STACK EMISSIONS MONITORING REPORT

Unit D
Bankside Trade Park
Cirencester
GL7 1YT
Tel: 01285 700 593

Your contact at ESG
Mike Davies Business Manager - South Tel: 07976 297 465 Email: mike.davies@esg.co.uk

Operator & Address:
Bolton Aerospace Limited PO Box 22 Hadleigh Road Ipswich Suffolk IP2 0EG

Permit:
EPR Permit: EP54/1/LB

Release Point:
A1 - Main Stack

Sampling Date(s):
14th & 15th September 2016

ESG Job Number:	LSO 160910
Report Date:	25th October 2016
Version:	1
Report By:	Owen May
MCERTS Number:	MM 10 1072
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

Bolton Aerospace Limited operates a non-ferrous alloy production process at Ipswich which is subject to EPR Permit EP54/1/LB, under the Environmental Permitting Regulations 2010.

ESG were commissioned by Bolton Aerospace Limited 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 EPR Permit, EP54/1/LB.

Plant

A1 - Main Stack

Operator

Bolton Aerospace Limited
PO Box 22
Hadleigh Road
Ipswich
Suffolk
IP2 0EG

EPR Permit: EP54/1/LB

Stack Emissions Monitoring Test House

ESG - 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	11.1	0.69	20	✓
Particulate Emission Rate	g/hr	950	58.9	-	
Dioxins & Furans - UPPER Limits					
Dioxins & Furans (NATO I-TEQ)	ng/m³	0.0139	0.0028	1.0	✓
Dioxins & Furans (NATO I-TEQ) Emission Rate	µg/hr	1.2381	0.2501	-	
Dioxins & Furans (WHO TEQ Humans / Mammals)	ng/m³	0.0131	0.0026	-	✓
Dioxins & Furans (WHO TEQ H / M) Emission Rate	µg/hr	1.1689	0.2361	-	
Dioxins & Furans (WHO TEQ Fish)	ng/m³	0.0155	0.0031	-	✓
Dioxins & Furans (WHO TEQ Fish) Emission Rate	µg/hr	1.3791	0.2786	-	
Dioxins & Furans (WHO TEQ Birds)	ng/m³	0.0265	0.0054	-	✓
Dioxins & Furans (WHO TEQ Birds) Emission Rate	µg/hr	2.3659	0.4779	-	
Dioxins & Furans - LOWER Limits					
Dioxins & Furans (NATO I-TEQ)	ng/m³	0.0139	0.0028	-	✓
Dioxins & Furans (NATO I-TEQ) Emission Rate	µg/hr	1.2381	0.2501	-	
Dioxins & Furans (WHO TEQ Humans / Mammals)	ng/m³	0.0131	0.0026	-	✓
Dioxins & Furans (WHO TEQ H / M) Emission Rate	µg/hr	1.1689	0.2361	-	
Dioxins & Furans (WHO TEQ Fish)	ng/m³	0.0155	0.0031	-	✓
Dioxins & Furans (WHO TEQ Fish) Emission Rate	µg/hr	1.3791	0.2786	-	
Dioxins & Furans (WHO TEQ Birds)	ng/m³	0.0265	0.0054	-	✓
Dioxins & Furans (WHO TEQ Birds) Emission Rate	µg/hr	2.3659	0.4779	-	
Dioxin-like PCBs - UPPER Limits					
Dioxin-like PCBs (WHO TEQ Humans / Mammals)	ng/m³	0.0031	0.0004	-	✓
Dioxin-like PCBs (WHO TEQ H / M) Emission Rate	µg/hr	0.2736	0.0331	-	
Dioxin-like PCBs (WHO TEQ Fish)	ng/m³	0.0002	0.0000	-	✓
Dioxin-like PCBs (WHO TEQ Fish) Emission Rate	µg/hr	0.0176	0.0021	-	
Dioxin-like PCBs (WHO TEQ Birds)	ng/m³	0.0153	0.0019	-	✓
Dioxin-like PCBs (WHO TEQ Birds) Emission Rate	µg/hr	1.3650	0.1652	-	
Dioxin-like PCBs - LOWER Limits					
Dioxin-like PCBs (WHO TEQ Humans / Mammals)	ng/m³	0.0031	0.0004	-	✓
Dioxin-like PCBs (WHO TEQ H / M) Emission Rate	µg/hr	0.2736	0.0331	-	
Dioxin-like PCBs (WHO TEQ Fish)	ng/m³	0.0002	0.0000	-	✓
Dioxin-like PCBs (WHO TEQ Fish) Emission Rate	µg/hr	0.0176	0.0021	-	
Dioxin-like PCBs (WHO TEQ Birds)	ng/m³	0.0153	0.0019	-	✓
Dioxin-like PCBs (WHO TEQ Birds) Emission Rate	µg/hr	1.3650	0.1652	-	
Cadmium & Thallium	mg/m³	0.0009	0.0002	1	✓
Cadmium & Thallium Emission Rate	g/hr	0.0794	0.0181	-	
Heavy Metals	mg/m³	12.82	2.922	32	✓
Heavy Metals Emission Rate	g/hr	1178	269	-	
Lead	mg/m³	0.52941	0.1207	2	✓
Lead Emissions Rate	g/hr	48.662	11.0949	-	
Tin	mg/m³	0.00041	0.00009	5	✓
Tin Emission Rate	g/hr	0.0379	0.0086	-	
Copper	mg/m³	0.29755	0.0678	20	✓
Copper Emission Rate	g/hr	27.35	6.2358	-	
Nickel	mg/m³	0.0169	0.0039	5	✓
Nickel Emission Rate	g/hr	1.5532	0.3541	-	
Cobalt, Chromium and Cadmium	mg/m³	0.01134	0.0026	1	✓
Cobalt, Chromium and Cadmium Emission Rate	g/hr	1.043	0.2378	-	
Hydrogen Fluoride	mg/m³	***0.02***	0.001	5	✓
Hydrogen Fluoride Emission Rate	g/hr	***1.57***	0.142	-	
Moisture	%	1.03	0.0	-	✓
Stack Gas Temperature	°C	30	-	-	✓
Stack Gas Velocity	m/s	12.4	0.31	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	107263	5578	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	96972	5043	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	95969	4990	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	96972	5043	-	

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	15 September 2016	09:40 - 11:11	90 minutes
Dioxins, Furans & Dioxin-like PCBs Run 1	14 September 2016	07:44 - 13:50	360 minutes
Cadmium & Thallium Run 1	15 September 2016	08:00 - 09:34	90 minutes
Heavy Metals Run 1	15 September 2016	08:00 - 09:34	90 minutes
Hydrogen Fluoride Run 1	14 September 2016	07:50 - 13:50	360 minutes
Preliminary Stack Traverse	14 September 2016	07:30	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Non-ferrous alloy production
Continuous or batch	Batch
Product Details	Various metal alloy components
Part of batch to be monitored (if applicable)	Any 6 hour part
Normal load, throughput or continuous rating	Approx 700kg / hour
Fuel used during monitoring	N/A
Abatement	None
Plume Appearance	None Visible

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard reference / alternative methods employed by ESG 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	0.3 mg/m³	6.2 %
PCDD/PCDF	SRM - BS EN 1948-1	AE 109	1015	Yes	0.001 ng/m³	20.2 %
PCBs	SRM - BS EN 1948-1	AE 109	1015	Yes	0 ng/m³	12.1 %
Cd & Tl	SRM - BS EN 14385	AE 108	1015	Yes	0.00065 mg/m³	22.8 %
Heavy Metals	SRM - BS EN 14385	AE 108	1015	Yes	0.005 mg/m³	22.8 %
Hydrogen Fluoride	SRM - BS ISO 15713	AE 113	1015	Yes	0 mg/m³	9 %
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	0%	2.9%
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	5 Pa	2.5 %

BS EN 14790 has been validated over a range of 4 - 40%. It is however the prefered method of the Environment Agency for concentrations below 4%

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
PCDD/PCDF	Gas Chromatography - High Resolution Mass Spectometry	ANU/SOP/3007	1549	Yes	ESG Bretby	ESG Bretby	3 months
PCBs	Gas Chromatography - High Resolution Mass Spectometry	ANU/SOP/3004	1549	Yes	ESG Bretby	ESG Bretby	3 months
Cd & Tl	Inductively coupled Plasma - Mass Spectrometry	ANU/SOP/117, 101,102	1015	Yes	ESG Bretby	ESG Bretby	3 months
Heavy Metals	Inductively coupled Plasma - Mass Spectrometry	ANU/SOP/117, 101,102	1015	Yes	ESG Bretby	ESG Bretby	3 months
Hydrogen Fluoride	Ion Chromatography	ASC/SOP/110/10	1015	Yes	ESG Bretby	ESG Bretby	3 months

ON-SITE TESTING							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	MCERTS Accredited Analysis	Laboratory	Data Archive Location	Archive Period
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	124	Pa	>= 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	11.95	m/s	-	-	-
Highest Gas Velocity	12.74	m/s	-	-	-
Ratio of Gas Velocities	1.07	: 1	< 3 : 1	Yes	BS EN 15259
Mean Velocity	12.39	m/s	-	-	-
Maximum angle of flow with regard to duct axis	<15	°	< 15°	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259

DUCT CHARACTERISTICS		
	Value	**Units**
Shape	Circular	-
Depth	1.75	m
Width	-	m
Area	2.41	m^2
Port Depth	90	mm

SAMPLING LINES & POINTS		
	Isokinetic	**Non-Iso & Gases**
Sample port size	4 " BSP	-
Number of lines used	2	-
Number of points / line	3	-
Duct orientation	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	No
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 should meet all the requirements as specified in EA Guidance Note M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Sampling points

Due to the limited size of the platform, it was not possible to test the sampling points towards the far-wall of both sampling lines.

APPENDICES

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

APPENDIX 3 - Measurement Uncertainty Budget Calculations

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	1
PCDD/PCDF	SRM - BS EN 1948-1	AE 109	1015	Yes	1
PCBs	SRM - BS EN 1948-1	AE 109	1015	Yes	1
Cd & Tl	SRM - BS EN 14385	AE 108	1015	Yes	1
Heavy Metals	SRM - BS EN 14385	AE 108	1015	Yes	1
Hydrogen Fluoride	SRM - BS ISO 15713	AE 113	1015	Yes	1
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	1
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	P1268	Horiba PG-250 Analyser	-	Laboratory Balance	P66
Box Thermocouples	P1268	FT-IR	-	Tape Measure	P2024
Meter In Thermocouple	P1268	FT-IR Oven Box	-	Stopwatch	P2614
Meter Out Thermocouple	P1268	Bernath 3006 FID	-	Protractor	-
Control Box Timer	-	Signal 3030 FID	-	Barometer	P1916
Oven Box	P1375	Servomex	-	Digital Micromanometer	P1915
Probe	P2628	JCT Heated Head Filter	-	Digital Temperature Meter	P1745
Probe Thermocouple	P2628	Thermo FID	-	Stack Thermocouple	-
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	P2078	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P1952	Chiller (JCT/MAK 10)	-	1m Heated Line (3)	-
Last Impinger Arm	P2171	Heated Line Controller (1)	-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	P1980	Heated Line Controller (2)	P1930	10m Heated Line (1)	-
Callipers	-	Site temperature Logger	-	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Wet Gas Meter	P497		-	20m Heated Line (1)	P2403
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 +/- %
-	-	-	-	-	-

STACK EMISSIONS MONITORING TEAM

MONITORING TEAM								
Personnel	**MCERTS Number**	**MCERTS**		**TE / H&S Qualifications and Expiry Date**				
		Level	**Expiry**	**TE1**	**TE2**	**TE3**	**TE4**	**H&S**
Owen May	MM 10 1072	MCERTS Level 2	Feb-18	Sep-21	Jun-21	Mar-17	Mar-22	Jun-20
Jamie Whiteman	MM 16 1364	MCERTS Level 1	Jan-21	-	-	-	-	Jan-19

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	09:40 - 11:11 15 September 2016	11.1	0.68	20	950
Blank	-	0.30	-	-	-

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	038690	0.15430	0.17090	0.01660	71.71890	71.72070	0.00180	0.01840

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	038689	0.15220	0.15230	0.00010	68.52890	68.52890	0.00000	0.00050

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	759.01
Stack static pressure, P_{static}	mm H_2O	-3.98
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	758.72
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	H_20 by Non Iso
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		1.821
Gas meter correction factor, Y_d		1.0135
Mean dry gas meter temperature, T_m		34.458
Mean pressure drop across orifice, DH	mmH_2O	45.107
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m + 273}$		1.644
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.6609
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		20.9
% 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}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0103
		1.03
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.82
Mean of velocity heads, DP_{avg}	mm H_2O	10.67
Mean square root of velocity heads, ÖDP		3.27
Mean stack gas temperature, T_s	°C	32
$V_s = \frac{(K_p)(C_p)(ÖDP)(Ö(T_s + 273))}{(M_s)(P_s)}$	m/s	11.08

Molecular weight of dry gas, M_d		
CO_2	%	0.03
O_2	%	20.90
Total	%	20.93
N_2 (100 -Total)	%	79.07
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.73
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	2.41
$Q_a = (60)(A_s)(V_s)$	m³/min	1599.0
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	1414.0
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O_2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	1428.78
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	6.22
Nozzle area, A_n	mm^2	30.39
Total sampling time, q	min	90
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	102.2
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.01660
Mass collected in probe, M_p	g	0.00180
Total mass collected, M_n	g	0.01840
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	11.078
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	11.194
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		949.72

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	20.51	0.18	0.24	-406.4	0.41	Yes

ISOKINETICITY

Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	102.24	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY

Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.30	1	Yes

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	0.30	20	2.0	Yes

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	32	180	160

GF = Glass Fibre

QF = Quartz Fibre

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXINS & FURANS SUMMARY - UPPER LIMIT

NATO I-TEQ					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.01389	0.00137	1	1.24
Field Blanks Run 1	-	0.00137	-	-	-

WHO TEQ (Humans / Mammals)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.01311	0.00173	-	1.17
Field Blanks Run 1	-	0.00157	-	-	-

WHO TEQ (Fish)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.01547	0.00201	-	1.38
Field Blanks Run 1	-	0.00173	-	-	-

WHO TEQ (Birds)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.02654	0.00201	-	2.37
Field Blanks Run 1	-	0.00201	-	-	-

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXINS & FURANS SUMMARY - LOWER LIMIT

NATO I-TEQ					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.01389	-	1	1.24
Field Blanks Run 1	-	0.00000	-	-	-

WHO TEQ (Humans / Mammals)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.01311	-	-	1.17
Field Blanks Run 1	-	0.00000	-	-	-

WHO TEQ (Fish)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.01547	-	-	1.38
Field Blanks Run 1	-	0.00000	-	-	-

WHO TEQ (Birds)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.02654	-	-	2.37
Field Blanks Run 1	-	0.00000	-	-	-

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXINS & FURANS ANALYSIS SUMMARY - RUN 1

NATO I-TEQ & WHO TEQ (Humans / Mammals)					
Congener	Result	NATO I-TEQ	WHO TEQ Humans / Mammals	Extraction Recovery	
				Actual	Permitted
	ng	ng	ng	%	%
Dioxins					
2378 Tetra CDD	0.0033	0.0033	0.0033	67	50 - 130
12378 Penta CDD	0.025	0.0125	0.025	58	50 - 130
123478 Hexa CDD	0.0073	0.00073	0.00073	0	50 - 130
123678 Hexa CDD	0.0088	0.00088	0.00088	81	50 - 130
123789 Hexa CDD	0.0087	0.00087	0.00087		
1234678 Hepta CDD	0.073	0.00073	0.00073	63	50 - 130
OCDD Octa CDD	0.08	0.00008	0.000024	48	20 - 150
Total -Dioxins	**0.2061**	**0.01909**	**0.031534**		
Furans					
2378 Tetra CDF	0.042	0.0042	0.0042	65	50 - 130
12378 Penta CDF	0.049	0.00245	0.00147	56	>=50
23478 Penta CDF	0.084	0.042	0.0252	0	50 - 130
123478 Hexa CDF	0.07	0.007	0.007	0	50 - 130
123678 Hexa CDF	0.078	0.0078	0.0078	83	50 - 130
234678 Hexa CDF	0.085	0.0085	0.0085	0	50 - 130
123789 Hexa CDF	0.027	0.0027	0.0027	65	>=50
1234678 Hepta CDF	0.22	0.0022	0.0022	68	20 - 150
1234789 Hepta CDF	0.018	0.00018	0.00018	0	>=50
OCDF Octa CDF	0.057	0.000057	0.0000171	0	20 - 150
Total -Furans	**0.73**	**0.077087**	**0.0592671**		
Mean Recoveries (%)				**65**	
Total Isomers	**0.9361**	**0.09618**	**0.09080**		
Total ITEQ (<LOD = 0)		**0.09618**	**0.09080**		

NOTE: The Total Isomers result includes all isomers below the limit of detection. This gives a "worst case" Dioxins & Furans result.

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXINS & FURANS ANALYSIS SUMMARY - RUN 1

WHO TEQ (Fish) & WHO TEQ (Birds)					
Congener	Result	WHO TEQ Fish	WHO TEQ Birds	Extraction Recovery	
				Actual	Permitted
	ng	ng	ng	%	%
Dioxins					
2378 Tetra CDD	0.0033	0.0033	0.0033	67	50 - 130
12378 Penta CDD	0.025	0.025	0.025	58	50 - 130
123478 Hexa CDD	0.0073	0.00365	0.000365	0	50 - 130
123678 Hexa CDD	0.0088	0.000088	0.000088	81	50 - 130
123789 Hexa CDD	0.0087	0.000087	0.000087		
1234678 Hepta CDD	0.073	0.000073	0.000073	63	50 - 130
OCDD Octa CDD	0.08	-	-	48	20 - 150
Total -Dioxins	**0.2061**	**0.032198**	**0.028913**		
Furans					
2378 Tetra CDF	0.042	0.0021	0.042	65	50 - 130
12378 Penta CDF	0.049	0.00245	0.00049	56	>=50
23478 Penta CDF	0.084	0.042	0.084	0	50 - 130
123478 Hexa CDF	0.07	0.007	0.007	0	50 - 130
123678 Hexa CDF	0.078	0.0078	0.0078	83	50 - 130
234678 Hexa CDF	0.085	0.0085	0.0085	0	50 - 130
123789 Hexa CDF	0.027	0.0027	0.0027	65	>=50
1234678 Hepta CDF	0.22	0.0022	0.0022	68	20 - 150
1234789 Hepta CDF	0.018	0.00018	0.00018	0	>=50
OCDF Octa CDF	0.057	0.0000057	0.0000057	0	20 - 150
Total -Furans	**0.73**	**0.0749357**	**0.1548757**		
Mean Recoveries (%)				**65**	
Total Isomers	**0.9361**	**0.1071337**	**0.1837887**		
Total ITEQ (<LOD = 0)		**0.1071337**	**0.1837887**		

NOTE: The Total Isomers result includes all isomers below the limit of detection. This gives a "worst case" Dioxins & Furans result.

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXINS & FURANS ANALYSIS SUMMARY - FIELD BLANK RUN 1

NATO I-TEQ & WHO TEQ (Humans / Mammals)					
Congener	Result	NATO I-TEQ	WHO TEQ Humans / Mammals	Extraction Recovery	
				Actual	Permitted
	ng	ng	ng	%	%
Dioxins					
2378 Tetra CDD	< 0.003	0.003	0.003	78	50 - 130
12378 Penta CDD	< 0.004	0.002	0.004	66	50 - 130
123478 Hexa CDD	< 0.003	0.0003	0.0003	0	50 - 130
123678 Hexa CDD	< 0.003	0.0003	0.0003	88	50 - 130
123789 Hexa CDD	< 0.003	0.0003	0.0003		
1234678 Hepta CDD	< 0.009	0.00009	0.00009	64	50 - 130
OCDD Octa CDD	< 0.02	0.00002	0.000006	44	20 - 150
Total -Dioxins	**0.045**	**0.00601**	**0.007996**		
Furans					
2378 Tetra CDF	< 0.002	0.0002	0.0002	73	50 - 130
12378 Penta CDF	< 0.002	0.0001	0.00006	62	>=50
23478 Penta CDF	< 0.003	0.0015	0.0009	0	50 - 130
123478 Hexa CDF	< 0.004	0.0004	0.0004	0	50 - 130
123678 Hexa CDF	< 0.004	0.0004	0.0004	88	50 - 130
234678 Hexa CDF	< 0.004	0.0004	0.0004	0	50 - 130
123789 Hexa CDF	< 0.004	0.0004	0.0004	69	>=50
1234678 Hepta CDF	< 0.004	0.00004	0.00004	69	20 - 150
1234789 Hepta CDF	< 0.005	0.00005	0.00005	0	>=50
OCDF Octa CDF	< 0.01	0.00001	0.000003	0	20 - 150
Total -Furans	**0.042**	**0.0035**	**0.002853**		
Mean Recoveries (%)				**70**	
Total Isomers	**0.087**	**0.00951**	**0.010849**		
Total ITEQ (<LOD = 0)		**0**	**0**		

NOTE: The Total Isomers result includes all isomers below the limit of detection. This gives a "worst case" Dioxins & Furans result.

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXINS & FURANS ANALYSIS SUMMARY - FIELD BLANK RUN 1

WHO TEQ (Fish) & WHO TEQ (Birds)					
Congener	Result	WHO TEQ Fish	WHO TEQ Birds	Extraction Recovery	
				Actual	Permitted
	ng	ng	ng	%	%
Dioxins					
2378 Tetra CDD	< 0.003	0.003	0.003	78	50 - 130
12378 Penta CDD	< 0.004	0.004	0.004	66	50 - 130
123478 Hexa CDD	< 0.003	0.0015	0.00015	0	50 - 130
123678 Hexa CDD	< 0.003	0.00003	0.00003	88	50 - 130
123789 Hexa CDD	< 0.003	0.00003	0.00003		
1234678 Hepta CDD	< 0.009	0.000009	0.000009	64	50 - 130
OCDD Octa CDD	< 0.02	-	-	44	20 - 150
Total -Dioxins	**0.045**	**0.008569**	**0.007219**		
Furans					
2378 Tetra CDF	< 0.002	0.0001	0.002	73	50 - 130
12378 Penta CDF	< 0.002	0.0001	0.00002	62	>=50
23478 Penta CDF	< 0.003	0.0015	0.003	0	50 - 130
123478 Hexa CDF	< 0.004	0.0004	0.0004	0	50 - 130
123678 Hexa CDF	< 0.004	0.0004	0.0004	88	50 - 130
234678 Hexa CDF	< 0.004	0.0004	0.0004	0	50 - 130
123789 Hexa CDF	< 0.004	0.0004	0.0004	69	>=50
1234678 Hepta CDF	< 0.004	0.00004	0.00004	69	20 - 150
1234789 Hepta CDF	< 0.005	0.00005	0.00005	0	>=50
OCDF Octa CDF	< 0.01	0.000001	0.000001	0	20 - 150
Total -Furans	**0.042**	**0.0034**	**0.0067**		
Mean Recoveries (%)				**70**	
Total Isomers	**0.087**	**0.0120**	**0.0139**		
Total ITEQ (<LOD = 0)		**0.0000**	**0.0000**		

NOTE: The Total Isomers result includes all isomers below the limit of detection. This gives a "worst case" Dioxins & Furans result.

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXIN-LIKE PCBs -UPPER LIMIT

WHO TEQ (Humans / Mammals)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.00307	0.00028	-	0.274
Field Blanks Run 1	-	0.00058	-	-	-

WHO TEQ (Fish)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.00020	0.00001	-	0.018
Field Blanks Run 1	-	0.00003	-	-	-

WHO TEQ (Birds)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.01531	0.00031	-	1.365
Field Blanks Run 1	-	0.00200	-	-	-

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXIN-LIKE PCBs - LOWER LIMIT

WHO TEQ (Humans / Mammals)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.00307	-	-	0.274
Field Blanks Run 1	-	0.00058	-	-	-

WHO TEQ (Fish)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.00020	-	-	0.018
Field Blanks Run 1	-	0.00003	-	-	-

WHO TEQ (Birds)					
Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:44 - 13:50 14 September 2016	0.01531	-	-	1.365
Field Blanks Run 1	-	0.00200	-	-	-

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXIN-LIKE PCBs ANALYSIS SUMMARY - RUN 1

Congener	LOD ng	Result ng	WHO TEQ Humans / Mammals ng	WHO TEQ Fish ng	WHO TEQ Birds ng	Recovery %
Non-ortho PCBs						
33'44' TCB (77)	0.0041	0.59	0.000059	0.000295	0.059	62
344'5 TCB (81)	0.0027	0.55	0.000165	0.000055	0.0275	56
33'44'5 PeCB (126)	0.016	0.19	0.019	0.00095	0.019	80
33'44'55' HxCB (169)	0.012	0.05	0.00162	0.0000027	0.000054	81
Mono-ortho PCBs						
233'44' PeCB (105)	0.049	3.00	0.00009	0.000015	0.0003	75
2344'5 PeCB (114)	0.023	0.23	0.0000069	0.00000115	0.000023	78
23'44'5 PeCB (118)	0.12	8.70	0.000261	0.0000435	0.000087	76
2'344'5 PeCB (123)	0.0026	0.80	0.000024	0.000004	0.000008	85
233'44'5 HxCB (156)	0.016	0.49	0.0000147	0.00000245	0.000049	91
233'44'5' HxCB (157)	0.015	0.14	0.0000042	0.0000007	0.000014	94
23'44'55' HxCB (167)	0.015	0.22	0.0000066	0.0000011	0.0000022	96
233'44'55' HpCB (189)	0.011	0.07	0.00000195	0.000000325	0.00000065	84
Internal Std Recovery						
13C PCB 52	-	-	-	-	-	58
13C PCB 101	-	-	-	-	-	62
13C PCB 118	-	-	-	-	-	48
Mean Analytical Recovery						56
Total PCBs		15.029	0.02125335	0.001370925	0.11	
Reported PCBs (>= or equal to Blank)		15.029	0.02125335	0.001370925	0.11	

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXIN-LIKE PCBs ANALYSIS SUMMARY - BLANK RUN 1

Congener	LOD ng	Result ng	WHO TEQ Humans / Mammals ng	WHO TEQ Fish ng	WHO TEQ Birds ng	Recovery %
Non-ortho PCBs						
344'5 TCB (81)	0.0041	0.09	0.0000088	0.000044	0.0088	77
33'44' TCB (77)	0.0027	0.04	0.0000114	0.0000038	0.0019	79
33'44'5 PeCB (126)	0.016	0.03	0.0031	0.000155	0.0031	77
33'44'55' HxCB (169)	0.012	0.03	0.0009	0.0000015	0.00003	64
Mono-ortho PCBs						
233'44' PeCB (105)	0.049	0.15	0.0000045	0.00000075	0.000015	81
2344'5 PeCB (114)	0.023	0.03	0.00000078	0.00000013	0.0000026	82
23'44'5 PeCB (118)	0.12	0.42	0.0000126	0.0000021	0.0000042	79
2'344'5 PeCB (123)	0.0026	0.05	0.00000156	0.00000026	0.00000052	86
233'44'5 HxCB (156)	0.016	0.05	0.00000147	0.000000245	0.0000049	80
233'44'5' HxCB (157)	0.015	0.03	0.00000093	0.000000155	0.0000031	77
23'44'55' HxCB (167)	0.015	0.04	0.00000108	0.00000018	0.00000036	82
233'44'55' HpCB (189)	0.011	0.03	0.00000102	0.00000017	0.00000034	76
Internal Std Recovery						
13C PCB 52	-	-	-	-	-	55
13C PCB 101	-	-	-	-	-	56
13C PCB 118	-	-	-	-	-	56
Mean Analytical Recovery						56
Total PCBs		0.985	0.00404414	0.00020829	0.01	

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 1 — Dioxins, Furans & PCBs

Absolute pressure of stack gas, P_s			**Molecular weight of dry gas, M_d**		
Barometric pressure, P_b	mm Hg	762.01	CO_2	%	0.03
Stack static pressure, P_{static}	mm H_2O	-3.98	O_2	%	20.90
$P_s = P_b + (P_{static})/13.6$	mm Hg	761.72	Total	%	20.93
			N_2 (100 -Total)	%	79.07
			$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Vol. of water vapour collected, V_{wstd}			**Molecular weight of wet gas, M_s**		
Moisture trap weight increase,Vlc	g	H_20 by Non Iso	$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.73
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-	**Velocity of stack gas, V_s**		
Volume of gas metered dry, V_{mstd}			Pitot tube velocity constant, K_p		34.97
			Velocity pressure coefficient, C_p		0.82
Volume of gas sample through gas meter, V_m		7.47	Mean of velocity heads, DP_{avg}	mm H_2O	11.56
Gas meter correction factor, Y_d		1.0135	Mean square root of velocity heads, ÖDP		3.40
Mean dry gas meter temperature, T_m		30.69	Mean stack gas temperature, T_s	°C	34
Mean pressure drop across orifice, DH	mmH_2O	47.98	$V_s = (K_p)(C_p)(ÖDP)(Ö(T_s + 273))/(M_s)(P_s)$	m/s	11.55
$V_{mstd} = (0.3592)(V_m)(P_b+(DH/13.6))(Y_d)/(T_m + 273)$		6.85	**Actual flow of stack gas, Q_a**		
			Area of stack, A_s	m^2	2.41
Volume of gas metered wet, V_{mstw}			$Q_a = (60)(A_s)(V_s)$	m^3/min	1666.6
			Total flow of stack gas, Q		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	6.9259	Conversion factor (K/mm.Hg)		
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$			$Q_{std} = (Q_a)P_s(0.3592)(1-B_{wo})/(T_s) +273$	Dry	1470.6
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No	$Q_{stdO2} = (Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)/(T_s) +273$	@O2ref	No O2 Ref
% oxygen measured in gas stream, act%O_2		20.90	$Q_{stw} = (Q_a)P_s(0.3592)/(T_s) +273$	Wet	1486
% oxygen reference condition		21			
O_2 Reference Factor $= O2\ Ref = 21.0 - act\%O2 / 21.0 - ref\%O2$		No O2 Ref	**Percent isokinetic, %I**		
			Nozzle diameter, D_n	mm	6.2
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref	Nozzle area, A_n	mm^2	30.4
Moisture content, B_{wo}			Total sampling time, q	min	360.0
			$\%I = (4.6398E6)(T_s+273)(V_{mstd})/(P_s)(V_s)(A_n)(q)(1-B_{wo})$	%	102.5
$B_{wo} = V_{wstd}/(V_{mstd} + V_{wstd})$	%	0.0103 1.03			
Moisture by FTIR	%	-	Acceptable isokinetic range 95% to 115%		Yes

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DIOXINS & FURANS & PCBs QUALITY ASSURANCE CHECKLIST

Leak Test Results	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 litre/min
Run 1	21.03	0.24	0.24	-406.4	1.05	Yes

Isokinetic Criterion Compliance	Isokinetic Variation %	Acceptable Isokineticity
Run 1	102.5	Yes

Acceptable isokinetic range 95% to 115%

Filtration	Filter Material	Filter Size mm	Maximum Filtration Temperature °C
Run 1	QF	90	120

GF = Glass Fibre

QF = Quartz Fibre

Critical Sampling Requirement	Maximum Temperature at Condenser / Adsorber °C	Maximum Temperature during storage / transit °C	Acceptable Temperature?
Run 1	15	22	Yes

Acceptable < 25°C

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS SOLID & VAPOUR PHASES COMBINED

CADMIUM & THALLIUM COMBINED					
Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	08:00 - 09:34 15 September 2016	0.0009	0.0006	1.00	0.08
Field Blank	-	0.0007	-	-	-
TOTAL HEAVY METALS COMBINED					
Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	08:00 - 09:34 15 September 2016	12.8170	0.0053	32	1178.12
Field Blank	-	0.0401	-	-	-

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

INDIVIDUAL METALS SUMMARY - SOLID & VAPOUR PHASES COMBINED

Metals	LOD mg/m³	Concentration mg/m³	Emission Rate g/hr
Cadmium	0.00031	0.00047	0.0437
Thallium	0.00036	0.00039	0.0357
Cadmium & Thallium	0.00065	0.00086	0.0794

Metals	LOD mg/m³	Concentration mg/m³	Emission Rate g/hr
Arsenic	0.00044	0.00069	0.0632
Antimony	0.00025	0.00043	0.0398
Chromium	0.00024	0.01067	0.9811
Cobalt	0.00014	0.00020	0.0182
Copper	0.00031	0.29755	27.350
Lead	0.00031	0.52941	48.662
Manganese	0.00028	0.00862	0.7923
Nickel	0.00028	0.01690	1.5532
Tin	0.00019	0.00041	0.0379
Vanadium	0.00163	0.00213	0.1956
Zinc	0.00128	11.9500	1098
Total Other Heavy Metals	0.00534	12.8170	1178

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS - RUN 1 SUMMARY

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³
Cadmium	0.00	0.50	0.00	0.00	0.34	0.00
Thallium	0.00	0.60	0.00	0.00	0.09	0.00
Cadmium & Thallium	0.00	1.10	0.00	0.00	0.43	0.00
Volume Sampled m^3		1.7700			1.7700	

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

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³
Arsenic	0.00034	0.80000	0.00045	0.00010	0.41630	0.00024
Antimony	0.00023	0.40000	0.00023	0.00002	0.36590	0.00021
Chromium	0.00017	3.50000	0.00198	0.00007	15.39200	0.00870
Cobalt	0.00011	0.20000	0.00011	0.00002	0.15140	0.00009
Copper	0.00028	510.00000	0.28814	0.00002	16.65600	0.00941
Lead	0.00028	930.00000	0.52543	0.00002	7.04080	0.00398
Manganese	0.00023	9.20000	0.00520	0.00005	6.05680	0.00342
Nickel	0.00023	21.00000	0.01186	0.00005	8.90860	0.00503
Tin	0.00017	0.30000	0.00017	0.00002	0.42900	0.00024
Vanadium	0.00113	2.00000	0.00113	0.00050	1.76600	0.00100
Zinc	0.00028	21000.00000	11.86458	0.00100	151.16800	0.08541
Total Other Heavy Metals	0.00345	22477.40000	12.69929	0.00190	208.35080	0.11771
Volume Sampled m^3		1.7700			1.7700	

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS - BLANK SUMMARY

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³
Cadmium	0.00028	0.5	0.00028	0.00002	0.04460	0.00003
Thallium	0.00028	0.6	0.00034	0.00002	0.04460	0.00003
Cadmium & Thallium	0.00056	1.1	0.00062	0.00002	0.08920	0.00005
Volume Sampled m^3		1.7700			1.7700	

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

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³
Arsenic	0.00034	0.60000	0.00034	0.00010	0.17840	0.00010
Antimony	0.00023	0.40000	0.00023	0.00002	0.04460	0.00003
Chromium	0.00017	1.00000	0.00056	0.00007	0.13380	0.00008
Cobalt	0.00011	0.20000	0.00011	0.00002	0.04460	0.00003
Copper	0.00028	2.00000	0.00113	0.00002	0.53520	0.00030
Lead	0.00028	2.00000	0.00113	0.00002	0.04460	0.00003
Manganese	0.00023	0.90000	0.00051	0.00005	0.08920	0.00005
Nickel	0.00023	2.00000	0.00113	0.00005	0.08920	0.00005
Tin	0.00017	20.00000	0.01130	0.00002	0.04460	0.00003
Vanadium	0.00113	2.00000	0.00113	0.00050	0.89200	0.00050
Zinc	0.00028	36.00000	0.02034	0.00100	1.78400	0.00101
Total Other Heavy Metals	0.00345	67.10000	0.03791	0.00190	3.88020	0.00219
Volume Sampled m^3		1.7700			1.7700	

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS RUN 1 — Cd, Tl & Heavy Metals

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	766.5
Stack static pressure, P_{static}	mm H_2O	-4.0
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	766.2
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	H_20 by Non Iso
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		1.883
Gas meter correction factor, Y_d		1.0135
Mean dry gas meter temperature, T_m		28.42
Mean pressure drop across orifice, DH	mn	50.33
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m + 273}$		1.75
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.7700
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		20.9
% oxygen reference condition		21
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0103
	%	1.03
Moisture by FTIR	%	-

Molecular weight of dry gas, M_d		
CO_2	%	0.03
O_2	%	20.90
Total	%	20.93
N_2 (100 -Total)	%	79.07
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.73
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.82
Mean of velocity heads, DP_{avg}	mm H_2O	12.08
Mean square root of velocity heads, ÖDP		3.48
Mean stack gas temperature, T_s	°C	31
$V_s = \frac{(K_p)(C_p)(ÖDP)(Ö(T_s + 273))}{(M_s)(P_s)}$	m/s	11.70
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	2.41
$Q_a = (60)(A_s)(V_s)$	m^3/min	1689.4
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	1516.1
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	1532.0
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	6.22
Nozzle area, A_n	mm^2	30.39
Total sampling time, q	min	90
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	101.6
Acceptable isokinetic range 95% to 115%		Yes

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS QA CHECKLIST

Leak Test Results	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 litre/min
Run 1	21.2	0.26	0.30	-406.4	0.42	Yes

Isokinetic Criterion Compliance	Isokinetic Variation %	Acceptable Isokineticity
Run 1	101.6	Yes

Filtration / Temp	Filter Material	Filter Size mm	Maximum Filtration Temperature °C	Maximum storage / transit Temperature °C
Run 1	QF	90	180	22

GF = Glass Fibre

QF = Quartz Fibre

Metals	Type of Absorbers - Metals	Absorption Solutions - Metals
Run 1	Glass	3.3% Nitric Acid, 1.5% Hydrogen Peroxide

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS ABSORBTION EFFICIENCY

Parameter		Total ug	3rd Absorber ug	Absorption Efficiency (%)	Required %	Pass / Fail
Cadmium	Run 1	0.84070	0.03	97	90	N/A <30% ELV
Thallium	Run 1	1.52900	0.03	98	90	N/A <30% ELV
Arsenic	Run 1	1.21630	0.10	92	90	Pass
Antimony	Run 1	0.76590	0.05	93	90	Pass
Chromium	Run 1	18.89200	2.77	85	90	Fail
Cobalt	Run 1	0.35140	0.03	93	90	Pass
Copper	Run 1	526.65600	1.51	100	90	Pass
Lead	Run 1	937.04080	0.73	100	90	Pass
Manganese	Run 1	15.25680	0.50	97	90	Pass
Nickel	Run 1	29.90860	0.71	98	90	Pass
Tin	Run 1	0.72900	0.05	93	90	Pass
Vanadium	Run 1	3.76600	0.50	87	90	Fail
Zinc	Run 1	21151.16800	12.35	100	90	Pass

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HYDROGEN FLUORIDE SUMMARY					
Test	**Sampling Times**	**Concentration mg/m³**	**LOD mg/m³**	**Limit mg/m³**	**Emission Rate g/hr**
Run 1	07:50 - 13:50 14 September 2016	***0.02***	0.00	5	***1.57***
Field Blank	-	0.008049997	-	-	-

Please note figures in bold italic font are at the limit of detection
Reference conditions are 273K, 101.3kPa without correction for water vapour

HYDROGEN FLUORIDE QUALITY ASSURANCE CHECKLIST

Leak Test Results	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	2.5	0.02	0.02	0.05	Yes

	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Max. Storage / Transit Temp. °C	Type of Absorbers	Absorption Solutions
Run 1	Quartz	47	31	23	Quartz	0.1N Sodium Hydroxide

GF = Glass Fibre

QF = Quartz Fibre

HYDROGEN FLUORIDE ABSORPTION EFFICIENCY

Parameter	**Total ug**	**IMP C ug**	**Absorption Efficiency %**	**Acceptable Absorption Efficiency %**	**Absorption Efficiency Acceptable ?**
Run 1	ND	ND	100	95	Yes

ND - None Detected

MOISTURE CALCULATIONS

Moisture Determination - Non Isokinetic							
Test Number	Sampling Time and Date	Start Weight kg	End Weight kg	Total gain kg	Concentration %	LOD %	Uncertainty %
Run 1	07:44 - 13:50 14 September 2016	4.3441	4.4070	0.0629	1.0	0.00	2.9

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	360	7499	20.8	0.240	0.260	0.417	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	1.75	m
Stack Width, W	-	m
Stack Area, A	2.41	m^2
Average stack gas temperature	30	^oC
Stack static pressure	-0.039	kPa
Barometric Pressure	101.6	kPa

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	0.030000	0.000300	0.000589	0.029690	0.000297	0.000583
O_2	32	1.427679	20.900000	0.209000	0.298385	20.683826	0.206838	0.295299
N_2	28	1.249219	79.070000	0.790700	0.987758	78.252159	0.782522	0.977541
H_2O	18	0.803070	-	-	-	1.034325	0.010343	0.008306

Where: p = M / 22.41 pi = r x p

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2867	kg/m^3
Wet Density (STP), P_{STW}	1.2817	kg/m^3
Dry Density (Actual), P_{Actual}	1.1633	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.159	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	14 September 2016
Time of Survey	07:30
Velocity Measurement Device:	S-Type Pitot

Sampling Line A

Traverse Point	Distance into duct (m)	DP pt mmH_2O (average of 3 readings)	DP pt Pa (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	0.08	12.6	124	29	11.95	28.75	-	<15
2	0.26	13.8	135	29	12.47	30.01	-	<15
3	0.52	14.1	138	30	12.65	30.42	-	<15
4	1.23	13.7	135	30	12.48	30.02	-	<15
5	1.49	13.4	131	30	12.33	29.66	-	<15
6	1.67	12.9	127	30	12.11	29.14	-	<15
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	13.4	132	30	12.33	29.67	-	

Sampling Line B

Traverse Point	Distance into duct (m)	DP pt mmH_2O (average of 3 readings)	DP pt Pa (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	-	12.9	127	30	12.11	29.14	-	<15
2	-	13.4	131	30	12.33	29.66	-	<15
3	-	13.7	134	29	12.44	29.94	-	<15
4	-	14.1	138	30	12.63	30.38	-	<15
5	-	14.3	140	30	12.74	30.64	-	<15
6	-	13.5	133	30	12.39	29.80	-	<15
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	13.7	134	30	12.44	29.93	-	

PRELIMINARY STACK SURVEY QUALITY ASSURANCE 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	90	88	2.2	Pass	92	90	2.2	Pass

To complete a compliant pitot leak check a pressure of over 80 mmH_2O (or 800 Pa) is applied and the pressure drop monitored over 5 mins. A drop of ≤ 5% must be observed.

S-Type Pitot Stagnation Check

Run	Stagnation (Pa)	Reference (Pa)	Difference (Pa)	Outcome (Permitted +/- 10 Pa)
Run 1	-39	-39	0.0	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	123.81	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	11.95	m/s	-	-
Highest Gas Velocity	12.74	m/s	-	-
Ratio of Gas Velocities	1.07	-	< 3 : 1	Yes
Maximum angle of flow with regard to duct axis	0	°	< 15°	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, V = K_{pt} x (1-e) * Ö(2 * DP_{pt} / $P_{ActualW}$)		
Where: K_{pt} = Pitot tube calibration coefficient (1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**12.39**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	30	0	°C
Total Pressure	101.561	101.3	kPa
Oxygen	20.9	21	%
Moisture	1.03	1.03	%
Pitot tube calibration coefficient, K_{pt}	0.82		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	12.39	m/s
Stack Area (A)	2.41	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	107263	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	96972	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	95969	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	96972	m^3/hr

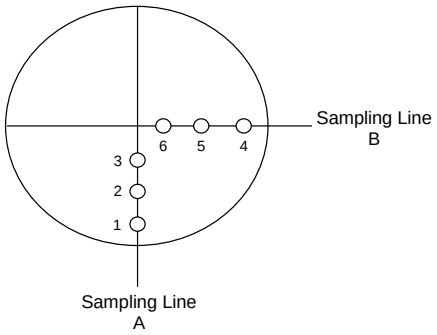
Where:
Q_{Actual} = Va x A x 3600
Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600
$Q_{STP,Dry}$ = Q (STP) / (100 - (100 / Ma)) x 3600
Q_{Ref} = Q (STP) x ((100 - Ma) / (100 - Ms)) x ((20.9 - O_2a) / (20.9 - O_2s))

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	1.75	m
Stack Width	-	m
Area	2.41	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
-	-	-	-

Isokinetic Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	4.4	0.08	< 15
2	14.6	0.26	< 15
3	29.5	0.52	< 15
4	4.4	0.08	< 15
5	14.6	0.26	< 15
6	29.5	0.52	< 15
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
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-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

SAMPLING LOCATION

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume m³	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 %	0.06	0.65	0.49	1.00	N/A	1.50522	1.17	0.003
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP) m³	Mass of particulate mg	O_2 Correction -	Leak mg/m³	Uncollected Mass mg	Combined uncertainty
Run 1	1.47	18.4000	1.00	0.075	0.0003	-
MU as mg/m³	0.14	0.3010	-	0.075	0.0002	**0.34**
MU as %	1.29	2.7174	-	0.676	0.0016	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.68**	**mg/m³**	**6.17**	**%**

(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 - DIOXINS & FURANS

Run	Sampled Volume m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Leak %
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**
Run 1	0.001	2	0.5	1	N/A	-
as a %	0.01	0.66	0.49	1.00	N/A	1.14
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP) m³	O2 Correction -	Leak ng/m³	Laboratory analysis -	Combined uncertainty
Run 1	6.2421	1.0000	0.0001	-	-
MU as ng/m³	0.0002	-	0.0001	0.0014	**0.0014**
MU as %	1.2947	-	0.6590	10.00	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.003**	**ng/m³**	**20.2**	**%**

(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 - PCBs

Run	Sampled Volume m^3	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Leak %	Uncollected Mass ng/m^3
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**	**≤ 10% ELV**
Run 1	0.001	2	1	1	N/A	-	-
as a %	0.01	0.66	0.98	1.00	N/A	1.42	N/A
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**N/A**

Run	Volume (STP) m^3	O2 Correction -	Leak ng/m^3	Uncollected Mass ng/m^3	Laboratory analysis -	Combined uncertainty
Run 1	6.2421	1.0000	0.0000	0.1654	-	-
MU as ng/m^3	0.0000	0.0000	0.0000	0.0000338	0.0003	**0.0004**
MU as %	1.5503	-	0.8195	1.1002	10.00	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.0007**	**ng/m^3**	**24**	**%**

(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 - CADMIUM & THALLIUM

Run	Sampled Volume m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Concentration in impinger mg	Leak %
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**<=2%**
Run 1	0.001	2.0	0.5	1	0.1	0.00	-
as a %	0.06	0.66	0.49	1.00	-	3.00	1.41
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**

Run	Volume (STP) m³	O2 Correction -	Leak mg/m³	Lab Uncertainty mg	Combined uncertainty
Run 1	1.6112	-	0.0000	-	-
MU as mg	0.0000	-	0.0000	0.00010	**0.0001**
MU as %	1.2982	-	0.8168	11.30000	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.00**	**mg/m³**	**22.81**	**%**

(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 - HEAVY METALS

Run	Sampled Volume m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Concentration in impinger mg	Leak %
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**<=2%**
Run 1	0.001	2.00	0.50	1.00	0.10	0.01	-
as a %	0.06	0.73	0.49	1.00	-	3.00	1.41
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**

Run	Volume (STP) m³	O2 Correction -	Leak mg/m³	Lab Uncertainty mg	Combined uncertainty
Run 1	1.7789	-	0.1047	-	-
MU as mg/m³	0.1711	-	0.1047	1.44832	**1.4621**
MU as %	1.3346	-	0.8168	11.30000	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**2.92**	**mg/m³**	**22.82**	**%**

(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 - NON-ISOKINETIC HYDROGEN FLUORIDE

Run	Sampled Volume m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Concentration in impinger mg	Limit of Detection % by mass	Leak %
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.000	2.000	0.500	1.000	0.100	0.001	0.000	-
as a %	0.005	0.676	0.492	1.000	-	3.000	3.007	0.797
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP) m³	Mass of Hydrogen Fluoride mg	O2 Correction -	Leak mg/m³	Lab Uncertainty mg	Combined uncertainty
Run 1	0.8446	0.0148	-	0.0001	-	-
MU as mg/m³	0.0002	0.0005	-	0.0001	0.0005	**0.0007**
MU as %	1.3034	3.0068	-	0.4600	3.1	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.00**	**mg/m³**	**9.00**	**%**

(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 m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Leak %
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**
Run 1	0.000	2	0.5	1	N/A	-
as a %	0.01	0.66	0.49	1.00	N/A	1.15
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP) m³	Mass Gained mg	O2 Correction -	Leak mg/m³	Uncollected Mass mg	Combined uncertainty
Run 1	6.8	62900.0	1.00	55.8	57.7	-
MU as % v/v	0.01	0.00	-	0.01	0.00	**0.02**
MU as %	1.3	0.2	-	0.7	0.1	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.03**	**% v/v**	**2.94**	**%**

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	12.4	m/s
Measured Volumetric Flow rate at Actual Conditions	107263	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	-	0.37		
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	3.91	<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	1.54	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	518		
Uncertainty associated with the estimate of density	-	0.007		
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	0.16
Expanded uncertainty at a 95% Confidence Interval	0.31

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	1.27
Expanded uncertainty at a 95% Confidence Interval	2.49

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	2827.94
Expanded uncertainty at a 95% Confidence Interval	5542.76

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	2.64
Expanded uncertainty at a 95% Confidence Interval	5.17

END OF REPORT

STACK EMISSIONS MONITORING REPORT

Unit D
Bankside Trade Park
Cirencester
GL7 1YT
Tel: 01285 700 593

Your contact at ESG
Mike Davies Business Manager - South Tel: 07976 297465 Email: mike.davies@esg.co.uk

Operator & Address:
Bolton Aerospace Limited PO Box 22 Hadleigh Road Ipswich Suffolk IP2 0EG

Permit:
EPR Permit: EP54/1/LB

Release Point:
A8 - Ball Mill

Sampling Date(s):
13 September 2016

ESG Job Number:	LSO 160910
Report Date:	25th October 2016
Version:	1
Report By:	Owen May
MCERTS Number:	MM 10 1072
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

CONTENTS

EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Bolton Aerospace Limited operates a production of non-ferrous metals process at Ipswich which is subject to EPR Permit EP54/1/LB, under the Environmental Permitting Regulations 2010.

ESG were commissioned by Bolton Aerospace Limited 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 EPR Permit, EP54/1/LB.

Plant

A8 - Ball Mill

Operator

Bolton Aerospace Limited
PO Box 22
Hadleigh Road
Ipswich
Suffolk
IP2 0EG

EPR Permit: EP54/1/LB

Stack Emissions Monitoring Test House

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

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	**Units**	**Result**	**Calculated Uncertainty +/-**	**Limit**	**MCERTS accredited result**
Total Particulate Matter	mg/m³	0.29	0.57	20	✓
Particulate Emission Rate	g/hr	0.79	1.57	-	
Moisture	%	2.9	0.1	-	✓
Stack Gas Temperature	°C	31	-	-	
Stack Gas Velocity	m/s	17.4	0.44	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	3084	160	-	✓
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	2759	143	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	2680	139	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	2759	143	-	

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	13 September 2016	09:14 - 10:14	60 minutes
Preliminary Stack Traverse	13 September 2016	10:16	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Production of non-ferrous metals
Continuous or batch	Batch
Product Details	Aluminium Bronze - 778 Kg
Part of batch to be monitored (if applicable)	Whole
Normal load, throughput or continuous rating	Normal Load
Fuel used during monitoring	N/A
Abatement	Bag Filter
Plume Appearance	None visible from sampling location

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard reference / alternative methods employed by ESG 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	0.29 mg/m³	200 %
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	0.01%	2.8%
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	5 Pa	2.5 %
Volumetric Flow Rate	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	-	5.2 %

BS EN 14790 has been validated over a range of 4 - 40%. It is however the prefered method of the Environment Agency for concentrations below 4%

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
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	260	Pa	>= 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	17.43	m/s	-	-	-
Highest Gas Velocity	17.46	m/s	-	-	-
Ratio of Gas Velocities	1.00	: 1	< 3 : 1	Yes	BS EN 15259
Mean Velocity	17.45	m/s	-	-	-
Maximum angle of flow with regard to duct axis	<15	°	< 15°	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259

DUCT CHARACTERISTICS		
	Value	**Units**
Shape	Circular	-
Depth	0.25	m
Width	-	m
Area	0.05	m^2
Port Depth	90	mm

SAMPLING LINES & POINTS		
	Isokinetic	**Non-Iso & Gases**
Sample port size	4 " BSP	-
Number of lines used	1	-
Number of points / line	1	-
Duct orientation	Vertical	-
Filtration for TPM	QF	-

SAMPLING PLATFORM	
General Platform Information	
Permanent / Temporary Platform / Ground level / Floor Level / Roof	Temporary
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	Yes
Depth of Platform = >Stack depth / diameter + wall and port thickness + 1.5m	No

Sampling Platform Improvement Recommendations (if applicable)

The sampling location should meet 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	1
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	1
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	P1268	Horiba PG-250 Analyser	-	Laboratory Balance	P66
Box Thermocouples	P1268	FT-IR	-	Tape Measure	P2024
Meter In Thermocouple	P1268	FT-IR Oven Box	-	Stopwatch	P2614
Meter Out Thermocouple	P1268	Bernath 3006 FID	-	Protractor	-
Control Box Timer	-	Signal 3030 FID	-	Barometer	P1916
Oven Box	-	Servomex	-	Digital Micromanometer	P1915
Probe	P1787	JCT Heated Head Filter	-	Digital Temperature Meter	P1745
Probe Thermocouple	P2277	Thermo FID	-	Stack Thermocouple	-
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	P2078	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P1952	Chiller (JCT/MAK 10)	-	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	-		-	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 +/- %
-	-	-	-	-	-

STACK EMISSIONS MONITORING TEAM

MONITORING TEAM								
Personnel	MCERTS Number	MCERTS		TE / H&S Qualifications and Expiry Date				
		Level	Expiry	TE1	TE2	TE3	TE4	H&S
Owen May	MM 10 1072	MCERTS Level 2	Feb-18	Sep-21	Jun-21	Mar-17	Mar-22	Jun-20
Jamie Whiteman	MM 16 1364	MCERTS Level 1	Jan-21	-	-	-	-	Jan-19

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	09:14 - 10:14 13 September 2016	0.29	0.57	20	0.8
Blank	-	0.29	-	-	-

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	038688	0.15280	0.15270	-0.00010	68.21850	68.21880	0.00030	0.00050

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	038687	0.15310	0.15290	-0.00020	71.43940	71.43960	0.00020	0.00050

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			**Molecular weight of dry gas, M_d**		
Barometric pressure, P_b	mm Hg	757.51	CO_2	%	0.03
Stack static pressure, P_{static}	mm H_2O	-7.24	O_2	%	20.90
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	756.98	Total	%	20.93
			N_2 (100 -Total)	%	79.07
Vol. of water vapour collected, V_{wstd}			$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Moisture trap weight increase,Vlc	g	40.0	**Molecular weight of wet gas, M_s**		
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.04984	$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.53
Volume of gas metered dry, V_{mstd}			**Actual flow of stack gas, Q_a**		
Volume of gas sample through gas meter, V_m		1.833	Area of stack, A_s	m^2	0.05
Gas meter correction factor, Y_d		1.0135	$Q_a = (60)(A_s)(V_s)$	m^3/min	50.9
Mean dry gas meter temperature, T_m		27.958	**Total flow of stack gas, Q**		
Mean pressure drop across orifice, DH	mmH_2O	108.362	Conversion factor (K/mm.Hg)		0.3592
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m + 273}$		1.697	$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) +273}$	Dry	44.5
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	1.7467	$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	45.80
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	**Percent isokinetic, %I**		
			Nozzle diameter, D_n	mm	6.22
% oxygen measured in gas stream, act%O_2		20.9	Nozzle area, A_n	mm^2	30.39
% oxygen reference condition		21	Total sampling time, q	min	60
O_2 Reference Factor $O_2 Ref = \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		No O2 Ref	$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	102.7
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref	Acceptable isokinetic range 95% to 115%		Yes
Moisture content, B_{wo}			**Particulate Concentration, C**		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0285	Mass collected on filter, M_f	g	-0.00010
	%	2.85	Mass collected in probe, M_p	g	0.00030
Moisture by FTIR	%	-	Total mass collected, M_n	g	0.00050
Velocity of stack gas, V_s			$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	0.286
Pitot tube velocity constant, K_p		34.97	$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	0.295
Velocity pressure coefficient, C_p		0.82			
Mean of velocity heads, DP_{avg}	mm H_2O	25.96			
Mean square root of velocity heads, ÖDP		5.09	$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Mean stack gas temperature, T_s	°C	29			
$V_s = \frac{(K_p)(C_p)(ÖDP)(Ö(T_s + 273))}{(M_s)(P_s)}$	m/s	17.28	**Particulate Emission Rates, E**		
			$E = [(C_{wet})(Q_{stw})(60)] / 1000$		0.79

As the total mass gained was less than the LOD, the LOD has been reported

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	30.96	0.16	0.2	-406.4	0.62	Yes

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	102.68	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.29	1	Yes

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	0.29	20	2.0	Yes

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	31	180	160

GF = Glass Fibre

QF = Quartz Fibre

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	09:14 - 10:14 13 September 2016	3.1071	3.1471	0.0400	2.9	0.007	2.8

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	1747	31.0	0.16	0.20	0.62	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.25	m
Stack Width, W	-	m
Stack Area, A	0.05	m^2
Average stack gas temperature	31	^oC
Stack static pressure	-0.071	kPa
Barometric Pressure	101	kPa

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	0.030000	0.000300	0.000589	0.029144	0.000291	0.000572
O_2	32	1.427679	20.900000	0.209000	0.298385	20.303652	0.203037	0.289871
N_2	28	1.249219	79.070000	0.790700	0.987758	76.813865	0.768139	0.959574
H_2O	18	0.803070	-	-	-	2.853339	0.028533	0.022914

Where: p = M / 22.41 pi = r x p

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2867	kg/m^3
Wet Density (STP), P_{STW}	1.2729	kg/m^3
Dry Density (Actual), P_{Actual}	1.1513	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.139	kg/m^3

Where:

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

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

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

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	13 September 2016
Time of Survey	10:16
Velocity Measurement Device:	S-Type Pitot

Sampling Line A

Traverse Point	Distance into duct (m)	DP pt mmH_2O (average of 3 readings)	DP pt Pa (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	0.13	26.5	260	31	17.43	0.86	-	<15
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	26.5	260	31	17.43	0.86	-	

Sampling Line B

Traverse Point	Distance into duct (m)	DP pt mmH_2O (average of 3 readings)	DP pt Pa (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	0.13	26.6	261	31	17.46	0.86	-	<15
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	26.6	261	31	17.46	0.86	-	

PRELIMINARY STACK SURVEY QUALITY ASSURANCE 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	90	88	2.2	Pass	92	90	2.2	Pass

To complete a compliant pitot leak check a pressure of over 80 mmH_2O (or 800 Pa) is applied and the pressure drop monitored over 5 mins. A drop of ≤ 5% must be observed.

S-Type Pitot Stagnation Check

Run	Stagnation (Pa)	Reference (Pa)	Difference (Pa)	Outcome (Permitted +/- 10 Pa)
Run 1	-71	-73	2.0	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	260.03	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	17.43	m/s	-	-
Highest Gas Velocity	17.46	m/s	-	-
Ratio of Gas Velocities	1.00	-	< 3 : 1	Yes
Maximum angle of flow with regard to duct axis	0	°	< 15°	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, $V = K_{pt} \times (1-e) * \sqrt{(2 * DP_{pt} / P_{ActualW})}$		
Where: K_{pt} = Pitot tube calibration coefficient (1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**17.45**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	31	0	°C
Total Pressure	100.929	101.3	kPa
Oxygen	20.9	21	%
Moisture	2.85	2.85	%
Pitot tube calibration coefficient, K_{pt}	0.82		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	17.45	m/s
Stack Area (A)	0.05	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	3084	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	2759	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	2680	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	2759	m^3/hr

Where:

$Q_{Actual} = Va \times A \times 3600$

$Q_{STP} = Q\ (Actual) \times (Ts / Ta) \times (Pa / Ps) \times 3600$

$Q_{STP,Dry} = Q\ (STP) / (100 - (100 / Ma)) \times 3600$

$Q_{Ref} = Q\ (STP) \times ((100 - Ma) / (100 - Ms)) \times ((20.9 - O_2a) / (20.9 - O_2s))$

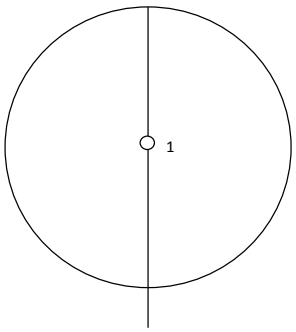
Nomenclature:

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	0.25	m
Stack Width	-	m
Area	0.05	m^2



Sampling Line

- ○ 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
-	-	-	-

Isokinetic Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	50.0	0.13	< 15
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
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-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

SAMPLING LOCATION

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak	Uncollected Mass
	m^3	K	kPa	% by volume	% by volume	% by 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 %	0.06	0.66	0.50	1.00	N/A	1.43125	0.65	0.003
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP)	Mass of particulate	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	1.58	0.5000	1.00	0.001	0.0003	-
MU as mg/m^3	0.00	0.2862	-	0.001	0.0002	**0.29**
MU as %	1.30	100.0000	-	0.373	0.0577	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.57**	**mg/m^3**	**200.02**	**%**

(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 m^3	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Leak %
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**
Run 1	0.001	2	0.5	1	N/A	-
as a %	0.06	0.66	0.50	1.00	N/A	0.65
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP) m^3	Mass Gained mg	O_2 Correction -	Leak mg/m^3	Uncollected Mass mg	Combined uncertainty
Run 1	1.58	40000.00	1.00	85.42	57.74	-
MU as % v/v	0.04	0.01	-	0.01	0.004	**0.04**
MU as %	1.30	0.25	-	0.37	0.14	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.08**	**% v/v**	**2.77**	**%**

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	17.4	m/s
Measured Volumetric Flow rate at Actual Conditions	3084	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	-	0.43		
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	5.79	<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	1.55	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	515		
Uncertainty associated with the estimate of density	-	0.007		
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	0.22
Expanded uncertainty at a 95% Confidence Interval	0.43

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	1.27
Expanded uncertainty at a 95% Confidence Interval	2.49

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	81.30
Expanded uncertainty at a 95% Confidence Interval	159.34

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	2.64
Expanded uncertainty at a 95% Confidence Interval	5.17

END OF REPORT