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Stack Emissions Testing Report

Operator & Address:
Tarmac Limited
Cliff Quay Dock
Cliff Road
Ipswich
Suffolk
IP3 0BG

Permit:
EPR Permit: RC1/VPA/06/11

Release Point:
Coating Plant

Sampling Date/s:
12th January 2012

Job Number:
LCH 00392

Report Date: Version:	3rd February 2012 1
Report By: MCERTS Number: MCERTS Level: Technical Endorsements:	Nik Agopian MM 08 902 MCERTS Level 2 - Team Leader 1, 3 & 4
Report Approved By: MCERTS Number: Business Title: Technical Endorsements: Signature:	Mark Allison MM 03 162 MCERTS Level 2 - Team Leader 1, 2, 3 & 4

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EXECUTIVE SUMMARY

Stack Emissions Monitoring Objectives

Tarmac Limited operates an asphalt plant at Ipswich which is subject to EPR Permit RC1/VPA/06/11, under the Environmental Permitting Regulations 2010.

Environmental Scientifics Group Limited were commissioned by Tarmac Limited to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under typical 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, RC1/VPA/06/11.

Plant

Coating Plant

Operator

Tarmac Limited
Cliff Quay Dock
Cliff Road
Ipswich
Suffolk
IP3 0BG

EPR Permit: RC1/VPA/06/11

Stack Emissions Monitoring

Environmental Scientifics Group Limited - Southeast
Unit 20 The Falcon Business Centre
Ashton Road
Romford
RM3 8UN
UKAS and MCERTS Accreditation Number: 1015

EXECUTIVE SUMMARY

Emissions Summary

Parameter	Units	Result	Calculated Uncertainty +/-	Limit
Total Particulate Matter	mg/m³	4.6	1.4	50
Particulate Emission Rate	g/hr	200	63	-
Dioxins & Furans - UPPER Limits				
Dioxins & Furans (NATO I-TEQ)	ng/m³	0.08	0.03	0.1
Dioxins & Furans (NATO I-TEQ) Emission Rate	µg/hr	2.9	1.1	-
Dioxins & Furans (WHO TEQ Humans / Mammals)	ng/m³	0.0740	0.0289	-
Dioxins & Furans (WHO TEQ H / M) Emission Rate	µg/hr	2.8163	1.1012	-
Dioxins & Furans (WHO TEQ Fish)	ng/m³	0.0780	0.0305	-
Dioxins & Furans (WHO TEQ Fish) Emission Rate	µg/hr	2.9702	1.1613	-
Dioxins & Furans (WHO TEQ Birds)	ng/m³	0.0962	0.0376	-
Dioxins & Furans (WHO TEQ Birds) Emission Rate	µg/hr	3.6602	1.4311	-
Dioxins & Furans - LOWER Limits				
Dioxins & Furans (NATO I-TEQ)	ng/m³	0.0632	0.0247	-
Dioxins & Furans (NATO I-TEQ) Emission Rate	µg/hr	2.4052	0.9404	-
Dioxins & Furans (WHO TEQ Humans / Mammals)	ng/m³	0.0555	0.0217	-
Dioxins & Furans (WHO TEQ H / M) Emission Rate	µg/hr	2.1127	0.8261	-
Dioxins & Furans (WHO TEQ Fish)	ng/m³	0.0549	0.0215	-
Dioxins & Furans (WHO TEQ Fish) Emission Rate	µg/hr	2.0906	0.8174	-
Dioxins & Furans (WHO TEQ Birds)	ng/m³	0.0783	0.0306	-
Dioxins & Furans (WHO TEQ Birds) Emission Rate	µg/hr	2.9785	1.1646	-
Cadmium	mg/m³	0.0002	0.0001	0.5
Cadmium Emission Rate	g/hr	0.01	0.002	-
Nickel	mg/m³	0.03	0.01	1
Nickel Emission Rate	g/hr	1.30	0.27	
Lead	mg/m³	0.04	0.01	5
Lead Emission Rate	g/hr	1.63	0.34	
Chromium, Copper & Vanadiium	mg/m³	0.03	0.01	1.5
Chromium, Copper & Vanadiium Emission Rate	g/hr	1.26	0.27	
Hydrogen Chloride	mg/m³	0.16	0.02	100
Hydrogen Chloride Emission Rate	g/hr	7.0	0.84	-
Hydrogen Fluoride	mg/m³	1.0	0.12	5
Hydrogen Fluoride Emission Rate	g/hr	52	6.2	-
Moisture	%	2.4	0.09	-
Stack Gas Temperature	°C	91.3	-	-
Stack Gas Velocity	m/s	17.2	-	-
Gas Volumetric Flow Rate (Actual)	m³/hr	69919	-	-
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	51853	-	-
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	50606	-	-
Gas Volumetric Flow Rate (@ref conditions)	m³/hr	51853	-	-

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 values.

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

EXECUTIVE SUMMARY

Monitoring Times

Parameter	Sampling Date	Sampling Times	Sampling Duration
Total Particulate Matter Run 1	12 January 2012	09:52 - 10:24	32 minutes
Dioxins & Furans Run 1	12 January 2012	07:31 - 08:35	64 minutes
Cadmium & Thallium Run 1	12 January 2012	09:08 - 09:40	32 minutes
Heavy Metals Run 1	12 January 2012	09:08 - 09:40	32 minutes
Hydrogen Chloride Run 1	11 January 2012	09:52 - 10:24	32 minutes
Hydrogen Fluoride Run 1	12 January 2012	09:08 - 09:38	30 minutes

EXECUTIVE SUMMARY

Process Details

Parameter	Process Details
Description of process	Mineral Drying and Roadstone Coating
Continuous or batch	Batch
Product Details	10mm Hot Roll, 28mm Base at 150 tonne/hr
Part of batch to be sampled during monitoring	N/A
Normal load, throughput or continuous rating	Typical for site
Fuel requirements during monitoring	CFO
Abatement	Bag Filter
Plume Appearance	Slightly Steamy

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard methods employed by Environmental Scientifics Group Limited is determined, wherever possible by the hierarchy of method selection outlined in Environment Agency Technical Guidance Document (Monitoring) M2. i.e. CEN, ISO, BS, US EPA etc.

The tables below summarise the monitoring methods, techniques and technical procedures employed, and details any deviations from the aforementioned hierarchy:

Sampling Methods with Subsequent Analysis

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 006	1015	Yes	0.72 mg/m³	31.5 %
PCDD/PCDF	SRM - BS EN 1948-1	AE 048	1015	Yes	0.028 ng/m³	39.1 %
Cd	SRM - BS EN 14385	AE 028	1015	Yes	0.00005 mg/m³	21.1 %
Heavy Metals	SRM - BS EN 14385	AE 028	1015	Yes	0.001 mg/m³	21.1 %
Hydrogen Chloride	SRM - BS EN 1911	AE 019	1015	Yes	0.01 mg/m³	12 %
Hydrogen Fluoride	SRM - BS ISO 15713	AE 055	1015	Yes	0.46 mg/m³	11.9 %

On-Site Testing

Species	Method Standard Reference Method / Alternative Method	ESG Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Limit of Detection (LOD)	MU +/- %
H_2O	SRM - BS EN 14790	AE 004	1015	Yes	0.0003 %	3.6%

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 Analysis	Laboratory	Sample Archive Location	Archive Period
TPM	Gravimetric	AE 006	1015	Yes	Mitcheldean	Mitcheldean	3 months
PCDD/PCDF	Gas Chromatography - High Resolution Mass Spectometry	HS/GWI/11/3007/8	1015	Yes	Didcot	Didcot	3 months
Cd	Inductively coupled Plasma - Mass Spectrometry	HS/GWI/1002/15	1015	Yes	Bretby	Bretby	3 months
Heavy Metals	Inductively coupled Plasma - Mass Spectrometry	HS/GWI/1002/15	1015	Yes	Bretby	Bretby	3 months
Hydrogen Chloride	Ion Chromatography	HS/WI/1087	1015	Yes	Bretby	Bretby	3 months
Hydrogen Fluoride	Ion Chromatography	HS/WI/1087	1015	Yes	Bretby	Bretby	3 months

On-Site Testing

Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	MCERTS Accredited Analysis	Laboratory	Sample Archive Location	Span Gas
H_2O	Gravimetric	AE 004	1015	Yes	Romford	N/A	N/A

EXECUTIVE SUMMARY

Sampling Location

Sampling Plane Validation Criteria	Value	Units	Requirement	Compliance	Method
Lowest Differential Pressure	181	Pa	>= 5 Pa	Yes	BS EN 13284-1
Lowest Gas Velocity	15.75	m/s	-	-	-
Highest Gas Velocity	19.40	m/s	-	-	-
Ratio of Above	1.23	: 1	< 3 : 1	Yes	BS EN 13284-1
Mean Velocity	17.17	m/s	-	-	-
Angle of flow with regard to duct axis	0	^{o}	< 15^{o}	Yes	BS EN 13284-1
No local negative flow	-	-	-	Yes	BS EN 13284-1

Duct Characteristics

	Value	Units
Type	Circular	-
Depth	1.20	m
Width	-	m
Area	1.13	m^2
Port Depth	90	mm

Sampling Lines & Sample Points

	Isokinetic (CEN Methods)	Isokinetic (ISO Methods)	Non-Iso & Gases
Sample Port Size	5.5 inch BSP	-	-
Number Used	1	-	-
Orientation	Horizontal	-	-
Number Points / Line	8	-	-
Filtration for TPM	Out Stack	-	-

Sampling Platform

General Platform Information	
Permanent / Temporary Platform	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	Yes
Depth of Platform = Minimum of 2m or Probe Length + 1m	No

Sampling Location / Platform Improvement Recommendations

Ideally, the platform should be increased in depth to meet the requirements of EA TGN M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Sample Lines

Only sample line B was used as port cap on Line A was stuck. The number of sampling points were therefore doubled to satify the requirements of the standard.

APPENDICES

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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 006	1015	Yes	1
PCDD/PCDF	SRM - BS EN 1948-1	AE 048	1015	Yes	1
Cd	SRM - BS EN 14385	AE 028	1015	Yes	1
Heavy Metals	SRM - BS EN 14385	AE 028	1015	Yes	1
Hydrogen Chloride	SRM - BS EN 1911	AE 019	1015	Yes	1
Hydrogen Fluoride	SRM - BS ISO 15713	AE 055	1015	Yes	1
H_2O	SRM - BS EN 14790	AE 004	1015	Yes	1

CALIBRATEABLE EQUIPMENT CHECKLIST

Extractive Sampling		Instrumental Analyser/s		Miscellaneous	
Equipment	**Equipment I.D.**	**Equipment**	**Equipment I.D.**	**Equipment**	**Equipment I.D.**
Control Box DGM	P1860	Horiba PG-250 Analyser	-	Laboratory Balance	P166
Box Thermocouples	P1860	JCT JCC P-1 Cooler	-	Tape Measure	LAB 1177
Meter In Thermocouple	P1860	MAK 10 Cooler	-	Stopwatch	-
Meter Out Thermocouple	P1860	FT-IR	-	Protractor	-
Control Box Timer	P1860	FT-IR Oven Box	-	Barometer	P223
Oven Box	0	Bernath 3006 FID	-	Digital Micromanometer	LSW 01-06
Probe	P1944	Signal 3030 FID	-	Digital Temperature Meter	-
Probe Thermocouple	P1944	Servomex	-	Stack Thermocouple	-
Probe	-	JCT Heated Head Filter	-	Mass Flow Controller	-
Probe Thermocouple	-	Thermo FID	-	Mass Flow Control Box	-
S-Pitot	-	Stackmaster	-	1m Heated Line (1)	-
L-Pitot	-	FTIR Heater Box for Heated Line	-	1m Heated Line (2)	-
Site Balance	P1952		-	1m Heated Line (3)	-
Last Impinger Arm	-		-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-		-	10m Heated Line (1)	-
Callipers	LCH 30-02		-	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	-		-	20m Heated Line (1)	-
			-	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.

STACK EMISSIONS MONITORING TEAM

Team Leader	Mark Allison MCERTS Level 2, Technical Endorsements 1, 2, 3 & 4 MM 03 162
Team Leader	Nik Agopian MCERTS Level 2, Technical Endorsements 1, 3 & 4 MM 08 902

TOTAL PARTICULATE MATTER SUMMARY

Parameter	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	09:52 - 10:24 12 January 2012	4.6	0.72	50	200
Blank	-	1.39	-	-	-

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

Acetone Blank Value mg/l	Acceptable Value mg/l
None detected	10

FILTER AND RINSE INFORMATION

Samples

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	113239	0.1563	0.1563	0.0000	68.6759	68.6782	0.0023	0.0023

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	113238	0.1600	0.1599	-0.0001	66.1972	66.1980	0.0008	0.0007

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

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	-5.10
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	764.63
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	9.7
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.0120862
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.451
Gas meter correction factor, Y_d		1.135
Mean dry gas meter temperature, T_m		14.500
Mean pressure drop across orifice, ΔH	mmH_2O	22.298
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.491
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.5027
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		17.0
% oxygen reference condition		21
O_2 Reference Factor $O2\ Ref = \frac{21.0 - act\%O2}{21.0 - ref\%O2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0240 / 2.40
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.80
Mean of velocity heads, ΔP_{avg}	mm H_2O	15.88
Mean square root of velocity heads, $\sqrt{\Delta P}$		3.98
Mean stack gas temperature, T_s	^oC	74
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	13.51

Molecular weight of dry gas, M_d		
CO_2	%	15.50
O_2	%	17.00
Total	%	32.50
N_2 (100 -Total)	%	67.50
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		31.16
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	30.84
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	1.13
$Q_a = (60)(A_s)(V_s)$	m^3/min	916.9
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	709.4
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	726.83
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	5.68
Nozzle area, A_n	mm^2	25.37
Total sampling time, θ	min	32
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	96.4
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0
Mass collected in probe, M_p	g	0.0023
Total mass collected, M_n	g	0.0023
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	4.575
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	4.688
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		199.53

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	16.01	0.08	0.1	-11	0.32	Yes

Isokineticity

Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	96.35	Yes

Acceptable isokinetic range 95% to 115%

LOD Less than 5% ELV

Run	LOD mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.72	2.5	Yes

Blank Value

Run	Overall Blank Value mg/m³	Daily Emission Limit Value mg/m³	Acceptable Blank Value mg/m³	Overall Blank Acceptable mg/m³
Blank 1	1.39	50	5	Yes

Filters

Run	Filter Material	Filter Size mm	Max Filtration Temperature °C	Pre-conditioning Filter Temperature °C	Post conditioning Filtration Temperature °C
Run 1	QF	47	160	180	160

GF = Glass Fibre

QF = Quartz Fibre

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	07:31 - 08:35 12 January 2012	0.07591	0.02816	0.1	2.88896
Field Blanks Run 1	-	0.02816	-	-	-

WHO TEQ (Humans / Mammals)

Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:31 - 08:35 12 January 2012	0.07400	0.03134	-	2.81635
Field Blanks Run 1	-	0.03134	-	-	-

WHO TEQ (Fish)

Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:31 - 08:35 12 January 2012	0.07804	0.03497	-	2.970185
Field Blanks Run 1	-	0.03497	-	-	-

WHO TEQ (Birds)

Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:31 - 08:35 12 January 2012	0.09618	0.04058	-	3.66021
Field Blanks Run 1	-	0.04058	-	-	-

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

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	07:31 - 08:35 12 January 2012	0.06320	-	0.1	2.40519
Field Blanks Run 1	-	0	-	-	-

WHO TEQ (Humans / Mammals)

Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:31 - 08:35 12 January 2012	0.05551	-	-	2.11269
Field Blanks Run 1	-	0	-	-	-

WHO TEQ (Fish)

Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:31 - 08:35 12 January 2012	0.0549	-	-	2.09061
Field Blanks Run 1	-	0	-	-	-

WHO TEQ (Birds)

Test	Sampling Times	Concentration ng/m³	LOD ng/m³	Limit ng/m³	Emission Rate µg/hr
Run 1	07:31 - 08:35 12 January 2012	0.07826	-	-	2.9785
Field Blanks Run 1	-	0	-	-	-

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

DIOXINS & FURANS ANALYSIS SUMMARY - RUN 1

NATO I-TEQ & WHO TEQ (Humans / Mammals)

Compound Name	Result	NATO I-TEQ	WHO TEQ Humans / Mammals	Extraction Recovery		Sampling Recovery	
				Actual	Permitted	Actual	Permitted
	ng	ng	ng	%	%	%	%
Dioxins							
2378 Tetra CDD	< 0.005	0.005	0.005	92	50 - 130		
12378 Penta CDD	< 0.01	0.005	0.01	96	50 - 130		
123478 Hexa CDD	< 0.01	0.001	0.001	100	50 - 130		
123678 Hexa CDD	0.024	0.0024	0.0024	65	50 - 130		
123789 Hexa CDD	0.027	0.0027	0.0027				
1234678 Hepta CDD	0.19	0.0019	0.0019	76	50 - 130		
OCDD Octa CDD	0.26	0.00026	0.000078	64	20 - 150		
Total 2378-Dioxins	**0.526**	**0.01826**	**0.023078**				
Furans							
2378 Tetra CDF	0.007	0.0007	0.0007	91	50 - 130		
12378 Penta CDF	0.024	0.0012	0.00072			97	>=50
23478 Penta CDF	0.029	0.0145	0.0087	100	50 - 130		
123478 Hexa CDF	0.046	0.0046	0.0046	76	50 - 130		
123678 Hexa CDF	0.065	0.0065	0.0065	83	50 - 130		
234678 Hexa CDF	0.13	0.013	0.013	83	50 - 130		
123789 Hexa CDF	0.032	0.0032	0.0032			89	>=50
1234678 Hepta CDF	0.27	0.0027	0.0027	74	20 - 150		
1234789 Hepta CDF	0.076	0.00076	0.00076			100	>=50
OCDF Octa CDF	0.27	0.00027	0.000081	68	20 - 150		
Total 2378-Furans	**0.949**	**0.04743**	**0.040961**				
Mean Recoveries (%)				**82**		**95**	
Total 2378 Isomers	**1.475**	**0.06569**	**0.06404**				
Total ITEQ (<LOD = 0)		**0.05469**	**0.04804**				

NOTE: The Total 2378 Isomers result includes all isomers below the limit of detection. This gives a "worst case" Dioxins & Furans result.

DIOXINS & FURANS ANALYSIS SUMMARY - RUN 1

WHO TEQ (Fish) & WHO TEQ (Birds)

Compound Name	Result	WHO TEQ Fish	WHO TEQ Birds	Extraction Recovery		Sampling Recovery	
				Actual	Permitted	Actual	Permitted
	ng	ng	ng	%	%	%	%
Dioxins							
2378 Tetra CDD	< 0.005	0.005	0.005	92	50 - 130		
12378 Penta CDD	< 0.01	0.01	0.01	96	50 - 130		
123478 Hexa CDD	< 0.01	0.005	0.0005	100	50 - 130		
123678 Hexa CDD	0.024	0.00024	0.00024	65	50 - 130		
123789 Hexa CDD	0.027	0.00027	0.00027				
1234678 Hepta CDD	0.19	0.00019	0.00019	76	50 - 130		
OCDD Octa CDD	0.26	-	-	64	20 - 150		
Total 2378-Dioxins	**0.526**	**0.0207**	**0.0162**				
Furans							
2378 Tetra CDF	0.007	0.00035	0.007	91	50 - 130		
12378 Penta CDF	0.024	0.0012	0.00024			97	>=50
23478 Penta CDF	0.029	0.0145	0.029	100	50 - 130		
123478 Hexa CDF	0.046	0.0046	0.0046	76	50 - 130		
123678 Hexa CDF	0.065	0.0065	0.0065	83	50 - 130		
234678 Hexa CDF	0.13	0.013	0.013	83	50 - 130		
123789 Hexa CDF	0.032	0.0032	0.0032			89	>=50
1234678 Hepta CDF	0.27	0.0027	0.0027	74	20 - 150		
1234789 Hepta CDF	0.076	0.00076	0.00076			100	>=50
OCDF Octa CDF	0.27	0.000027	0.000027	68	20 - 150		
Total 2378-Furans	**0.949**	**0.046837**	**0.067027**				
Mean Recoveries (%)				**82**		**95**	
Total 2378 Isomers	**1.475**	**0.067537**	**0.083227**				
Total ITEQ (<LOD = 0)		**0.047537**	**0.067727**				

NOTE: The Total 2378 Isomers result includes all isomers below the limit of detection. This gives a "worst case" Dioxins & Furans result.

DIOXINS & FURANS ANALYSIS SUMMARY - FIELD BLANK RUN 1

NATO I-TEQ & WHO TEQ (Humans / Mammals)

Compound Name	Result	NATO I-TEQ	WHO TEQ Humans / Mammals	Extraction Recovery		Sampling Recovery	
				Actual	Permitted	Actual	Permitted
	ng	ng	ng	%	%	%	%
Dioxins							
2378 Tetra CDD	< 0.005	0.005	0.005	67	50 - 130		
12378 Penta CDD	< 0.01	0.005	0.01	67	50 - 130		
123478 Hexa CDD	< 0.01	0.001	0.001	62	50 - 130		
123678 Hexa CDD	< 0.02	0.002	0.002	64	50 - 130		
123789 Hexa CDD	< 0.01	0.001	0.001				
1234678 Hepta CDD	< 0.01	0.0001	0.0001	56	50 - 130		
OCDD Octa CDD	< 0.03	0.00003	0.000009	44	20 - 150		
Total 2378-Dioxins	**0.095**	**0.01413**	**0.019109**				
Furans							
2378 Tetra CDF	< 0.005	0.0005	0.0005	61	50 - 130		
12378 Penta CDF	< 0.01	0.0005	0.0003			110	>=50
23478 Penta CDF	< 0.01	0.005	0.003	59	50 - 130		
123478 Hexa CDF	< 0.01	0.001	0.001	59	50 - 130		
123678 Hexa CDF	< 0.01	0.001	0.001	54	50 - 130		
234678 Hexa CDF	< 0.01	0.001	0.001	55	50 - 130		
123789 Hexa CDF	< 0.01	0.001	0.001			110	>=50
1234678 Hepta CDF	< 0.01	0.0001	0.0001	52	20 - 150		
1234789 Hepta CDF	< 0.01	0.0001	0.0001			98	>=50
OCDF Octa CDF	< 0.04	0.00004	0.000012	49	20 - 150		
Total 2378-Furans	**0.125**	**0.01024**	**0.008012**				
Mean Recoveries (%)				**58**		**106**	
Total 2378 Isomers	**0.22**	**0.02437**	**0.027121**				
Total ITEQ (<LOD = 0)		**0**	**0**				

NOTE: The Total 2378 Isomers result includes all isomers below the limit of detection. This gives a "worst case" Dioxins & Furans result.

DIOXINS & FURANS ANALYSIS SUMMARY - FIELD BLANK RUN 1

WHO TEQ (Fish) & WHO TEQ (Birds)

Compound Name	Result	WHO TEQ Fish	WHO TEQ Birds	Extraction Recovery		Sampling Recovery	
				Actual	Permitted	Actual	Permitted
	ng	ng	ng	%	%	%	%
Dioxins							
2378 Tetra CDD	< 0.005	0.005	0.005	67	50 - 130		
12378 Penta CDD	< 0.01	0.01	0.01	67	50 - 130		
123478 Hexa CDD	< 0.01	0.005	0.0005	62	50 - 130		
123678 Hexa CDD	< 0.02	0.0002	0.0002	64	50 - 130		
123789 Hexa CDD	< 0.01	0.0001	0.0001				
1234678 Hepta CDD	< 0.01	0.00001	0.00001	56	50 - 130		
OCDD Octa CDD	< 0.03	-	-	44	20 - 150		
Total 2378-Dioxins	**0.095**	**0.02031**	**0.01581**				
Furans							
2378 Tetra CDF	< 0.005	0.00025	0.005	61	50 - 130		
12378 Penta CDF	< 0.01	0.0005	0.0001			110	>=50
23478 Penta CDF	< 0.01	0.005	0.01	59	50 - 130		
123478 Hexa CDF	< 0.01	0.001	0.001	59	50 - 130		
123678 Hexa CDF	< 0.01	0.001	0.001	54	50 - 130		
234678 Hexa CDF	< 0.01	0.001	0.001	55	50 - 130		
123789 Hexa CDF	< 0.01	0.001	0.001			110	>=50
1234678 Hepta CDF	< 0.01	0.0001	0.0001	52	20 - 150		
1234789 Hepta CDF	< 0.01	0.0001	0.0001			98	>=50
OCDF Octa CDF	< 0.04	0.000004	0.000004	49	20 - 150		
Total 2378-Furans	**0.125**	**0.0100**	**0.0193**				
Mean Recoveries (%)				**58**		**106**	
Total 2378 Isomers	**0.22**	**0.0303**	**0.0351**				
Total ITEQ (<LOD = 0)		**0**	**0**				

NOTE: The Total 2378 Isomers result includes all isomers below the limit of detection. This gives a "worst case" Dioxins & Furans result.

ISOKINETIC SAMPLING EQUATIONS RUN 1

Dioxins & Furans

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	765.01
Stack static pressure, P_{static}	mm H_2O	-5.10
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	764.63
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	-
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.77
Gas meter correction factor, Y_d		1.14
Mean dry gas meter temperature, T_m		10.63
Mean pressure drop across orifice, ΔH	m	16.81
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.84
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.8654
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		17.00
% 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}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0240
	%	2.40
Moisture by FTIR	%	-

Molecular weight of dry gas, M_d		
CO_2	%	15.50
O_2	%	17.00
Total	%	32.50
N_2 (100 -Total)	%	67.50
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		31.16
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	30.84
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.80
Mean of velocity heads, ΔP_{avg}	mm H_2O	11.75
Mean square root of velocity heads, $\sqrt{\Delta P}$		3.43
Mean stack gas temperature, T_s	°C	64
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	11.46
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	1.13
$Q_a = (60)(A_s)(V_s)$	m^3/min	777.7
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) +273}$	Dry	619.0
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	634
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	5.7
Nozzle area, A_n	mm^2	25.4
Total sampling time, θ	min	64.0
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	95.0
Acceptable isokinetic range 95% to 115%		Yes

DIOXINS & FURANS 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	13.60	0.05	0.05	-12	0.68	Yes

Isokinetic Criterion Compliance	Isokinetic Variation %	Acceptable Isokineticity
Run 1	95.0	Yes

Acceptable isokinetic range 95% to 115%

Filtration	Filter Material	Filter Size mm	Maximum Filtration Temperature °C
Run 1	QF	47	121

GF = Glass Fibre

QF = Quartz Fibre

Critical Sampling Requirement	Maximum Temperature at Condenser / Adsorber °C	Acceptable Temperature?
Run 1	10	Yes

Acceptable < 20°C

CADMIUM, THALLIUM & HEAVY METALS - PARTICULATE & VAPOUR PHASES COMBINED

Cadmium and Thallium Combined

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	09:08 - 09:40 12 January 2012	0.0002	0.00005	0.50	0.01
Field Blank	-	0.0001	-	-	-

Total Other Heavy Metals Combined

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	09:08 - 09:40 12 January 2012	0.0906	0.0010	7.5	4.19
Field Blank	-	0.0031	-	-	-

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

INDIVIDUAL METALS SUMMARY - PARTICULATE & VAPOUR PHASES COMBINED

Metals	LOD mg/m³	Concentration mg/m³	Emission Rate g/hr
Cadmium	0.00005	0.0002	0.01

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

Metals	LOD mg/m³	Concentration mg/m³	Emission Rate g/hr
Chromium	0.00029	0.0130	0.60
Copper	0.00026	0.0140	0.65
Lead	0.00006	0.0353	1.63
Nickel	0.00022	0.0281	1.30
Vanadium	0.00013	0.0002	0.01
Total Other Heavy Metals	0.00096	0.0906	4.19

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

CADMIUM & HEAVY METALS - SUMMARY RUN 1"

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	0.00001	0.04	0.0001	0.00004	0.10	0.0002
Volume Sampled m^3		0.56			0.56	

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
Chromium	0.00007	3.20000	0.00568	0.00022	4.12100	0.00732
Copper	0.00012	3.60000	0.00639	0.00013	4.31030	0.00765
Lead	0.00002	17.00000	0.03018	0.00004	2.87040	0.00510
Nickel	0.00009	15.00000	0.02663	0.00013	0.82200	0.00146
Vanadium	0.00012	0.07000	0.00012	0.00001	0.04910	0.00009
Total Other Heavy Metals	0.00043	38.87000	0.06901	0.00053	12.17280	0.02161
Volume Sampled m^3		0.563			0.5633	

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

CADMIUM & HEAVY METALS - SUMMARY BLANK"

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	0.00001	0.004	0.00001	0.00004	0.02560	0.00005
Volume Sampled m^3		0.5633			0.5633	

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
Chromium	0.00007	0.30000	0.00053	0.00022	0.08960	0.00016
Copper	0.00012	0.10000	0.00018	0.00013	0.67840	0.00120
Lead	0.00002	0.08000	0.00014	0.00004	0.25600	0.00045
Nickel	0.00009	0.10000	0.00018	0.00013	0.03840	0.00007
Vanadium	0.00012	0.07000	0.00012	0.00001	0.00640	0.00001
Total Other Heavy Metals	0.00043	0.65000	0.00115	0.00053	1.06880	0.00190
Volume Sampled m^3		0.5633			0.5633	

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

ISOKINETIC SAMPLING EQUATIONS RUN 1

Cd & Heavy Metals

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	765.0
Stack static pressure, P_{static}	mm H_2O	-5.1
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	764.6
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	-
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.5027
Gas meter correction factor, Y_d		1.135
Mean dry gas meter temperature, T_m		12.88
Mean pressure drop across orifice, ΔH	m	24.62
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.55
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.5633
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		17.0
% 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}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0240
	%	2.40
Moisture by FTIR	%	-

Molecular weight of dry gas, M_d		
CO_2	%	15.50
O_2	%	17.00
Total	%	32.50
N_2 (100 -Total)	%	67.50
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		31.16
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	30.84
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.80
Mean of velocity heads, ΔP_{avg}	mm H_2O	18.13
Mean square root of velocity heads, $\sqrt{\Delta P}$		4.26
Mean stack gas temperature, T_s	°C	80
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	14.56
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	1.13
$Q_a = (60)(A_s)(V_s)$	m^3/min	988.4
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	751.3
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	769.9
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	5.68
Nozzle area, A_n	mm^2	25.37
Total sampling time, θ	min	32
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	101.9
Acceptable isokinetic range 95% to 115%		Yes

CADMIUM & HEAVY METALS 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	17.8	0.06	0.06	-13	0.36	Yes

Isokinetic Criterion Compliance	Isokinetic Variation %	Acceptable Isokineticity
Run 1	101.9	Yes

Filtration	Filter Material	Filter Size mm	Maximum Filtration Temperature °C
Run 1	QF	47	180

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

CADMIUM & HEAVY METAS ABSORPTION EFFICIENCIES

Parameter		Total ug	3rd Absorber ug	Absorption Efficiency (%)	Required %	Pass / Fail
Cadmium	Run 1	0.14020	0.03	77	90	N/A <30% ELV
Chromium	Run 1	7.32100	0.48	93	90	N/A <30% ELV
Copper	Run 1	7.91030	1.23	84	90	N/A <30% ELV
Lead	Run 1	19.87040	0.75	96	90	N/A <30% ELV
Nickel	Run 1	15.82200	0.16	99	90	N/A <30% ELV
Vanadium	Run 1	0.11910	0.02	87	90	N/A <30% ELV

HYDROGEN CHLORIDE SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	09:52 - 10:24 11 January 2012	0.16	0.01	100	7.01
Field Blank	-	0.002	-	-	-

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 CHLORIDE 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	16.0	0.08	0.10	0.32	Yes

Filtration	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Type of Absorbers	Absorption Solutions
Run 1	QF	47	88	Glass	HPLC Water

GF = Glass Fibre

QF = Quartz Fibre

HYDROGEN CHLORIDE ABSORPTION EFFICIENCY

Parameter	Total ug	IMP C ug	Absorption Efficiency %	Acceptable Absorption Efficiency %	Absorption Efficiency Acceptable ?
Run 1	79.5	6	92	95	No

ND - None Detected

ISOKINETIC SAMPLING EQUATIONS 1

Hydrogen Chloride

Absolute pressure of stack gas, P_s			**Velocity of stack gas, V_s**		
Barometric pressure, P_b	mm Hg	765	Pitot tube velocity constant, K_p		34.97
Stack static pressure, P_{static}	mm H_2O	-5	Velocity pressure coefficient, C_p		0.80
$P_s = P_b + (P_{static})$ / 13.6	mm Hg	765	Mean of velocity heads, ΔP_{avg}	mm H_2O	15.88
			Mean square root of velocity heads, $\sqrt{\Delta P}$		3.98
Vol. of water vapour collected, V_{wstd}			Mean stack gas temperature, T_s	°C	74
Moisture trap weight increase,Vlc	g	0.0			
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0	$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	13.4
Volume of gas metered dry, V_{mstd}			**Actual flow of stack gas, Q_a**		
Volume of gas sample through gas meter, V_m		0.4513	Area of stack, A_s	m^2	1.13
Gas meter correction factor, Y_d		1.135	$Q_a = (60)(A_s)(V_s)$	m^3/min	910
Mean dry gas meter temperature, T_m		14.50	**Dry total flow of stack gas, Q_{std}**		
Mean pressure drop across orifice, ΔH	mmH_2O	22.30	Conversion factor (K/mm.Hg)		0.3592
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.49	$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) +273}$	m^3/min	721
Volume of gas metered wet, V_{mstw}			**Wet total flow of stack gas, Q_{stw}**		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.4906	$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	m^3/min	721
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$			**Dry total flow of stack gas at X% O_2, Q_{stdO2}**		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No	$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	m^3/min	No O2 Ref
% oxygen measured in gas stream, act%O_2		20.9			
% oxygen reference condition		21	**Percent isokinetic, %I**		
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		No O2 Ref	Nozzle diameter, D_n	mm	5.68
			Nozzle area, A_n	mm^2	25.37
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref	Total sampling time, θ	min	32
Moisture content, B_{wo}			$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	95
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0000 0.00	Acceptable isokinetic range 95% to 115%		No
Moisture by FTIR	%	-	**Hydrogen Chloride Concentration, C**		
Molecular weight of dry gas, M_d			Mass collected , M	ug	80
CO_2		15.50	$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	0.162
O_2		20.9			
Total		36.40	$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	0.162
N_2 (100 -Total)		63.60			
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		31.32	$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	No O2 Ref
Molecular weight of wet gas, M_s			**Hydrogen Chloride Emission Rates, E**		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	31.3	$E = [(C_{wet})(Q_{stw})(60)] / 1000$	g/hr	7.01

HYDROGEN FLUORIDE SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	09:08 - 09:38 12 January 2012	1.00	0.46	5	51.96
Field Blank	-	0.214710475	-	-	-

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	2.0	0.00	0.00	0.04	Yes

Filtration	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Type of Absorbers	Absorption Solutions
Run 1	QF	47	160	Glass	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	61.6	16.5	73	95	N/A <30% ELV

N/A - As the result is less than 30% of the ELV an absorption efficiency greater than 95% is not required.

MOISTURE CALCULATIONS

Moisture Determination - Isokinetic

Test	Sampling Times	Start Weight Kg	End Weight Kg	Total gain Kg	Concentration %	LOD %	Uncertainty %
Run 1	09:52 - 10:24 12 January 2012	3.2515	3.2612	0.0097	2.4	0.00025	3.641420171

Moisture Quality Assurance

Test	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	32	502.6848418	16.00598281	0.08	0.1	0.320119656	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics

Stack Diameter / Depth, D	1.20	m
Stack Width, W	-	m
Stack Area, A	1.13	m^2
Average stack gas temperature	91	^oC
Pitot static pressure	-0.05	kPa
Barometric Pressure	100.3	kPa
Pitot tube calibration coefficient, K_{pt}	0.84	-

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	15.500000	0.155000	0.304274	15.127329	0.151273	0.296958
O_2	32	1.427679	17.000000	0.170000	0.242705	16.591264	0.165913	0.236870
N_2	28	1.249219	67.500000	0.675000	0.843223	65.877078	0.658771	0.822949
H_2O	18	0.803070	-	-	-	2.404330	0.024043	0.019308

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

Calculation of Stack Gas Densities

Determinand	Result	Units
Dry Density (STP), P_{STD}	1.3902	kg/m^3
Wet Density (STP), P_{STW}	1.3761	kg/m^3
Dry Density (Actual), P_{Actual}	1.0310	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.021	kg/m^3

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	02 March 2011
Time of Survey	10:20 - 10:30
Velocity Measurement Device:	S-Type Pitot

Sampling Line A

Traverse Point	Distance into duct (m)	ΔP pt mmH_2O	ΔP pt Pa	Temp ^oC	Velocity m/s	O_2 % Vol	Angle of Swirl ^{o}
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	

Sampling Line B

Traverse Point	Distance into duct (m)	ΔP pt mmH_2O	ΔP pt Pa	Temp ^oC	Velocity m/s	O_2 % Vol	Angle of Swirl ^{o}
1	0.06	18.5	181	91	15.75	-	0
2	0.18	19.2	188	91	16.04	-	0
3	0.30	20.2	198	90	16.43	-	0
4	0.42	20.1	197	91	16.42	-	0
5	0.54	22.0	216	92	17.20	-	0
6	0.66	25.8	253	92	18.62	-	0
7	0.78	28.0	274	92	19.40	-	0
8	0.90	26.1	256	92	18.73	-	0
9	1.02	21.6	212	92	17.04	-	0
10	1.14	19.3	189	90	16.06	-	0
Mean	-	22.1	216	91	17.17	-	

PRELIMINARY STACK SURVEY (CONTINUED)

TRAVERSE 1 CONTINUED

Sampling Line C							
Traverse Point	Distance into duct (m)	ΔP pt mmH_2O	ΔP pt Pa	Temp °C	Velocity m/s	O_2 % Vol	Angle of Swirl °
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	

Sampling Line D							
Traverse Point	Distance into duct (m)	ΔP pt mmH_2O	ΔP pt Pa	Temp °C	Velocity m/s	O_2 % Vol	Angle of Swirl °
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	

PRELIMINARY STACK SURVEY (CONTINUED)

Sampling Plane Validation Criteria

EA Technical Guidance Document (Monitoring) M1	Result	Units	Requirement	Compliant
Lowest Differential Pressure	181.3	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	15.75	m/s	-	-
Highest Gas Velocity	19.40	m/s	-	-
Ratio of Above	1.23	-	< 3 : 1	Yes
Angle of flow with regard to duct axis	0	^{o}	< 15^{o}	Yes
No local negative flow	-	-	-	Yes

Other Sampling Method Criteria	Result	Units	Requirement	Compliant
Mean Velocity	17.17	m/s	-	-
Standard Deviation of Velocity from Mean	7.56	%	< 10%	Yes
Mean Oxygen	-	%	-	-
Standard Deviation of Oxygen from Mean	-	%	< 15%	-
Homogeneous flow stream / gas velocity	-	-	-	Yes

Where:

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

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

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

$P_{ActualW}$ (at each sampling point) = P_{STW} x (Ts / Ps) x (Pa / Ta)

Calculation of Stack Gas Velocity, V

Velocity at Traverse Point, $V = K_{pt} \times (1-\varepsilon) * \sqrt{(2 * \Delta P_{pt} / P_{ActualW})}$

Where:

K_{pt} = Pitot tube calibration coefficient

$(1-\varepsilon)$ = Compressibility correction factor, assumed at a constant 0.998

Average Stack Gas Velocity, Va **17.17** m/s

PRELIMINARY STACK SURVEY (CONTINUED)

Calculation of Stack Gas Volumetric Flowrate, Q

Sampling plane reference conditions

Duct gas flow conditions	Actual	Reference	Units
Temperature	91	0	^{o}C
Total Pressure	100.25	101.3	kPa
Oxygen	17	21	%
Moisture	2.40	2.40	%

Gas Volumetric Flowrate	Result	Units
Gas Volumetric Flowrate (Actual), Q_{Actual}	69919	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	51853	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	50606	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	51853	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

STACK DIAGRAM

	Value	Units
Stack Depth	1.20	m
Stack Width	-	m
Area	1.13	m^2

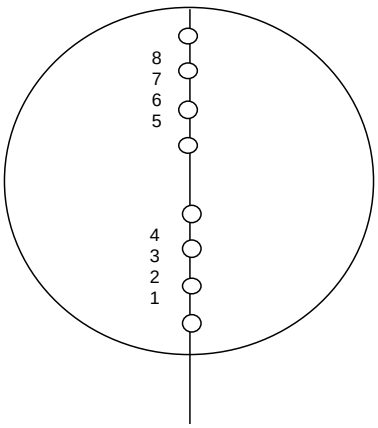
Non-Isokinetic Sampling

Sampling Point	Distance (% of Depth)	Distance into Stack	Units
-	-	-	-

Isokinetic Sampling CEN Methods

Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl º
1	4.2	0.05	0
2	10.5	0.13	0
3	19.4	0.23	0
4	32.3	0.39	0
5	67.7	0.81	0
6	80.6	0.97	0
7	89.5	1.07	0
8	95.8	1.15	0

Circular 1 line 8 points



O Isokinetic sampling point

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	0.3606	-	-
as a %	0.20	0.70	0.49	1.00	N/A	1.43452	0.62	0.001
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP)	Mass of particulate	O2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.48	2.3000	1.00	0.017	0.0004	-
MU as mg/m^3	0.06	0.7173	-	0.017	0.0008	**0.72**
MU as %	1.33	15.6763	-	0.361	0.0176	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**1.44**	**mg/m^3**	**31.47**	**%**

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

Developed for the STA by R Robinson, NPL

MEASUREMENT UNCERTAINTY BUDGET - DIOXINS & FURANS

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 ng/m3
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% ELV**
Run 1	0.001	2	0.5	1	N/A	0.2200	-	-
as a %	0.12	0.71	0.49	1.00	N/A	11.32216	0.37	28.16
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**No**	**Yes**	**No**

Run	Volume (STP) m^3	Mass of Dioxin & Furan mg	O2 Correction -	Leak ng/m^3	Uncollected Mass ng/m3	Laboratory analysis -	Combined uncertainty
Run 1	0.8383	1.4750	1.0000	0.0002	0.0163	-	-
MU as mg/m^3	0.0010	0.0113	-	0.0002	0.0008	0.0095	**0.0148**
MU as %	1.3236	14.9153	-	0.2123	1.1023	12.50	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.030**	**mg/m^3**	**39.1**	**%**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
Developed for the STA by R Robinson, NPL

MEASUREMENT UNCERTAINTY BUDGET - CADMIUM

Run	Sampled Volume m^3	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	0.001	2.0	0.5	1	0.1	0.000006	0.000004	-
as a %	0.18	0.70	0.49	1.00	-	3.00	0.001	0.34
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP) m^3	Mass of Cadmium & Thallium mg	O2 Correction -	Leak mg/m^3	Lab Uncertainty mg	Combined uncertainty
Run 1	0.5390	0.0001	-	0.0000005	-	-
MU as mg	0.000003	0.00001	-	0.0000005	0.00002	**0.00003**
MU as %	1.3291	3.0069	-	0.1943	10.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.0001**	**mg/m^3**	**21.06**	**%**

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

Developed for the STA by R Robinson, NPL

MEASUREMENT UNCERTAINTY BUDGET - HEAVY METALS

Run	Sampled Volume m^3	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	0.001	2.00	0.50	1.00	0.10	0.001	0.002	-
as a %	0.18	0.73	0.49	1.00	-	3.00	0.04	0.34
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP) m^3	Mass of Heavy Metals mg	O2 Correction -	Leak mg/m^3	Lab Uncertainty mg	Combined uncertainty
Run 1	0.5644	0.0510	-	0.0002	-	-
MU as mg/m^3	0.0012	0.0027	-	0.0002	0.0091	**0.0095**
MU as %	1.3456	3.0069	-	0.1943	10.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.02**	**mg/m^3**	**21.06**	**%**

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

Developed for the STA by R Robinson, NPL

MEASUREMENT UNCERTAINTY BUDGET - ISOKINETIC HYDROGEN CHLORIDE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Concentration in impinger	Limit of Detection	Leak
	m^3	K	kPa	% by volume	% by volume	mg	% by mass	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.490598637	287.50	101.5	1.0	-	0.0005	0.00025	-
as a %	0.20	0.70	0.49	1.00	-	3.00	0.005	0.62
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP)	Mass of Hydrogen Chloride	O2 Correction	Leak	Lab Uncertainty	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.4668	0.0003	-	0.0006	-	-
MU as mg/m^3	0.0022	0.0049	-	0.0006	0.0081	**0.0097**
MU as %	1.3314	3.0067	-	0.3607	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.02**	**mg/m^3**	**11.99**	**%**

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

Developed for the STA by R Robinson, NPL

MEASUREMENT UNCERTAINTY BUDGET - NON-ISOKINETIC HYDROGEN FLUORIDE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Concentration in impinger	Limit of Detection	Leak
	m^3	K	kPa	% by volume	% by volume	mg	% by mass	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.00004	2.000	0.500	1.000	0.100	0.003	0.002	-
as a %	0.065	0.683	0.065	1.000	-	3.000	3.005	0.20
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP)	Mass of Hydrogen Fluoride	O2 Correction	Leak	Lab Uncertainty	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.4324	0.0616	-	0.001	-	-
MU as mg/m^3	0.0121	0.0301	-	0.001	0.0501	**0.0597**
MU as %	1.2126	3.0053	-	0.115	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.12**	**mg/m^3**	**11.92**	**%**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
Developed for the STA by R Robinson, NPL

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 %	0.20	0.70	0.49	1.00	N/A	0.62
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**
Run	Volume (STP)	Mass Gained	O2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.48	9700.00	1.00	69.60	57.74	-
MU as % v/v	0.03	0.03	-	0.01	0.014	**0.04**
MU as %	1.33	1.03	-	0.36	0.60	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.09**	**% v/v**	**3.64**	**%**

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