from the gas burner, which provides heat to the SRF rotary drum dryers, and the RTO used at after-treatment. The specific chemistry of NOx formation in the burner, drum dryers, reception area and RTO is very complex and challenging to accurately quantify and hence a conservative assumption was used. Stack

emissions monitoring of a similar system in operation in Swindon suggests that such systems emit significantly lower NOx emissions than has been assumed for the Nine Mile Point dispersion modelling study. Overall, it is judged that the model inputs are conservative and robust.

Andritz Drum Drying

Project:	Hazrem
Proj. Code:	XXX
Rev.:	0
issued:	SE/TK; 20.03.15
checked:	SE/MW
Program Rev. / Date	Rev. D; 08.04.15

Drum Drying

Input		
Feed		
Feed-Type	-	RDF
Feed-Type (apparence)	-	fluff
Feed	t/h	17,500
MC IN	m%	50,00%
bulk density	kg/m3	130
Plant / process		
operating hours	h/a	6.240
MC Product	m%	15,0%
Calculated Evaporation Rate	kg/h	7.206
Evaporation Rate	kg/h	7.206
Recycle / Fresh Air (Once through)	-	**Recycle**
Drying		
drum outlet temp	°C	105
drum intlet temp	°C	295
thermal loss (% of Pevap)	%	6,0%
leakage inlet [% flow]	%	6,0%
Heatsource: Burner fuel Gas		
massflow Gas	kg/h	
Temperature	°C	20
Lambda	-	1,4
N2	v%	4,25
O2	v%	0
CO2	v%	0
H2O (v)	v%	0
H2	v%	0
CO	v%	0
CH4	v%	90
C2H2	v%	0
C2H4	v%	0
C2H6	v%	5,75
C3H6	v%	0
C3H8	v%	0
C4H8	v%	0
n-C4H10	v%	0
iso-C4H10	v%	0
H2S	v%	0
Ambient		
T	°C	20
rel. Hum	%	70%
pressure	bar	1,01
Iterations	1,04E-04	
Errrors	1,20E-03	

Feed
17.500 kg/h
8.750 kg/h db
20,0 °C
135 Bm3/h
MC= 50,0%

Dosing Bin
t= 8 min
Vnet= 17,9 m3
Vgross= 20,0 m3
D= 3,0 m
H= 2,8 m

RTO
22,5% 66,8 Nm³/h

Fresh Air

Recycle
70.073 kg/h
86.352 Bm3/h
104 °C
14.915 kW

Offgas
33.368 kg/h
40.903 Bm3/h
102 °C
7.080 kW

DN
DN 1000
14,47 m/s

Δp tot
3540 Pa
50 kW

OPTION

Offgas after scrubber

DN	33.642 kg/h
DN 1400	34.448 Bm3/h
6,22 m/s	74 °C
Dustload	80 mg/m3

Water
2.274 kg/h

Waste Water
2.000 kg/h
-0,1% DS

DN
DN 1250
19,55 m/s

Δp tot
4146 Pa
181 kW

DN
DN 1400
22,73 m/s

Selected drum type
DX-1500
WE= 7.206 kg/h

Thermal Load (total)	spec. Thermal Load (total)
P= 6,74 MW	P spec.= 0,94kWh/kg
Electrical Load consumed)	Electrical Load (installed)
P= 0,0 kW	**P= 0,0 kW**
spec. electrical Load (total)	Utilization
P spec.= 0,000kWh/kg	**#DIV/0!**

DN
DN 1250
28,51 m/s

Separation-Eff.
98,0%

Separation-Eff. | **Dustload**
99,60% | 0,82 kg/h
6,46 mg/m3
14 mg/Nm3 dry

Drum OUT
101.658 kg/h
125.943 Bm3/h
105 °C
30,2% rel. hum.
21.995 kW

Leakage
1.782 kg/h
1.500 Bm3/h
20 °C

Thermal Losses
404 kW sensible

Product
10.293 kg/h
1.544 kg/h db
90,0 °C
127 Bm3/h
MC= 15,0%

10.088 kg/h

205 kg/h

Fuel Gas
522 kg/h
674 Nm3/h
20 °C
NCV= 35996 kJ/Nm3
6.741 kW

Comb. Air
11.699 kg/h
9.845 Bm3/h
9.146 Nm3/h
20 °C

Mix Drum IN
94.452 kg/h
170.538 Bm3/h
295 °C
0,4% rel. hum.
22.706 kW

Leakage
12.159 kg/h
10.232 Bm3/h
20 °C

IN	OUT
0 kg/h	101.658 kg/h
70.073 kg/h	
12.159 kg/h	
7.206 kg/h	
89.437 kg/h	

Select Iteration Gas-Burner

U:\Verkauf + Vertragswesen\Projekte\02_PROJECTS_budget\2015\RDF\RDF_Wales_DX\02 Technical Design\[150608_Swansea_max-max.xlsm]Input_Output

Specification for the Dryer

Project Name:
Project Number:

1. DESIGN OVERVIEW

This budget offer includes the equipment, engineering, supervision of mechanical erection, insulation, electrical installation and commissioning and start-up required to operate

1 line of Andritz Drum dryer DX-1500

drying

RDF	Nominal Capacity	15,000	kg/h
	Max. Capacity	17,500	kg/h

	min	nom	max
MC_{in}	30%	40%	50%
MC_{out}	15%	15%	15%

Evap., nom.	[kg/h]	2,647	4,412	6,176
Evap., max.	[kg/h]	3,088	5,147	7206

and utilizing natural gas as heat source.

Overview and Preliminar Process description as per Appendix 13.

2. DESIGN, PROCESS AND CONSUMPTION DATA

For this offer we have based our design on 15-17,5 t/h RDF, to be dried in one (1) drum DX-1500. Moisture content in the wet RDF is 30% up to 50% MC.

Data given are expected values!

The below mentioned data refer to the plant operation at an outside temperature of 20°C and a relative moisture of 70%.

Project Name:
Project Number:

2.1 Overview Process Data / Design data

Input [t/h]	MC_{in} [%]	MC_{out} [%]	Evap. [t/h]	Output [t/h]	Inlet temperature [°C]	Outlet temperature [°C]	Exhaust gas to RTO [Nm³/h]	Gas_{Dryer} [Nm³/h]	Gas_{RTO} [Nm³/h]	Gas_{total} [Nm³/h]
15,0	30	15	2,65	12,35	200	105	16050	300	36	336
15,0	40	15	4,41	10,59	245	105	20950	440	47	487
15,0	50	15	6,18	8,82	270	105	26600	581	60	641
17,5	30	15	3,09	14,41	215	105	17500	347	39	386
17,5	40	15	5,15	12,35	250	105	23950	512	54	566
17,5	50	15	7,21	10,29	295	105	29700	674	67	741

2.2 Design / Technical Data for Min. Capacity with Min. Moisture Content (15 t/hr @ 30% MC)

Drum drying system design (Data at Moisture content 30%)	**AIR RECIRCULATION**	
Product type	RDF	
Product size	90%<30 mm 99%<50 mm	mm
Inert content (sand, glass, metals etc)	**<1%**	
Bulk density	approx. 200 (to be confirmed)	kg/m³
Product quantity	**15**	ton/hr
Dry substance quantity	10,5	ton DS/hr
Moisture content of the wet product	30	%DS
Dried product		
Quantity	12,35	ton/hr
Moisture content	15	%MC
Water evaporation	2,650	kg/hr
Operating time	24 5 Resp. 6,240	hr/day days/week hr/a
Location		
Country	UK	
Site	Wales	
Number of lines	1 x DX-1500	
Required area	See Preliminary Layout attached	Metres (L x W X H)
Consumption data		
Installed $power_e$ (approx.)	595	kW
$Power_e$ absorption (approx.)	456	kW
Natural Gas (NCV = 36 MJ/Nm³), Dryer	300	Nm³/hr

Project Name:
Project Number:

Drum drying system design (Data at Moisture content 30%)	**AIR RECIRCULATION**	
(approx.)		
Natural Gas RTO (approx.)	36	Nm³/hr
Thermal requirement	3,0	MW
Emissions	**AIR RECIRCULATION**	
Exhaust air quantity (approx.)	16,050	Nm³/hr
Exhaust air temperature (approx.)	105	℃
Noise Emissions**		
Sound pressure level at 1 m distance	≤ 85	dB(A)

2.3 Design / Technical Data for Max. Capacity with Max. Moisture Content (17,5 t/hr @ 50%MC)

Drum drying system design (Data at Moisture content 30%)	**AIR RECIRCULATION**	
Product type	RDF	
Product size	90%<30 mm 99%<50 mm	mm
Inert content (sand, glass, metals etc)	**<1%**	
Bulk density	approx. 200 (to be confirmed)	kg/m³
Product quantity	**17,5**	ton/hr
Dry substance quantity	8,75	ton DS/hr
Moisture content of the wet product	50	%DS
Dried product		
Quantity	10,29	ton/hr
Moisture content	15	%MC
Water evaporation	7,210	kg/hr
Operating time	24 5 Resp. 6,240	hr/day days/week hr/a
Location		
Country	UK	
Site	Wales	
Number of lines	1 x DX-1500	
Required area	See Preliminary Layout attached	Metres (L x W X H)
Consumption data		
Installed power$_e$ (approx.)	595	kW
Power$_e$ absorption (approx.)	456	kW
Natural Gas (NCV = 36 MJ/Nm³), Dryer	674	Nm³/hr

Drum drying system design (Data at Moisture content 30%)	**AIR RECIRCULATION**	
(approx.)		
Natural Gas RTO (approx.)	67	Nm^3/hr
Thermal requirement	6,75	MW
Emissions	**AIR RECIRCULATION**	
Exhaust air quantity (approx.)	29,700	Nm^3/hr
Exhaust air temperature (approx.)	105	℃
Noise Emissions**		
Sound pressure level at 1 m distance	≤ 85	dB(A)

** Related Standards:

Determination of sound power levels and mechanical vibration produced by gears units shall be subject to ISO 45635.

Sound pressure levels shall be measured in dB (A) using a calibrated sound meter meeting the requirements of EN 60651.

Letter from Andritz Separation dated 26/09/2016

ANDRITZ Separation

ANDRITZ Fliessbett Systeme GmbH, Goethestr. 36, D-88214 Ravensburg

Machinex Industries Inc.
Mr. Jonathan Ménard
Executive Vice-President Sales &
Strategic Positioning
2121 Rue Olivier
Plessisville, QC, G6L 3G9
Kanada

From/Von: Klaus Stanke/fl
Dept./Abt.: SEPARATION
Date/Datum: 26.09.2016

Fax: +49 (751) 56058-930
Phone/Tel.: +49 (751) 56058-123
E-mail: klaus.stanke@andritz.com

Nine Mile Point SRF/RDF facilities

Dear Jonathan,

With respect to your question how the NOx emission rate of the quoted DX-1500 rotary drum drier would differ over the emission result of the DX-1250 please note the following.

1. There is an official measurement of exhaust gas parameters dated March 20th, 2015, performed by ESG (Environment Scientifics Group), please see attachment to this letter.

2. The report states an average NOx emission of 40.1 mg/Nm3 over the measuring period.

3. The highs and the lows over the sampling period where around 75 mg/Nm3 and 10 mg/Nm3 reflecting the controls of the burners at both, dryer and RTO.

4. Main parameters influencing the NOx emission of such plant can be identified as
   a. Dryer burner (design) and operating temperature
   b. RTO burner (design) and operating temperature
   c. Particulate matter quantity from bag house to RTO
   d. Dryer and RTO fuel composition
   e. Composition of material to be dried

5. The drier size as such is of minor importance regarding the specific NOx/Nm3 emission level

6. Extrapolating the result from the measurement taken at Swindon to Nine Mile Point can be done using the following assumptions:

   A design with
   a. Similar dryer burner temperature
   b. Same or better dryer burner design
   c. Same or better RTO burner design
   d. Same bag house design
   e. Similar fuel composition
   f. Similar composition of material to be dried

   will lead to similar NOx concentration at the RTO stack.

7. Under this precondition and considering some margin for uncertainties, we believe it is a fair assumption to expect a NOx concentration of about 50 mg/Nm3 at the stack for the Nine Mile Point project.

We hope that the above explanation is helpful to understand the critical parameters that we expect to have an influence on the result and why it is not possible at this stage to give a more precise answer to your question.

Sincerely yours,

ANDRITZ Fliessbett Systeme GmbH

Klaus Stanke

STACK EMISSIONS MONITORING REPORT

Unit D
Bankside Trade Park
Cirencester
GL7 1YT
Tel: 01285 700593

Your contact at ESG
Mike Davies Business Manager - South Tel: 01285 700593 Email: mike.davies@esg.co.uk

Operator & Address:
Public Power Solutions Ltd Water Side Park Darby Close Cheney Manor Industrial Estate Swindon SN2 2PN

Permit:
N/A - Internal Data Gathering Test

Release Point:
A1 - SRF Dryer Stack

Sampling Date(s):
20 March 2015

ESG Job Number:	LSO 150211
Report Date:	30th March 2015
Version:	1
Report By:	Jonathan Ward
MCERTS Number:	MM 02 080
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Mike Davies
MCERTS Number:	MM 02 087
Business Title:	MCERTS Level 2 - Business Manager
Technical Endorsements:	1, 2, 3 & 4
Signature:	

UKAS TESTING 1015

MCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

CONTENTS

EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Public Power Solutions Ltd operates a waste dryer process at Cheney Manor Industrial Estate which is subject to Permit Internal Data Gathering, under the Environmental Permitting Regulations 2010.

Environmental Scientifics Group Limited were commissioned by Public Power Solutions Ltd to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under normal operating conditions.

The results of these tests shall be used to demonstrate compliance with a set of emission limit values for prescribed pollutants as specified in the Plant's Permit, Internal Data Gathering.

Plant

A1 - SRF Dryer Stack

Operator

Public Power Solutions Ltd
Water Side Park
Darby Close
Cheney Manor Industrial Estate
Swindon
SN2 2PN

Permit: Internal Data Gathering

Stack Emissions Monitoring Test House

ESG Limited - Cirencester Laboratory
Unit D
Bankside Trade Park
Cirencester
GL7 1YT
UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.
MCERTS accredited results will only be claimed where both the sampling and analytical stages are UKAS accredited.

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	**Units**	**Result**	**Calculated Uncertainty +/-**	**Limit**	**MCERTS accredited result**
Total Particulate Matter	mg/m³	1.7	0.7	-	✓
Particulate Emission Rate	g/hr	17	7.4	-	
Oxides of Nitrogen (as NO_2)	mg/m³	40.1	3.3	-	✓
Oxides of Nitrogen (as NO_2) Emission Rate	g/hr	447	37.1	-	
Sulphur Dioxide	mg/m³	1.1	3.4	-	✓
Sulphur Dioxide Emission Rate	g/hr	12.3	38.3	-	
Carbon Monoxide	mg/m³	185	6.9	-	✓
Carbon Monoxide Emission Rate	g/hr	2069	77	-	
Carbon Dioxide	% v/v	2.40	0.3	-	✓
Oxygen	% v/v	16.7	0.4	-	✓
Moisture	%	27.5	0.75	-	✓
Stack Gas Temperature	°C	146	-	-	✓
Stack Gas Velocity	m/s	7.0	0.17	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	17002	765	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	11159	502	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	7933	357	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	11159	502	-	

ND = None Detected,
Results at or below the limit of detection are highlighted by bold italic text.
The above volumetric flow rate is calculated using data from the preliminary survey. Mass emissions for non isokinetic tests are calculated using these values. For all isokinetic testing the mass emission is calculated using test specific flow data and not the above values.

Reference conditions are 273K, 101.3kPa without correction for water vapour

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	**Sampling Date(s)**	**Sampling Times**	**Sampling Duration**
Total Particulate Matter Run 1	20 March 2015	10:30 - 11:32	60 minutes
Total Particulate Matter Run 2	20 March 2015	12:35 - 13:37	60 minutes
Combustion Gases	20 March 2015	10:30 - 12:30	120 minutes
Stack Gas Flow Rate & Temperature Run 1	20 March 2015	09:05 - 10:00	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Waste Dryer
Continuous or batch	Continuous
Product Details	Municipal Waste
Part of batch to be monitored (if applicable)	Any Representative Period
Normal load, throughput or continuous rating	10 Tonnes/Hour
Fuel used during monitoring	Natural Gas
Abatement	Bag Filter
Plume Appearance	White Steam Plume Visible

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard reference / alternative methods employed by ESG Limited is determined, wherever possible by the hierarchy of method selection outlined in Environment Agency Technical Guidance Note (Monitoring) M2. i.e. CEN, ISO, BS, US EPA etc.

MONITORING METHODS						
Species	**Method** Standard Reference Method / Alternative Method	**ESG Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Limit of Detection (LOD)**	**Calculated MU +/- %**
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	0.35 mg/m³	43.6 %
NO_X	SRM - BS EN 14792	AE 102	1015	Yes	0.51 mg/m³	8.28%
SO_2	AM - M21	AE 102	1015	Yes	0.62 mg/m³	311%
CO	SRM - BS EN 15058	AE 102	1015	Yes	0.88 mg/m³	3.74%
CO_2	SRM - ISO 12039	AE 102	1015	Yes	0.002 %	11.18%
O_2	AM - BS EN 14789	AE 102	1015	Yes	0.01%	2.15%
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	0.01%	2.74%
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	5 Pa	2.5 %

EXECUTIVE SUMMARY

Analytical Methods

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

SAMPLING METHODS WITH SUBSEQUENT ANALYSIS							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	UKAS Accredited Lab Analysis	Analysis Lab (ESG or Subcontract)	Sample Archive Location	Archive Period
TPM	Gravimetric	AE 106	1015	Yes	ESG - Cirencester	ESG - Cirencester	3 months
-	-	-	-	-	-	-	-

ON-SITE TESTING							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	MCERTS Accredited Analysis	Laboratory	Data Archive Location	Archive Period
NO_X	Chemiluminescence	AE 102	1015	Yes	ESG - Cirencester	ESG - Cirencester	5 years
SO_2	Non Dispersive Infra Red	AE 102	1015	Yes	ESG - Cirencester	ESG - Cirencester	5 years
CO	Non Dispersive Infra Red	AE 102	1015	Yes	ESG - Cirencester	ESG - Cirencester	5 years
CO_2	Non Dispersive Infra Red	AE 102	1015	Yes	ESG - Cirencester	ESG - Cirencester	5 years
O_2	Zirconia Cell	AE 102	1015	Yes	ESG - Cirencester	ESG - Cirencester	5 years
H_2O	Gravimetric	AE 105	1015	Yes	ESG - Cirencester	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	26	Pa	>= 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	6.45	m/s	-	-	-
Highest Gas Velocity	7.49	m/s	-	-	-
Ratio of Gas Velocities	1.16	: 1	< 3 : 1	Yes	BS EN 15259
Mean Velocity	6.95	m/s	-	-	-
Maximum angle of flow with regard to duct axis	<15	^{o}	< 15^{o}	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259
Highly homogeneous flow stream / gas velocity	Yes	-	-	Yes	BS EN 15259

DUCT CHARACTERISTICS		
	Value	**Units**
Shape	Circular	-
Depth	0.93	m
Width	-	m
Area	0.68	m^2
Port Depth	150	mm

SAMPLING LINES & POINTS			
	Isokinetic (CEN Methods)	**Isokinetic** (ISO Methods)	**Non-Iso & Gases**
Sample port size	4" Flange	-	4" Flange
Number of lines used	2	-	1
Number of points / line	4	-	1
Duct orientation	Vertical	-	Vertical
Filtration for TPM	QF	-	-

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

M1 Platform requirements	
Is there a sufficient working area so work can be performed in a compliant manner	Yes
Platform has 2 levels of handrails (approximately 0.5 m & 1.0 m high)	Yes
Platform has vertical base boards (approximately 0.25 m high)	Yes
Platform has removable chains / self closing gates at the top of ladders	Yes
Handrail / obstructions do not hamper insertion of sampling equipment	No
Depth of Platform = >Stack depth / diameter + wall and port thickness + 1.5m	No

Sampling Platform Improvement Recommendations (if applicable)

The sampling location meets all the requirements as specified in EA Guidance Note M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

In this instance there were no deviations from the sampling and analytical methods employed.

APPENDICES

CONTENTS

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

MONITORING SCHEDULE					
Species	**Method** Standard Reference Method / Alternative Method	**ESG Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Number of Samples**
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	2
NOx	SRM - BS EN 14792	AE 102	1015	Yes	1
SO_2	AM - M21	AE 102	1015	Yes	1
CO	SRM - BS EN 15058	AE 102	1015	Yes	1
CO_2	SRM - ISO 12039	AE 102	1015	Yes	1
O_2	AM - BS EN 14789	AE 102	1015	Yes	1
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	2
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	1

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

CALIBRATEABLE EQUIPMENT CHECKLIST

Extractive Sampling		Instrumental Analyser/s		Miscellaneous	
Equipment	**Equipment I.D.**	**Equipment**	**Equipment I.D.**	**Equipment**	**Equipment I.D.**
Control Box DGM	P1298	Horiba PG-250 Analyser	P1982	Laboratory Balance	P66
Box Thermocouples	P1298	FT-IR	-	Laboratory Balance	P66
Meter In Thermocouple	P1298	FT-IR Oven Box	-	Laboratory Balance	P66
Meter Out Thermocouple	P1298	Bernath 3006 FID	-	Tape Measure	P1299
Control Box Timer	P734	Signal 3030 FID	-	Stopwatch	P734
Oven Box	-	Servomex	-	Barometer	P2366
Probe	P2100	JCT Heated Head Filter	-	Digital Temperature Meter	P1271
Probe Thermocouple	P267	Thermo FID	-	Stack Thermocouple	P2148
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	P2042	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P2316	Chiller (JCT/MAK 10)	P2051	1m Heated Line (3)	-
Last Impinger Arm	-	Heated Line Controller (1)	-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	-	10m Heated Line (1)	-
Callipers	-	Site temperature Logger	-	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	P2369		-	20m Heated Line (1)	-
Inclinometer (Swirl Device)	P2096		-	20m Heated Line (2)	-

NOTE: If the equipment I.D is represented by a dash (-), then this piece of equipment has not been used for this test.

CALIBRATION GASES

Gas (traceable to ISO 17025)	Cylinder I.D Number	Supplier	ppm	%	Analytical Tolerance +/- %
Oxygen	DAM2	BOC	-	10.14	2
Nitric Oxide	DAE3	BOC	204	-	2
Sulphur Dioxide	DAE3	BOC	157	-	2
Carbon Monoxide	DAM2	BOC	163	-	2
Carbon Dioxide	DAM2	BOC	-	12.11	2
-	-	-	-	-	-

STACK EMISSIONS MONITORING TEAM

MONITORING TEAM							
Personnel	**MCERTS Number**	**MCERTS Qualification**	**TE / H&S Qualifications and Expiry Date**				
			TE1	**TE2**	**TE3**	**TE4**	**H&S**
Jonathan Ward	MM 02 080	MCERTS Level 2 - Team Leader	Mar-18	Jun-18	Aug-16	Mar-16	Sep-17
Owain Redfern	MM 13 1248	MCERTS Level 1 - Technician	-	-	-	-	Mar-18

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER SUMMARY					
Parameter	Sampling Times	Concentration mg/m³	Uncertainty mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	10:30 - 11:32 20 March 2015	1.7	0.70	-	19
Run 2	12:35 - 13:37 20 March 2015	1.6	0.75	-	16
Blank	-	0.94	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

Acetone Blank Value mg/l	Acceptable Value mg/l
2.0	10

FILTER INFORMATION

SAMPLES								
Test	Filter & Probe Rinse Number	Filter Start Weight g	Filter End Weight g	Mass Gained on Filter g	Probe Rinse Start Weight g	Probe Rinse End Weight g	Mass Gained on Probe g	Combined Total Mass Gained g
Run 1	116644	0.15690	0.15680	-0.00010	74.87670	74.87890	0.00220	0.00210
Run 2	116645	0.15320	0.15300	-0.00020	71.31110	71.31310	0.00200	0.00180

If total mass gained is less than the LOD then the LOD is reported

BLANKS								
Test	Filter & Probe Number	Filter Start Weight g	Filter End Weight g	Mass Gained Filter g	Probe Start Weight g	Probe End Weight g	Mass Gained Probe g	Combined Total Mass Gained g
Run 1	116646	0.14950	0.14950	0.00000	69.12190	69.12320	0.00130	0.00130

If total mass gained is less than the LOD then the LOD is reported

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 1 — TPM

Absolute pressure of stack gas, P_S		
Barometric pressure, P_b	mm Hg	765.01
Stack static pressure, P_{static}	mm H_2O	4.49
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	765.34
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	297.5
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.370685
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		1.026
Gas meter correction factor, Y_d		1.0730
Mean dry gas meter temperature, T_m		15.208
Mean pressure drop across orifice, ΔH	mmH_2O	43.367
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		1.054
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.4242
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No
% oxygen measured in gas stream, act%O_2		16.3
% oxygen reference condition		21
O_2 Reference Factor O_2 Ref $= \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.2603
	%	26.03
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		.82
Mean of velocity heads, ΔP_{avg}	mm H_2O	2.76
Mean square root of velocity heads, $\sqrt{\Delta P}$		1.66
Mean stack gas temperature, T_s	°C	150
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	6.92

Molecular weight of dry gas, M_d		
CO_2	%	2.40
O_2	%	16.30
Total	%	18.70
N_2 (100 -Total)	%	81.30
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.04
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	26.16
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.68
$Q_a = (60)(A_s)(V_s)$	m^3/min	282.3
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) +273}$	Dry	135.6
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O_2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	183.30
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	10.82
Nozzle area, A_n	mm^2	91.96
Total sampling time, θ	min	60
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	95.7
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00020
Mass collected in probe, M_p	g	0.00220
Total mass collected, M_n	g	0.00240
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	1.685
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	2.278
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		18.53

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 2 — TPM

Absolute pressure of stack gas, P_S			**Molecular weight of dry gas, M_d**		
Barometric pressure, P_b	mm Hg	765.01	CO_2	%	2.40
Stack static pressure, P_{static}	mm H_2O	4.49	O_2	%	16.30
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	765.34	Total	%	18.70
			N_2 (100 -Total)	%	81.30
Vol. of water vapour collected, V_{wstd}			$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.04
Moisture trap weight increase,Vlc	g	310.8	**Molecular weight of wet gas, M_s**		
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.38726	$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	25.84
Volume of gas metered dry, V_{mstd}			**Actual flow of stack gas, Q_a**		
Volume of gas sample through gas meter, V_m		0.927	Area of stack, A_s	m^2	0.68
Gas meter correction factor, Y_d		1.0730	$Q_a = (60)(A_s)(V_s)$	m^3/min	241.7
Mean dry gas meter temperature, T_m		14.958	**Total flow of stack gas, Q**		
Mean pressure drop across orifice, ΔH	mmH_2O	31.797	Conversion factor (K/mm.Hg)		0.3592
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.952	$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) +273}$	Dry	112.6
Volume of gas metered wet, V_{mstw}			$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O_2ref	No O2 Ref
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.3393	$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	158.45
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$			**Percent isokinetic, %I**		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No	Nozzle diameter, D_n	mm	10.82
% oxygen measured in gas stream, act%O_2		16.3	Nozzle area, A_n	mm^2	91.96
% oxygen reference condition		21	Total sampling time, θ	min	60
O_2 Reference Factor O_2 Ref = $\frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		No O2 Ref	$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	104.1
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	No O2 Ref	Acceptable isokinetic range 95% to 115%		Yes
Moisture content, B_{wo}			**Particulate Concentration, C**		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.2891	Mass collected on filter, M_f	g	0.00020
	%	28.91	Mass collected in probe, M_p	g	0.00200
Moisture by FTIR	%	-	Total mass collected, M_n	g	0.00220
Velocity of stack gas, V_s			$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	1.64
Pitot tube velocity constant, K_p		34.97	$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	2.31
Velocity pressure coefficient, C_p		.82	$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Mean of velocity heads, ΔP_{avg}	mm H_2O	2.02	**Particulate Emission Rates, E**		
Mean square root of velocity heads, $\sqrt{\Delta P}$		1.42	$E = [(C_{wet})(Q_{stw})(60)] / 1000$		15.62
Mean stack gas temperature, T_s	°C	146			
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	5.93			

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER QUALITY ASSURANCE CHECKLIST

LEAK RATE						
Run	Mean Sampling Rate litre/min	Pre-sampling Leak Rate litre/min	Post-sampling Leak Rate litre/min	Maximum Vacuum mm Hg	Acceptable Leak Rate litre/min	Leak Tests Acceptable?
Run 1	18.34	0.12	0.12	-381	0.37	Yes
Run 2	16.58	0.11	0.1	-381	0.33	Yes

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	95.66	Yes
Run 2	104.08	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.35	No ELV	N/A - No ELV
Run 2	0.37	No ELV	N/A - No ELV

The above is based on both the Filter and rinse uncertainty

BLANK VALUE				
Run	Overall Blank Value mg/m^3	Daily Emission Limit Value mg/m^3	Acceptable Blank Value mg/m^3	Overall Blank Acceptable mg/m^3
Blank 1	0.94	-	-	-

FILTERS					
Run	Filter Material	Filter Size mm	Max Filtration Temperature °C	Pre-use Filter Conditioning Temperature °C	Post-use Filter Conditioning Temperature °C
Run 1	QF	47	155	180	160
Run 2	QF	47	157	180	160

GF = Glass Fibre

QF = Quartz Fibre

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

COMBUSTION GASES SUMMARY

Test	Sampling Time and Date	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
NOx	10:30 - 12:30 20 March 2015	40.1	0.51	-	447
SO_2	10:30 - 12:30 20 March 2015	1.10	0.62	-	12.3
CO	10:30 - 12:30 20 March 2015	185.37	0.88	-	2069

Test	Sampling Time and Date	Concentration %	LOD %
CO_2	10:30 - 12:30 20 March 2015	2.40	0.002
O_2	10:30 - 12:30 20 March 2015	16.7	0.01

Reference conditions are 273K, 101.3kPa without correction for water vapour

PRE-SAMPLING CALIBRATION DATA

Date	20 March 2015
Start Time	09:40
End Time	09:55

Chiller Temperature (°C)	2.2
Requirement	< 4°C
Compliant	Yes

Gas	Range (ppm / %)	Zero Reading at analyser	Span Reading at analyser	Zero Check at analyser	Zero Check down line	Span Check down line	Response Time (Secs)	Leak Rate %
NO	250	0	209	0.2	1	209.4	99	-0.19
SO2	200	0	169.8	0.2	1.1	170.3	174	-0.29
CO	500	0	163	0.8	0.2	163.8	89	-0.49
CO2	20	0	12.11	0.02	0.04	12.2	78	-0.74
O_2	25	0	10.14	0.01	0.05	10.18	67	-0.39

POST-SAMPLING CALIBRATION DATA

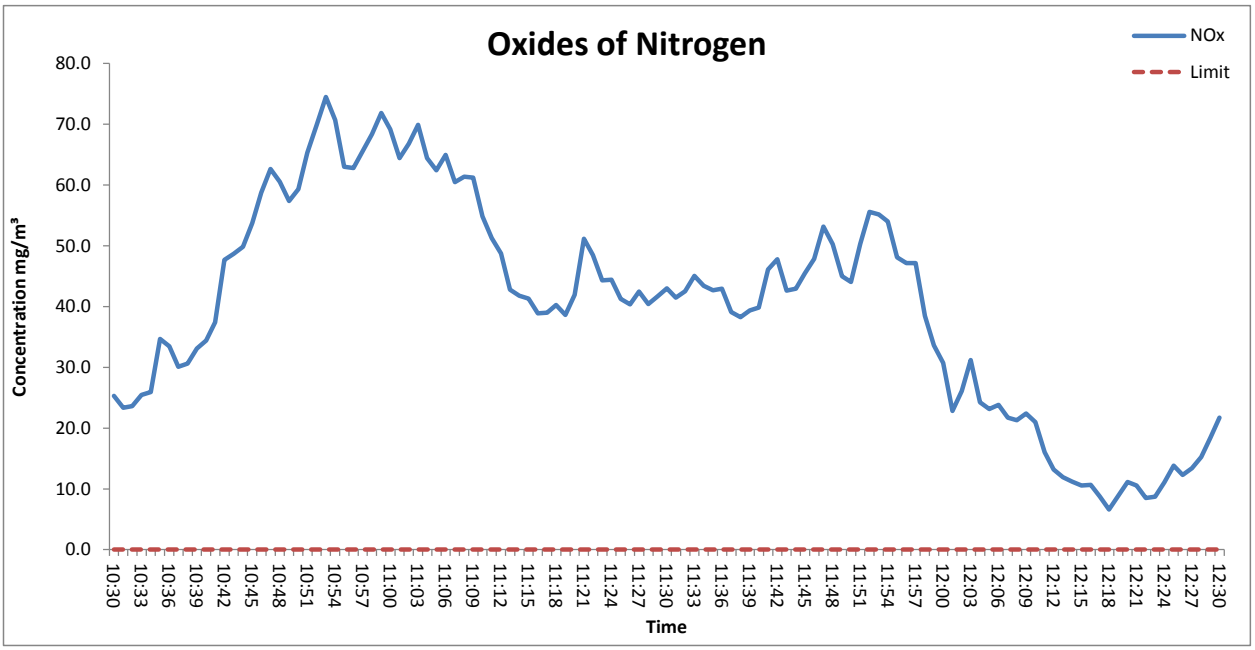
Date	20 March 2015
Start Time	13:40
End Time	13:55

Chiller Temperature (°C)	2.6
Requirement	< 4°C
Compliant	Yes

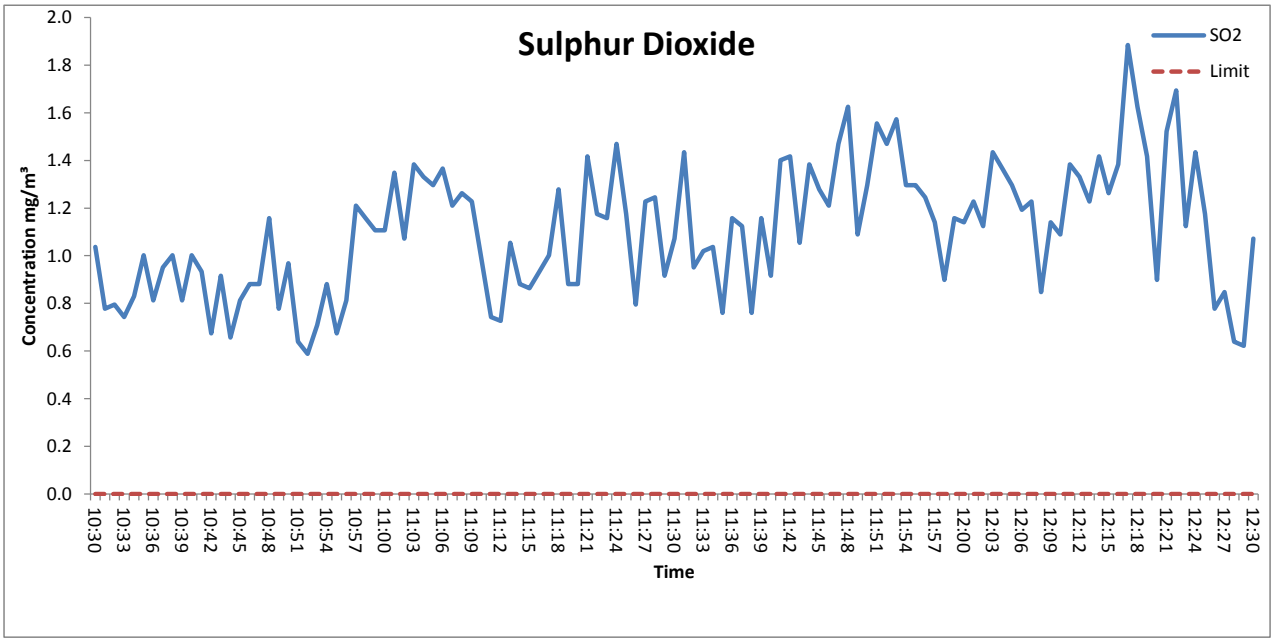
Gas	Zero Check down line	Span Check down line	Zero Drift (%)	Span Drift (%)
NO	0.9	208.7	-0.04	-0.24
SO2	1.2	170.5	0.05	0.05
CO	1.1	163.5	0.18	-0.24
CO2	0.02	12.12	-0.10	-0.30
O_2	0.01	10.12	-0.16	-0.08

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

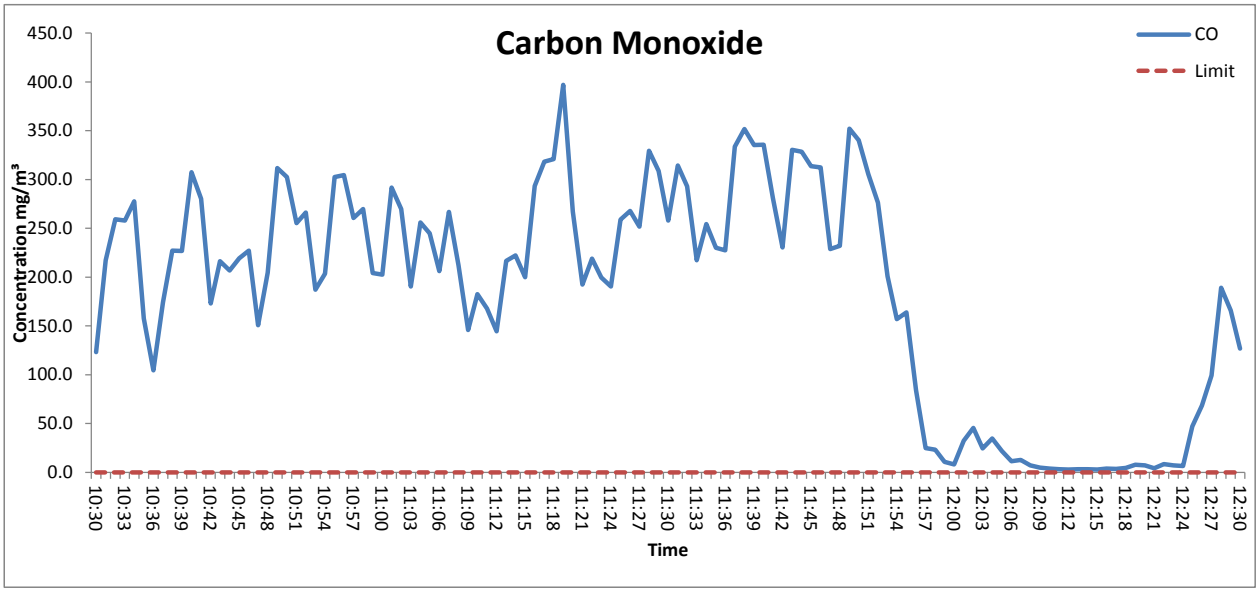
OXIDES OF NITROGEN (as NO_2) EMISSIONS CHART



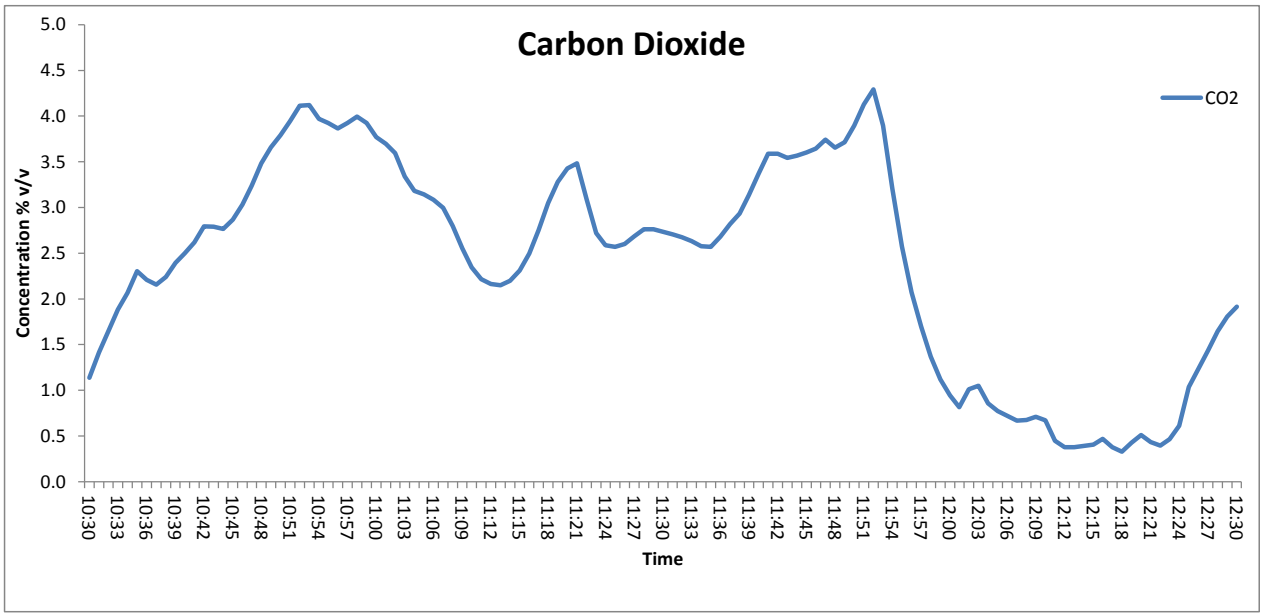
SULPHUR DIOXIDE EMISSIONS CHART



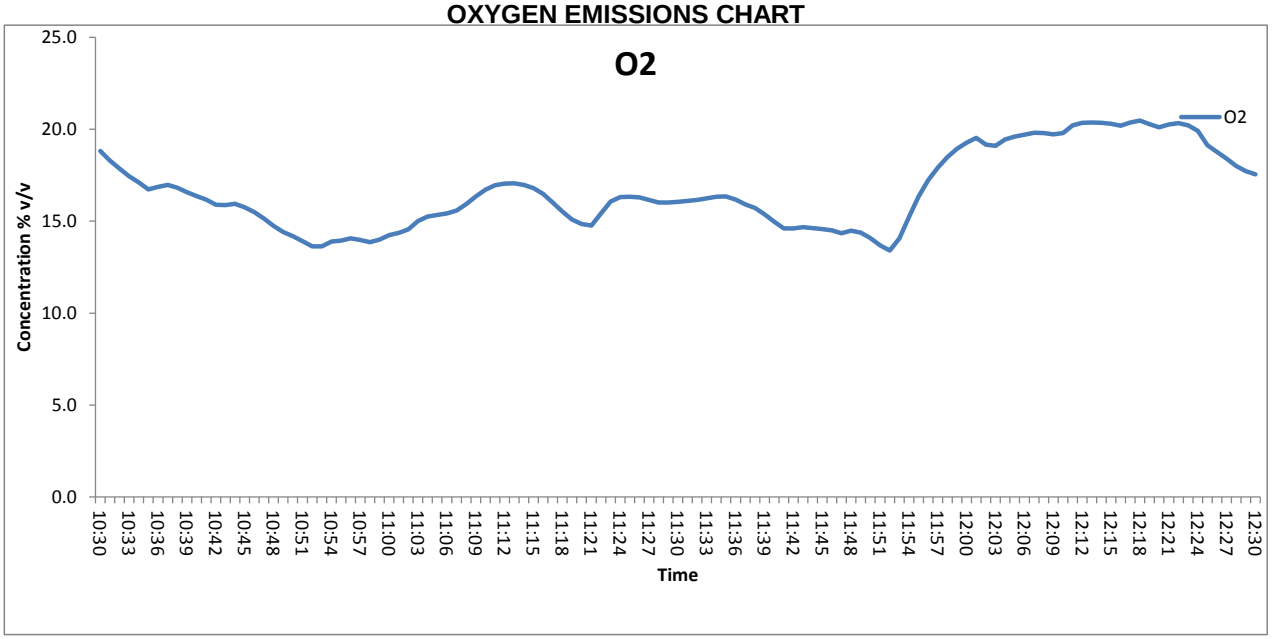
CARBON MONOXIDE EMISSIONS CHART



CARBON DIOXIDE EMISSIONS CHART



OXYGEN EMISSIONS CHART



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MOISTURE CALCULATIONS

Moisture Determination - Isokinetic							
Test Number	Sampling Time and Date	Start Weight kg	End Weight kg	Total gain kg	Concentration %	LOD %	Uncertainty %
Run 1	10:30 - 11:32 20 March 2015	3.2204	3.5179	0.2975	26.0	0.009	2.7
Run 2	12:35 - 13:37 20 March 2015	2.8342	3.1450	0.3108	28.9	0.009	2.7

Moisture Quality Assurance							
Test Number	Sampling Duration mins	Total Volume Sampled l	Sampling Rate l/min	Start Leak Rate l/min	End Leak Rate l/min	Acceptable Leak Rate l/min	Leak Tests Acceptable?
Run 1	60	1424	18.3	0.1200	0.1200	0.3668	Yes
Run 2	60	1339	16.6	0.1100	0.1000	0.3316	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.93	m
Stack Width, W	-	m
Stack Area, A	0.68	m^2
Average stack gas temperature	146	^oC
Stack static pressure	0.044	kPa
Barometric Pressure	102	kPa
Pitot tube calibration coefficient, K_{pt}	0.82	-

Stack Gas Composition & Molecular Weights

Component	Molar Mass M	Density kg/m^3 p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m^3 pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m^3 pi
CO_2	44	1.963059	2.399022	0.023990	0.047094	1.739991	0.017400	0.034157
O_2	32	1.427679	20.900000	0.209000	0.298385	15.158599	0.151586	0.216416
N_2	28	1.249219	76.700978	0.767010	0.958163	55.630592	0.556306	0.694948
H_2O	18	0.803070	-	-	-	27.470817	0.274708	0.220610

Where: p = M / 22.41 p*i* = r x p

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.3036	kg/m^3
Wet Density (STP), P_{STW}	1.1661	kg/m^3
Dry Density (Actual), P_{Actual}	0.8556	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	0.765	kg/m^3

Where:

P_{STD} = sum of component concentrations, kg/m^3 (not including water vapour)

$P_{STW} = (P_{STD} + pi \text{ of } H_2O) / (1 + (pi \text{ of } H_2O / 0.8036))$

$P_{Actual} = P_{STD} \times (Ts / Ps) \times (Pa / Ta)$

$P_{ActualW} = P_{STW} \times (Ts / Ps) \times (Pa / Ta)$

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	20 March 2015
Time of Survey	09:05 - 10:00
Velocity Measurement Device:	S-Type Pitot

Sampling Line A

Traverse Point	Distance into duct (m)	ΔP pt mmH_2O (average of 3)	ΔP pt Pa (average of 3)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	0.02	2.8	27	146	6.55	4.45	-	<15
2	0.08	2.9	29	146	6.73	4.57	-	<15
3	0.14	3.2	32	146	7.04	4.79	-	<15
4	0.21	2.9	28	146	6.69	4.54	-	<15
5	0.32	3.2	31	146	6.97	4.74	-	<15
6	0.61	3.2	31	146	6.99	4.75	-	<15
7	0.72	3.5	34	146	7.36	5.00	-	<15
8	0.79	3.6	36	146	7.49	5.09	-	<15
9	0.85	3.3	33	146	7.17	4.87	-	<15
10	0.91	3.0	29	146	6.80	4.62	-	<15
Mean	-	3.2	31	146	6.98	4.74	-	

Sampling Line B

Traverse Point	Distance into duct (m)	ΔP pt mmH_2O (average of 3)	ΔP pt Pa (average of 3)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	0.02	2.9	29	146	6.71	4.56	-	<15
2	0.08	2.7	26	146	6.45	4.38	-	<15
3	0.14	2.9	28	146	6.63	4.50	-	<15
4	0.21	3.1	30	146	6.90	4.68	-	<15
5	0.32	3.0	30	146	6.82	4.63	-	<15
6	0.61	3.4	33	146	7.19	4.88	-	<15
7	0.72	3.2	32	146	7.04	4.79	-	<15
8	0.79	3.6	35	146	7.40	5.03	-	<15
9	0.85	3.3	32	146	7.10	4.82	-	<15
10	0.91	3.2	31	146	7.01	4.76	-	<15
Mean	-	3.1	31	146	6.92	4.70	-	

PRELIMINARY STACK SURVEY QUALITY ASSURRANCE CHECKLIST

PITOT LEAK CHECK								
Run	Pre Traverse Leak Rate				Post Traverse Leak Rate			
	Start Value mmH_2O	End Value mmH_2O	Difference %	Outcome	Start Value mmH_2O	End Value mmH_2O	Difference %	Outcome
Run 1	83.0	84.0	-1.2	Pass	88.00	86	2.3	Pass

To complete a compliant pitot leak check a pressure of over 80mmH_2O is applied and the pressure drop monitored over 5 mins. A drop of less than 5% must be observed.

S-Type Pitot Stagnation Check				
Run	Stagnation (Pa)	Reference (Pa)	Difference (Pa)	Outcome
Run 1	42	41	-1	Pass

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY (CONTINUED)

Sampling Plane Validation Criteria				
EA Technical Guidance Note (Monitoring) M1	Result	Units	Requirement	Compliant
Lowest Differential Pressure	26.46	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	6.45	m/s	-	-
Highest Gas Velocity	7.49	m/s	-	-
Ratio of Gas Velocities	1.16	-	< 3 : 1	Yes
Maximum angle of flow with regard to duct axis	0	^{o}	< 15^{o}	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, V = K_{pt} x (1-ε) * √(2 * ΔP_{pt} / $P_{ActualW}$)		
Where: K_{pt} = Pitot tube calibration coefficient (1-ε) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**6.95**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	146	0	^{o}C
Total Pressure	102.044	101.3	kPa
Oxygen	16.3	21	%
Moisture	28.91	28.91	%

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	6.95	m/s
Stack Area (A)	0.68	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	17002	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	11159	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	7933	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	11159	m^3/hr

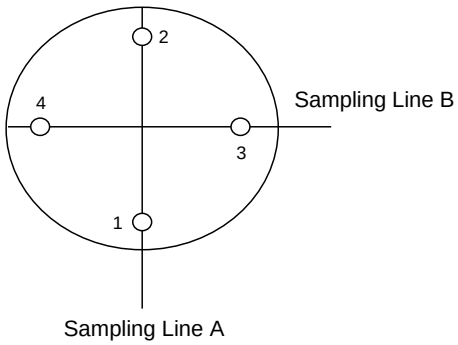
Where:
Q_{Actual} = Va x A x 3600
Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600
$Q_{STP,Dry}$ = Q (STP) / (100 - (100 / Ma)) x 3600
Q_{Ref} = Q (STP) x ((100 - Ma) / (100 - Ms)) x ((20.9 - O_2a) / (20.9 - O_2s))

Nomenclature:
Ts = Absolute Temperature, Standard Conditions, 273 K
Ps = Absolute Pressure, Standard Conditions, 101.3 kPa
Ta = Absolute Temperature, Actual Conditions, K
Pa = Absolute Pressure, Actual Conditions, kPa
Ma = Water vapour, Actual Conditions, % Vol
Ms = Water vapour, Reference Conditions, % Vol
O_2a = Oxygen, Actual Conditions, % Vol
O_2s = Oxygen, Reference Conditions, % Vol

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK DIAGRAM

	Value	Units
Stack Depth	0.93	m
Stack Width	-	m
Area	0.68	m^2

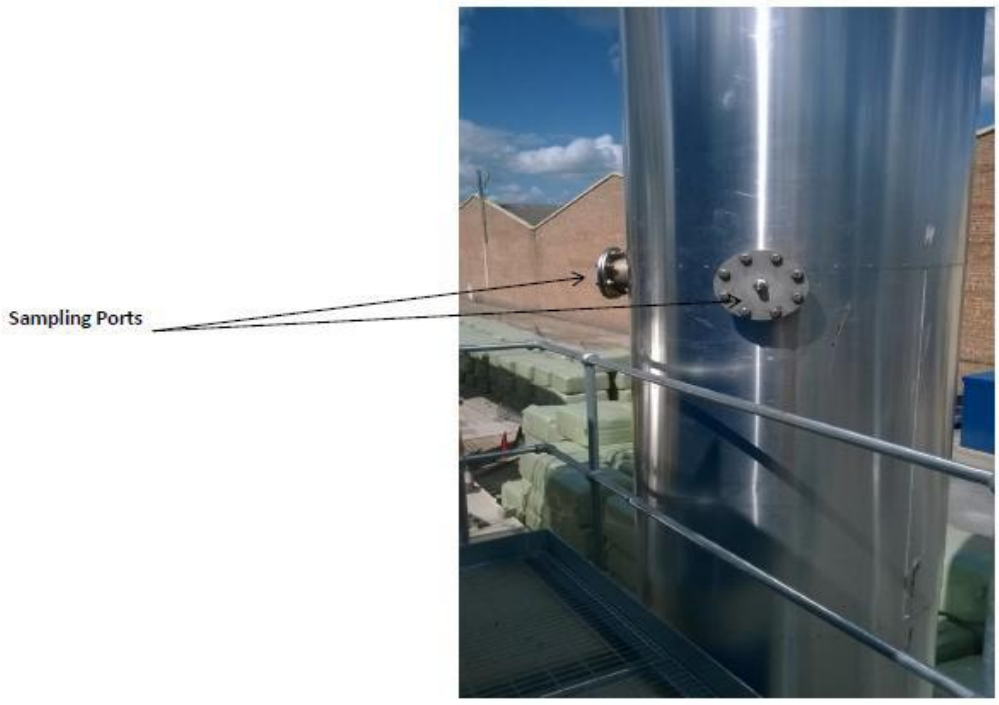


- Isokinetic sampling point
- Isokinetic sampling points not used
- Non Isokinetic/Gases sampling point

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	50	0.47	m

Isokinetic Sampling CEN Methods			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	6.7	0.06	< 15
2	25.0	0.23	< 15
3	75.0	0.70	< 15
4	93.3	0.87	< 15
5	6.7	0.06	< 15
6	25.0	0.23	< 15
7	75.0	0.70	< 15
8	93.3	0.87	< 15
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

SAMPLING LOCATION



APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume m^3	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %	Uncollected Mass mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.001	2	0.5	1	N/A	0.5000	-	-
as a %	0.07	0.69	0.49	1.00	N/A	N/A	0.65	N/A
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**	**N/A**
Run 2	0.001	2	0.5	1.00	N/A	0.500	-	-
as a %	0.07	0.69	0.49	1.00	N/A	N/A	0.60	N/A
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**	**N/A**

Run	Volume (STP) m^3	Mass of particulate mg	O_2 Correction -	Leak mg/m^3	Uncollected Mass mg	Combined uncertainty
Run 1	1.36	2.4000	1.00	0.006	0.0008	-
MU as mg/m^3	0.02	0.3511	-	0.006	0.0005	**0.35**
MU as %	1.31	20.8333	-	0.378	0.0313	-
Run 2	1.28	2.2000	1.00	0.006	0.0008	-
MU as mg/m^3	0.02	0.3733	-	0.006	0.0006	**0.37**
MU as %	1.3	22.7273	-	0.348	0.0341	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.70**	**mg/m^3**	**41.76**	**%**

R2 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.75**	**mg/m^3**	**45.54**	**%**

(k is a coverage factor which gives a 95% confidence in the quoted figures)

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - MOISTURE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Leak
	m^3	K	kPa	% by volume	% by volume	%
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**
Run 1	0.001	2	0.5	1	N/A	-
as a %	0.07	0.69	0.49	1.00	N/A	0.65
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**
Run 2	0.001	2	0.5	1	N/A	-
as a %	0.07	0.69	0.49	1.00	N/A	0.60
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP)	Mass Gained	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	1.36	297500.00	1.00	789.14	57.74	-
MU as % v/v	0.34	0.01	-	0.10	0.005	**0.36**
MU as %	1.31	0.03	-	0.38	0.02	-
Run 2	1.28	310800.00	1.00	808.16	57.74	-
MU as % v/v	0.38	0.01	-	0.10	0.01	**0.40**
MU as %	1.31	0.03	-	0.35	0.02	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.72**	**% v/v**	**2.74**	**%**

R2 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.79**	**% v/v**	**2.72**	**%**

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXIDES OF NITROGEN

Limit value	-	mg/m^3
Concentration @ Ref conditions	40.1	mg/m^3
Cal gas conc	418.2	mg/m^3
Analyser Full Scale	513	mg/m^3

Performance characteristics	Value	Units	specification	MU Met?
Response time	99	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.7	% of value	<2 % range	Yes
Zero drift	-0.10	% full scale	<2% range / 24hr	Yes
Span drift	-0.60	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.02	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.8	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	0.01	% full scale/10K	<3% range / 10 K	Yes
dependence on voltage	0.1	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	-0.19	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	0.01
Standard deviation of repeatability at span level	urs	0.01
Lack of fit	ufit	2.07
Drift	u0dr	-0.10
volume or pressure flow dependence	uspres	0.00
atmopsheric pressure dependence	uapres	0.13
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	0.44
losses in the line (leak)	uleak	-0.06
Uncertainty of calibration gas	ucalib	0.32
Uncertainty in factor	uf	0.79

Measurement uncertainty (Concentration Measured)	55.27	mg/m^3
Combined uncertainty	2.29	mg/m^3
Expanded at a 95% confidence interval	4.58	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**-**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**4.58**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**8.28**	**% value**

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - SULPHUR DIOXIDE

Limit value	-	mg/m^3
Concentration @ Ref conditions	1.1	mg/m^3
Cal gas conc	445.9	mg/m^3
Analyser Full Scale	572	mg/m^3

Performance characteristics	Value	Units	specification	MU Met?
Response time	174	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.7	% of value	<2 % range	Yes
Zero drift	0.10	% full scale	<2% range / 24hr	Yes
Span drift	0.10	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.02	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.8	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	0.01	% full scale/10K	<3% range / 10 K	Yes
dependence on voltage	0.1	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	-0.29	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	0.014
Standard deviation of repeatability at span level	urs	0.01
Lack of fit	ufit	2.31
Drift	u0dr	0.06
volume or pressure flow dependence	uspres	0.00
atmopsheric pressure dependence	uapres	0.14
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	0.49
losses in the line (leak)	uleak	0.00
Uncertainty of calibration gas	ucalib	0.01
Uncertainty in factor	uf	0.02

Measurement uncertainty (Concentration Measured)	1.5	mg/m^3
Combined uncertainty	2.37	mg/m^3
Expanded uncertainty	4.7	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**-**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**4.74**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**310.99**	**% value**

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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - CARBON MONOXIDE

Limit value	-	mg/m^3
Concentration @ Ref conditions	185.4	mg/m^3
Cal gas conc	203.8	mg/m^3
Analyser Full Scale	625	mg/m^3

Performance characteristics	Value	Units	specification	MU Met?
Response time	89	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.7	% of value	<2 % range	Yes
Zero drift	0.90	% full scale	<2% range / 24hr	Yes
Span drift	-1.20	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.02	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.80	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	0.01	% full scale/10K	<3% range / 10 K	Yes
dependence on voltage	0.10	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	-0.49	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	0.01
Standard deviation of repeatability at span level	urs	0.01
Lack of fit	ufit	2.53
Drift	u0dr	-0.35
volume or pressure flow dependence	uspres	0.00
atmopsheric pressure dependence	uapres	0.15
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	0.54
losses in the line (leak)	uleak	-0.72
Uncertainty of calibration gas	ucalib	1.48
Uncertainty in factor	uf	3.65

Measurement uncertainty (Concentration Measured)	255.6	mg/m^3
Combined uncertainty	4.8	mg/m^3
Expanded uncertainty	9.6	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**-**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**9.56**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**3.74**	**% value**

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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - CARBON DIOXIDE

Limit value	-	%vol
Reported Concentration	2.40	%vol
Calibration gas	12.11	%vol
Analyser Full Scale	20	%vol

Performance characteristics	Value	Units	specification	MU Met?
Response time	78	seconds	< 200 s	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.015	% by volume	<0.2 % range	Yes
Repeatability at span level	0.014	% by volume	<0.4 % range	Yes
Deviation from linearity	0.13	% vol	<0.3 % volume	Yes
Zero drift (during measurement period)	-0.02	% vol at zero level	<2% of volume / 24hr	Yes
Span drift (during measurement period)	-0.06	% vol at span level	<2% volume/24hr	Yes
volume or pressure flow dependence	0.02	% of fs / 10l/h	<1% range	Yes
atmospheric pressure dependence	0.8	% of fs/kPa	< 1.5 % range	Yes
ambient temperature dependence	0.01	% by volume /10K	<0.3% volume 10 K	Yes
Combined interference	0.56	% range	<2% range	Yes
Dependence on voltage	0.1	% by volume /10V	< 0.1%vol /10 volt	Yes
Losses in the line (leak)	-0.74	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	-
Standard deviation of repeatability at span level	urs	0.00
Lack of fit	ufit	0.08
Drift	u0dr	-0.02
volume or pressure flow dependence	uspres	0.00
atmospheric pressure dependence	uapres	0.01
ambient temperature dependence	utemp	0.00
Combined interference (from mcerts)	-	0.06
dependence on voltage	uvolt	0.086
losses in the line (leak)	uleak	-0.01
Uncertainty of calibration gas	ucalib	0.01

Measurement uncertainty (Concentration Measured)	2.40	%vol
Combined uncertainty	0.13	%vol
% of value	5.59	%

Expanded uncertainty expressed with a level of confidence of 95%	**11.18**	**% of value**

Expanded uncertainty expressed with a level of confidence of 95%	**0.27**	**% vol**

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXYGEN

Reference	N/A	%vol
Reported Concentration	16.67	%vol
Calibration gas	10.14	%vol
Analyser Full Scale	25	%vol

Performance characteristics	Value	Units	specification	MU Met?
Response time	67	seconds	< 200 s	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.015	% by volume	<0.2 % range	Yes
Repeatability at span level	0.014	% by volume	<0.4 % range	Yes
Deviation from linearity	0.13	% vol	<0.3 % volume	Yes
Zero drift (during measurement period)	-0.04	% vol at zero level	<2% of volume / 24hr	Yes
Span drift (during measurement period)	-0.02	% vol at span level	<2% volume/24hr	Yes
volume or pressure flow dependence	0.02	% of fs / 10l/h	<1% range	Yes
atmospheric pressure dependence	0.80	% of fs/kPa	< 1.5 % range	Yes
ambient temperature dependence	0.01	% by volume /10K	<0.3% volume 10 K	Yes
Combined interference	0.14	% range	<2% range	Yes
Dependence on voltage	0.10	% by volume /10V	< 0.1%vol /10 volt	Yes
Losses in the line (leak)	-0.39	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1.00	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	-
Standard deviation of repeatability at span level	urs	0.0013
Lack of fit	ufit	0.0751
Drift	u0dr	-0.0421
volume or pressure flow dependence	uspres	0.00003
atmospheric pressure dependence	uapres	0.0122
ambient temperature dependence	utemp	0.0005
Combined interference (from mcerts)	-	0.0808
dependence on voltage	uvolt	0.0862
losses in the line (leak)	uleak	-0.0380
Uncertainty of calibration gas	ucalib	0.0963

Measurement uncertainty (Concentration Measured)	16.67	%vol
Combined uncertainty	0.18	%vol
% of value	1.08	%

Expanded uncertainty expressed with a level of confidence of 95%	**2.15**	**% of value**

Expanded uncertainty expressed with a level of confidence of 95%	**0.359**	**% vol**

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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	7.0	m/s
Measured Volumetric Flow rate at Actual Conditions	17002	m³/hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination				
Uncertainty of pitot tube coefficient	-	0.010		
Uncertainty of mean local dynamic pressures	-	0.34		
Factor loading, function of the number of measurements.	3 readings	0.591	minimum 3	Yes
Range of measurment device	pa	1000		
Resolution	pa	1.00		
Calibration uncertainty	pa	0.25	<1% of Value or 20 Pa whichever is greater	Yes
Drift	% range	0.10		
Linearity	% range	0.06	<2% of value	Yes
Uncertainty of gas density determination				
Uncertainty of molar mass determination	kg/mol	0.00003		
Uncertainty of temperature measurement	K	0.78	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	521		
Uncertainty associated with the estimate of density	-	0.009		
Uncertainty associated with the measurement of local velocity	-	0.0001		
Uncertainty associated with the measurement of mean velocity	-	0.0002		

Measurement Uncertainty - Velocity	m/s
Combined uncertainty	0.09
Expanded uncertainty at a 95% Confidence Interval	0.17

Note - The expanded uncertainty uses a coverage factor of k = 2.

Expanded Measurement Uncertainty of Velocity at a 95% Confidence Interval	%
Expressed as a % of the Measured Concentration	1.28
Expanded uncertainty at a 95% Confidence Interval	2.51

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	392.64
Expanded uncertainty at a 95% Confidence Interval	769.58

Note - The expanded uncertainty uses a coverage factor of k = 2.

Expanded Measurement Uncertainty of Volumetric Flow Rate at a 95% Confidence Interval	%
Expressed as a % of the Measured Concentration	2.31
Expanded uncertainty at a 95% Confidence Interval	4.53

END OF REPORT

MARCHWOOD SCIENTIFIC SERVICES
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TEST REPORT

Certificate No.	116/1412
Received Date:	02/02/2016
Ref.	HE/116/1412
Sampling Date:	13/01/2016
Date of Analysis:	10/02/2016
Conforming:	Yes

10/02/2016

Analysis of a Sample of RDF Ref. Service Sample 13/1/16 for Range of Determinands

Please find below the tabulated results for the sample received. (AR= as received; D = Dry basis)

Determinand	Units	AR	D	Method
Gross CV	KJ/Kg	12506	22377	WI 3015
Net CV	KJ/Kg	10612	20914	WI 3015
Proximate Analysis				
Moisture	% w/w	44.1	-	WI 3013
Ash	% w/w	8.1	14.4	WI 3014
Fixed Carbon	% w/w	3.6	6.4	-
Volatile Matter	% w/w	44.2	79.2	-
Total	% w/w	100	100	Calculation
Ultimate Analysis				
Sulphur	% w/w	0.2	0.4	WI 3016
Chlorine	% w/w	0.06	0.11	WI 3016
Carbon	% w/w	28.1	50.3	WI 3024
Hydrogen	% w/w	3.9	6.9	WI 3024
Nitrogen	% w/w	1.1	1.9	WI 3024
Oxygen by difference#	% w/w	14.5	26.0	By Calculation
Total #	% w/w	100	100	By Calculation
Halides				
Bromine	% w/w	<0.01	<0.01	WI 3016
Fluorine	% w/w	0.02	0.04	WI 3016
Iodine	% w/w	<0.01	<0.01	WI 3016
Total Halides	% w/w	0.02	0.04	WI 3016
Metals				
Mercury	ppm	<1	<1	ICP-OES
Cadmium	ppm	<1	<1	ICP-OES
Thallium	ppm	<1	<1	ICP-OES
Antimony	ppm	10	17	ICP-OES
Arsenic	ppm	<1	<1	ICP-OES
Chromium	ppm	20	36	ICP-OES
Cobalt	ppm	<1	<1	ICP-OES
Copper	ppm	224	401	ICP-OES
Lead	ppm	49	87	ICP-OES
Manganese	ppm	20	36	ICP-OES
Nickel	ppm	14	25	ICP-OES
Tin	ppm	<1	<1	ICP-OES
Vanadium	ppm	<1	<1	ICP-OES
Total group of 11 Metals	ppm	336	602	ICP-OES
Biomass	% w/w	-	56.0	WI 3009
Non-Biomass	% w/w	-	29.6	WI 3009
Inert-Mass	% w/w	-	14.4	WI 3009

#Oxygen and Total calculations include ash and moisture as appropriate

Certificate Number:	**116/1412**
Sample Identifier:	**Amber Service Sample 13/1/16**

Physical Characterisation

Material Category	Results (% w/w)
Paper and Card	25.1
Plastic Film	15.1
Dense Plastic	7.4
Textiles	41.2
Miscellaneous combustible	0.9
Miscellaneous non-combustible	ND
Glass&Stones	ND
Putrescibles	3.8
Ferrous metal	ND
Non-Ferrous metal	ND
WEEE	ND
Potentially hazardous	ND
<5mm	6.5
Total	100

*ND=not detected

Reported by: J Fursman

Position: Director

For/on behalf of Marchwood Scientific Services Ltd

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TEST REPORT

Certificate No.	116/568
Received Date:	14/01/2016
Ref.	HE/116/568
Sampling Date:	13/01/2016
Date of Analysis:	27/01/2016
Conforming:	Yes

28/01/2016

Analysis of a Sample of Fines Ref. Fines for Range of Determinands

Please find below the tabulated results for the sample received. (AR= as received; D = Dry basis)

Determinand	Units	AR	D	Method
Gross CV	KJ/Kg	4432	9296	WI 3015
Net CV	KJ/Kg	2751	8448	WI 3015
Proximate Analysis				
Moisture	% w/w	52.3	-	WI 3013
Ash	% w/w	24.3	51.0	WI 3014
Fixed Carbon	% w/w	2.5	5.2	-
Volatile Matter	% w/w	20.9	43.8	-
Total	% w/w	100	100	Calculation
Ultimate Analysis				
Sulphur	% w/w	0.1	0.1	WI 3016
Chlorine	% w/w	0.59	1.25	WI 3016
Carbon	% w/w	13.5	28.3	WI 3024
Hydrogen	% w/w	1.9	4.0	WI 3024
Nitrogen	% w/w	0.4	0.8	WI 3024
Oxygen by difference#	% w/w	6.9	14.5	By Calculation
Total #	% w/w	100	100	By Calculation
Halides				
Bromine	% w/w	<0.01	<0.01	WI 3016
Fluorine	% w/w	<0.01	<0.01	WI 3016
Iodine	% w/w	<0.01	<0.01	WI 3016
Total Halides	% w/w	<0.01	<0.01	WI 3016
Metals				
Mercury	ppm	<1	<1	ICP-OES
Cadmium	ppm	<1	<1	ICP-OES
Thallium	ppm	<1	<1	ICP-OES
Antimony	ppm	5.7	12	ICP-OES
Arsenic	ppm	<1	<1	ICP-OES
Chromium	ppm	6.2	13	ICP-OES
Cobalt	ppm	<1	<1	ICP-OES
Copper	ppm	131	275	ICP-OES
Lead	ppm	49	103	ICP-OES
Manganese	ppm	21	45	ICP-OES
Nickel	ppm	5.2	11	ICP-OES
Tin	ppm	<1	<1	ICP-OES
Vanadium	ppm	<1	<1	ICP-OES
Total group of 11 Metals	ppm	219	459	ICP-OES
Biomass	% w/w	-	40.7	WI 3009
Non-Biomass	% w/w	-	8.3	WI 3009
Inert-Mass	% w/w	-	51.0	WI 3009

#Oxygen and Total calculations include ash and moisture as appropriate

Certificate Number:	**116/568**
Sample Identifier:	**Bryn 2 Fines**

Physical Characterisation

Material Category	Results (% w/w)
Paper and Card	28.6
Plastic Film	4.8
Dense Plastic	7.4
Textiles	4.3
Miscellaneous combustible	17.2
Miscellaneous non-combustible	1.5
Glass&Stones	35.8
Putrescibles	0.5
Ferrous metal	ND
Non-Ferrous metal	ND
WEEE	ND
Potentially hazardous	ND
<5mm	ND
Total	100

*ND=not detected

Reported by: J Fursman

Position: Director

For/on behalf of Marchwood Scientific Services Ltd

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TEST REPORT

Certificate No.	116/567
Received Date:	14/01/2016
Ref.	HE/116/567
Sampling Date:	13/01/2016
Date of Analysis:	27/01/2016
Conforming:	Yes

28/01/2016

Analysis of a Sample of RDF Ref. RDF for Range of Determinands

Please find below the tabulated results for the sample received. (AR= as received; D = Dry basis)

Determinand	Units	AR	D	Method
Gross CV	KJ/Kg	9655	19410	WI 3015
Net CV	KJ/Kg	7891	18329	WI 3015
Proximate Analysis				
Moisture	% w/w	50.3	-	WI 3013
Ash	% w/w	12.2	24.5	WI 3014
Fixed Carbon	% w/w	3.5	7.0	-
Volatile Matter	% w/w	34.1	68.5	-
Total	% w/w	100	100	Calculation
Ultimate Analysis				
Sulphur	% w/w	0.5	1.1	WI 3016
Chlorine	% w/w	0.23	0.47	WI 3016
Carbon	% w/w	18.8	37.7	WI 3024
Hydrogen	% w/w	2.5	5.1	WI 3024
Nitrogen	% w/w	0.7	1.4	WI 3024
Oxygen by difference#	% w/w	14.8	29.8	By Calculation
Total #	% w/w	100	100	By Calculation
Halides				
Bromine	% w/w	<0.01	<0.01	WI 3016
Fluorine	% w/w	<0.01	<0.01	WI 3016
Iodine	% w/w	<0.01	<0.01	WI 3016
Total Halides	% w/w	<0.01	<0.01	WI 3016
Metals				
Mercury	ppm	<1	<1	ICP-OES
Cadmium	ppm	<1	<1	ICP-OES
Thallium	ppm	<1	<1	ICP-OES
Antimony	ppm	9.9	20	ICP-OES
Arsenic	ppm	<1	<1	ICP-OES
Chromium	ppm	17	35	ICP-OES
Cobalt	ppm	<1	<1	ICP-OES
Copper	ppm	166	333	ICP-OES
Lead	ppm	44	89	ICP-OES
Manganese	ppm	17	34	ICP-OES
Nickel	ppm	15	30	ICP-OES
Tin	ppm	<1	<1	ICP-OES
Vanadium	ppm	<1	<1	ICP-OES
Total group of 11 Metals	ppm	269	541	ICP-OES
Biomass	% w/w	-	57.5	WI 3009
Non-Biomass	% w/w	-	18.0	WI 3009
Inert-Mass	% w/w	-	24.5	WI 3009

#Oxygen and Total calculations include ash and moisture as appropriate

Certificate Number:	**116/567**
Sample Identifier:	**Bryn 1 RDF**

Physical Characterisation

Material Category	Results (% w/w)
Paper and Card	20.9
Plastic Film	3.5
Dense Plastic	5.6
Textiles	43.2
Miscellaneous combustible	4.3
Miscellaneous non-combustible	ND
Glass&Stones	13.0
Putrescibles	ND
Ferrous metal	9.1
Non-Ferrous metal	0.1
WEEE	0.3
Potentially hazardous	ND
<5mm	ND
Total	100

*ND=not detected

Reported by: J Fursman

Position: Director

For/on behalf of Marchwood Scientific Services Ltd

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TEST REPORT

Certificate No.	116/591
Received Date:	15/01/2016
Ref.	HE/116/591
Sampling Date:	13/01/2016
Date of Analysis:	28/01/2016
Conforming:	Yes

29/01/2016

Analysis of a Sample of RDF Ref. RDF/C & I Waste W. M 13/1/16 for Range of Determinands

Please find below the tabulated results for the sample received. (AR= as received; D = Dry basis)

Determinand	Units	AR	D	Method
Gross CV	KJ/Kg	11498	21046	WI 3015
Net CV	KJ/Kg	9627	19647	WI 3015
Proximate Analysis				
Moisture	% w/w	45.4	-	WI 3013
Ash	% w/w	6.7	12.2	WI 3014
Fixed Carbon	% w/w	3.7	6.8	-
Volatile Matter	% w/w	44.2	81.0	-
Total	% w/w	100	100	Calculation
Ultimate Analysis				
Sulphur	% w/w	0.1	0.3	WI 3016
Chlorine	% w/w	0.27	0.49	WI 3016
Carbon	% w/w	28.1	51.5	WI 3024
Hydrogen	% w/w	3.6	6.6	WI 3024
Nitrogen	% w/w	1.5	2.8	WI 3024
Oxygen by difference#	% w/w	14.3	26.1	By Calculation
Total #	% w/w	100	100	By Calculation
Halides				
Bromine	% w/w	<0.01	<0.01	WI 3016
Fluorine	% w/w	<0.01	<0.01	WI 3016
Iodine	% w/w	<0.01	<0.01	WI 3016
Total Halides	% w/w	<0.01	<0.01	WI 3016
Metals				
Mercury	ppm	<1	<1	ICP-OES
Cadmium	ppm	<1	<1	ICP-OES
Thallium	ppm	<1	<1	ICP-OES
Antimony	ppm	7.1	13	ICP-OES
Arsenic	ppm	<1	<1	ICP-OES
Chromium	ppm	14	25	ICP-OES
Cobalt	ppm	<1	<1	ICP-OES
Copper	ppm	207	379	ICP-OES
Lead	ppm	62	113	ICP-OES
Manganese	ppm	25	46	ICP-OES
Nickel	ppm	11	21	ICP-OES
Tin	ppm	<1	<1	ICP-OES
Vanadium	ppm	<1	<1	ICP-OES
Total group of 11 Metals	ppm	326	597	ICP-OES
Biomass	% w/w	-	56.6	WI 3009
Non-Biomass	% w/w	-	31.2	WI 3009
Inert-Mass	% w/w	-	12.2	WI 3009

#Oxygen and Total calculations include ash and moisture as appropriate

Certificate Number:	**116/591**
Sample Identifier:	**RDF/C & I Waste 13/1/16**

Physical Characterisation

Material Category	Results (% w/w)
Paper and Card	27.4
Plastic Film	7.1
Dense Plastic	5.0
Textiles	21.8
Miscellaneous combustible	8.2
Miscellaneous non-combustible	0.3
Glass&Stones	8.4
Putrescibles	16.1
Ferrous metal	2.1
Non-Ferrous metal	0.7
WEEE	ND
Potentially hazardous	ND
<5mm	2.9
Total	100

*ND=not detected

Reported by: J Fursman

Position: Director

For/on behalf of Marchwood Scientific Services Ltd