AIR & EMISSIONS TESTING GROUP

52 Offerton Industrial Estate
Hempshaw Lane
Stockport
SK2 5TJ
Tel: 0161 477 3004
Fax: 0161 480 4642

Your contact at Scientifics:
Andrew Palliser
Business Manager
Tel: 0161 477 3004
Fax: 0161 480 4642
Email: andrew.palliser@scientifics.com

Stack Emissions Testing Report

Site:
Hanson Aggregates Ltd

Location:
St Ives

Site:
Coating Plant

Sampling Date/s:
15th September 2009

Job Number:
LAB 08760

Report Date: Version:	29th October 2009 1
Report By: MCERTS Number: MCERTS Level: Technical Endorsements:	Ibai Castezubi MM 05 674 Level 2, Team Leader TE1, TE2, TE3 & TE4
Report Approved By: MCERTS Number: Business Title: Technical Endorsements: Signature:	Andrew Hegarty MM 03 397 Level 2, Technical Manager TE1, TE2, TE3 & TE4

CONTENTS

EXECUTIVE SUMMARY (Page 1 of 12)

Stack Emissions Monitoring Objectives

Hanson Aggregates Ltd operates a Roadstone coating process at St Ives which is subject to PPC Permit PG 3/15b (04), under the Pollution Prevention & Control Regulations 2000.

Scientifics Limited were commissioned by Hanson Aggregates Ltd to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under 20 mm gravel 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 PPC Permit, PG 3/15b (04).

Plant

Coating Plant

Operator

PPC Permit: PG 3/15b (04)

Hanson Aggregates Ltd
Meadow Lane
St Ives
Cambridgeshire
PE27 4 LG

Stack Emissions Monitoring

Scientifics Limited - Stockport Laboratory
52 Offerton Industrial Estate
Hempshaw Lane
Stockport
SK2 5TJ

UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.

EXECUTIVE SUMMARY

Emissions Summary

Parameter	Units	Result	Uncertainty +/-	Limit
Total Particulate Matter	mg/m³	35	1.5	50
Particulate Emission Rate	g/hr	2182	92	-
Cadmium	mg/m³	0.02	0.005	0.5
Cadmium Emission Rates	g/hr	1.5	0.3	-
Nickel	mg/m³	0.57	0.1	1
Nickel Emission Rates	g/hr	39	8.3	-
Lead	mg/m³	0.1	0.02	5
Lead Emission Rates	g/hr	5.4	1.1	-
Combined Chromium, Copper and Vanadium	mg/m³	0.47	0.1	1.5
Combined Cr,Cu & V Emission Rates	g/hr	32	6.8	-
Hydrogen Chloride	mg/m³	0.57	0.04	100
Hydrogen Chloride Emission Rate	g/hr	36	2.4	-
Hydrogen Fluoride	mg/m³	0.41	0.05	5
Hydrogen Fluoride Emission Rate	g/hr	25	3.0	-
Moisture	%	0.9	0.05	-
Stack Gas Temperature	°C	82.0	-	-
Stack Gas Velocity	m/s	14.6	-	-
Gas Volumetric Flow Rate (Actual)	m³/hr	80648	-	-
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	62130	-	-
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	61584	-	-
Gas Volumetric Flow Rate (@ref conditions)	m³/hr	62130	-	-

where ND = None Detected

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

EXECUTIVE SUMMARY

Monitoring Times

Parameter	Sampling Date	Sampling Times	Sampling Duration
Total Particulate Matter Run 1	15th September 2009	10:23 - 10:55	32 minutes
Heavy Metals Run 1	15th September 2009	07:52 - 08:27	32 minutes
Hydrogen Chloride Run 1	15th September 2009	10:23 - 10:55	32 minutes
Hydrogen Fluoride Run 1	15th September 2009	11:31 - 12:01	30 minutes

EXECUTIVE SUMMARY

Process Details

Parameter	Process Details
Process Status	20 mm gravel
Capacity (of 100%) and Tonnes / Hour	110 T/h
Continuous or Batch Process	Batch Process
Feedstock (if applicable)	Gravel
Abatement System	Bag Filter
Abatement System Running Status	On
Fuel	CFO
Plume Appearance	None visible from sampling location

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard methods employed by Scientifics 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	Standard Method	Scientifics Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Limit of Detection (LOD)	MU of Method +/- %	MU +/- %
TPM	BS EN 13284-1	AE 006	1015	Yes	0.48 mg/m³	30%	4.2 %
Heavy Metals	BS EN 14385	AE 028	1015	Yes	0.038 mg/m³	30%	21.1 %
Hydrogen Chloride	BS EN 1911	AE 019	1015	Yes	0.0018 mg/m³	30%	6.8 %
Hydrogen Fluoride	BS ISO 15713	AE 055	1015	Yes	0.17 mg/m³	30%	12 %

On-Site Testing

Species	Standard Method	Scientifics Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Limit of Detection (LOD)	MU of Method +/- %	MU +/- %
H_2O	BS EN 14790	AE 004	1015	Yes	0.0002 %	10	6.3%

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	Stockport	Stockport	3 months
Heavy Metals	Inductively Coupled Plasma, Mass Spectrometry	HS/GWI/1002/15	1015	Yes	Harwell	Harwell	3 months
Hydrogen Chloride	IC	HS/WI/1087	1015	Yes	Harwell	Harwell	3 months
Hydrogen Fluoride	Ion Chromatography	HS/WI/1087	1015	Yes	Harwell	Harwell	3 months

On-Site Testing

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

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

Sampling Location

Sampling Plane Validation Criteria	Value	Units	Requirement	Compliance	Method
Lowest Differential Pressure	170	Pa	>= 5 Pa	Yes	All
Lowest Gas Velocity	14.39	m/s	-	-	-
Highest Gas Velocity	14.72	m/s	-	-	-
Ratio of Above	1.02	: 1	< 3 : 1	Yes	All
Mean Velocity	14.55	m/s	-	-	-
Angle of flow with regard to duct axis	0	^{o}	< 15^{o}	Yes	All
No local negative flow	-	-	-	Yes	All
Highly homogeneous flow stream / gas velocity	-	-	-	Yes	ISO 10396

Duct Characteristics

	Value	Units
Type	Circular	-
Depth	1.40	m
Width	-	m
Area	1.54	m^2
Port Depth	90	mm

Sampling Lines & Sample Points

	Isokinetic (CEN Methods)	Isokinetic (ISO Methods)	Non-Iso & Gases
Sample Port Size	4 inch BSP	-	4 inch BSP
Number Used	2	-	1
Orientation	Horizontal	-	Horizontal
Number Points / Line	4	-	1
Filtration	Out Stack	-	Out Stack
Filtration for TPM	Out Stack	-	-

Sampling Platform

General Platform Information	
Permanent / Temporary Platform	Permanent
Inside / Outside	Outside

M1 Platform requirements	
Minimum Platform Area 5 m^2	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	Yes

Sampling Location / Platform Improvement Recommendations

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

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Heavy Metals Absorbtion efficiency

Several of the metals didn't meet the required absorbtion requirement. However, this was due to the levels being very low so this is not thought to have had a significant effect on the result.

APPENDICES

CONTENTS

CONTENTS

APPENDICES

STACK EMISSIONS MONITORING TEAM

Team Leader	Ibai Castezubi Level 2, TE1, TE2, TE3 & TE4 MM 05 674
Technician	Craig Whittingham Level 1 MM 05 669

TOTAL PARTICULATE MATTER SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	10:23 - 10:55 15th September 2009	35	0.48	50	2182
Blank	-	1.4	-	-	-

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

Acetone Blank Value mg/l	Acceptable Value mg/l
5.00	10

ISOKINETIC SAMPLING EQUATIONS- RUN 1

TPM

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	757.51
Stack static pressure, P_{static}	mm H_2O	48.95
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	761.11
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	4.3
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.0053578
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.745
Gas meter correction factor, Y_d		0.860
Mean dry gas meter temperature, T_m		17.000
Mean pressure drop across orifice, ΔH	mmH	57.707
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.605
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.6101
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 $O2\ Ref = \frac{21.0 - act\%O2}{21.0 - ref\%O2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0088
	%	0.88
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.81
Mean of velocity heads, ΔP_{avg}	mm H_2O	18.18
Mean square root of velocity heads, $\sqrt{\Delta P}$		4.26
Mean stack gas temperature, T_s	°C	82
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s} + 273)}{\sqrt{(M_s)(P_s)}}$	m/s	14.75

Molecular weight of dry gas, M_d		
CO_2	%	15.80
O_2	%	20.9
Total	%	36.70
N_2 (100 -Total)	%	63.30
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		31.36
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	31.25
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	1.54
$Q_a = (60)(A_s)(V_s)$	m^3/min	1362.9
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	1040.4
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2 I}{(T_s) +273}$	@O2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	1049.58
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	5.90
Nozzle area, A_n	mm^2	27.34
Total sampling time, θ	min	32
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	102.3
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.01444
Mass collected in probe, M_p	g	0.0067
Total mass collected, M_n	g	0.0211
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	34.651
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	34.958
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		2182.14

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	20.03	0.12	0.11	-508	0.40	Yes

Isokineticity

Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	102.27	Yes

Acceptable Isokinetic rate 90 -110%

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	1.44	50	5	No

Filters

Run	Filter Material	Filter Size mm	Max Filtration Temperature °C	Pre-conditioning Filter Temperature °C	Post conditioning Filtration Temperature °C
Run 1	GF	47	82	180	160

GF = Glass Fibre

QF = Quartz Fibre

HEAVY METALS - PARTICULATE & VAPOUR PHASES COMBINED

Total Other Heavy Metals Combined

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	07:52 - 08:27 15th September 2009	1.1	0.04	-	78
Field Blank	-	0.05	-	-	-

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

INDIVIDUAL METALS SUMMARY - PARTICULATE & VAPOUR PHASES COMBINED

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

Metals	LOD mg/m³	Concentration mg/m³	Emission Rate g/hr	Limit mg/m^3
Lead	0.0191	0.079	5.41	5
Nickel	0.0008	0.570	39.17	1
Cadmium	0.0001	0.022	1.53	0.5
Chromium	0.0116	0.044	3.03	-
Vanadium	0.0001	0.004	0.28	-
Copper	0.0061	0.418	28.70	-
Combined Cr, Cu & V	0.0178	0.466	32.01	1.5
Total Other Heavy Metals	0.0378	1.137	78.13	

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

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
Lead	0.00003	9.600	0.014	0.019	46.20	0.065
Nickel	0.00004	8.000	0.011	0.001	395.76	0.559
Cadmium	0.00001	0.260	0.000	0.000	15.55	0.022
Chromium	0.00014	3.500	0.005	0.011	27.72	0.039
Vanadium	0.00003	2.700	0.004	0.000	0.23	0.000
Copper	0.00042	3.600	0.005	0.006	292.26	0.412
Total Other Heavy Metals	0.00068	27.660	0.039	0.037	777.72	1.098
Volume Sampled m^3		0.7086				

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

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
Lead	0.00003	0.20000	0.00028	0.01905	13.80000	0.01948
Nickel	0.00004	0.49000	0.00069	0.00076	0.55200	0.00078
Cadmium	0.00001	0.01000	0.00001	0.00008	4.55400	0.00643
Chromium	0.00014	0.70000	0.00099	0.01143	8.28000	0.01169
Vanadium	0.00003	0.66000	0.00093	0.00010	0.06900	0.00010
Copper	0.00042	0.30000	0.00042	0.00572	4.14000	0.00584
Total Other Heavy Metals	0.00068	2.36000	0.00333	0.03713	31.39500	0.04431
Volume Sampled m^3		0.7086				

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

ISOKINETIC SAMPLING EQUATIONS RUN 1

Heavy Metals

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	757.5
Stack static pressure, P_{static}	mm H_2O	48.9
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	761.1
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	4.3
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.005
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m	m	0.876
Gas meter correction factor, Y_d		0.8603
Mean dry gas meter temperature, T_m	°C	20.56
Mean pressure drop across orifice, ΔH	mmH	69.64
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.7032
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.7086
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 $O2\ Ref = \frac{21.0 - act\%O2}{21.0 - ref\%O2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0075
	%	0.75
Moisture by FTIR	%	-

Molecular weight of dry gas, M_d		
CO_2	%	15.80
O_2	%	20.9
Total	%	36.70
N_2 (100 -Total)	%	63.30
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		31.36
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	31.26
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.81
Mean of velocity heads, ΔP_{avg}	mm H_2O	21.75
Mean square root of velocity heads, $\sqrt{\Delta P}$		4.66
Mean stack gas temperature, T_s	°C	83
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s + 273})}{\sqrt{(M_s)(P_s)}}$	m/s	16.17
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	1.54
$Q_a = (60)(A_s)(V_s)$	m^3/min	1493.4
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	1137.0
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	1145.6
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	5.90
Nozzle area, A_n	mm^2	27.34
Total sampling time, θ	min	32
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	108.8
Acceptable isokinetic range 95% to 115%		Yes

HEAVY METALS QUALITY ASSURANCE CHECKLIST

Leak Test Results	Mean Sampling Rate	Pre-sampling Leak Rate	Post-sampling Leak Rate	Maximum Vacuum	Acceptable Leak Rate	Leak Tests
	litre/min	litre/min	litre/min	mm Hg	litre/min	litre/min
Run 1	23.6	0.09	0.09	-304.8	0.47	Yes

Isokinetic Criterion Compliance	Isokinetic Variation	Acceptable Isokineticity
	%	
Run 1	108.8	Yes

Filtration	Filter Material	Filter Size	Maximum Filtration Temperature
		mm	°C
Run 1	QF	47	0

GF = Glass Fibre

QF = Quartz Fibre

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

HEAVY METALS - ABSORPTION EFFICIENCIES

Parameter		Total ug	3rd Absorber ug	Absorption Efficiency (%)	Required %	Pass / Fail
Lead	Run 1	55.8	7.80	86	90	Failed
Nickel	Run 1	403.76	15.60	96	90	Passed
Cadmium	Run 1	15.81	2.50	84	90	Failed
Chromium	Run 1	31.2	4.68	85	90	Failed
Vanadium	Run 1	2.93	0.04	99	90	Passed
Copper	Run 1	295.9	2.34	99	90	Passed

HYDROGEN CHLORIDE SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	10:23 - 10:55 15th September 2009	0.57	0.002	100	35.7
Field Blank	-	0.006	-	-	-

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

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	20.0	0.12	0.11	0.40	Yes

Filtration	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Type of Absorbers	Absorption Solutions
Run 1	QF	47	82	Glass	HPLC Water

GF = Glass Fibre

QF = Quartz Fibre

HYDROGEN CHLORIDE ABSORPTION EFFICIENCY

Parameter	Total ug	IMP 2 ug	Absorption Efficiency %	Acceptable Absorption Efficiency %	Absorption Efficiency Acceptable ?
Run 1	346	1.4	N/A	95	N/A

ISOKINETIC SAMPLING EQUATIONS 1

Hydrogen Chloride

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	758
Stack static pressure, P_{static}	mm H_2O	49
$P_s = P_b + (P_{static})$ / 13.6	mm Hg	761
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	4.3
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.005332
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m	m	0.7450
Gas meter correction factor, Y_d		0.8603
Mean dry gas meter temperature, T_m	o	17.00
Mean pressure drop across orifice, ΔH	mmH	57.71
$V_{mstd} = (0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d) / T_m + 273$		0.60
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.6101
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: 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}		
$B_{wo} = V_{wstd} / (V_{mstd} + V_{wstd})$		0.0087
	%	0.87
Moisture by FTIR	%	-
Molecular weight of dry gas, M_d		
CO_2		15.80
O_2		20.9
Total		36.70
N_2 (100 -Total)		63.30
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		31.36
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	31.2

Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.81
Average of velocity heads, Δpavg		18.18
Average square root of velocity heads, $\sqrt{\Delta P}$		4.26
Average stack gas temperature, T_s		82
$V_s = (K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s} + 273) / \sqrt{(M_s)(P_s)}$		14.8
Actual flow of stack gas, Q_a		
Area of stack, A_s		1.54
$Q_a = (60)(A_s)(V_s)$		1363
Dry total flow of stack gas, Q_{std}		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = (Q_a)P_s(0.3592)(1-B_{wo}) / (T_s) +273$		1040
Wet total flow of stack gas, Q_{stw}		
$Q_{stw} = (Q_a)P_s(0.3592) / (T_s) +273$		1050
Dry total flow of stack gas at X% O_2, Q_{stdO2}		
$Q_{stdO2} = (Q_a)P_s(0.3592)(1-B_{wo})(O_2REF) / (T_s) +273$	m^3/min	No O2 Ref
Percent isokinetic, %I		
Nozzle diameter, D_n		5.90
Nozzle area, A_n		27.34
Total sampling time, θ	min	32
$\%I = (4.6398E6)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(\theta)(1-B_{wo})$		102
Acceptable isokinetic range 95% to 115%		Yes
Hydrogen Chloride Concentration, C		
Mass collected , M	ug	346
$C_{wet} = M / V_{mstw}$	mg/m^3	0.567
$C_{dry} = M / V_{mstd}$	mg/m^3	0.572
$Cdry@X\%O2 = M / V_{mstd@X\%oxygen}$	mg/m^3	No O2 Ref
Hydrogen Chloride Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$	g/hr	35.73

HYDROGEN FLUORIDE SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	11:31 - 12:01 15th September 2009	0.41	0.17	5	25.3
Field Blank	-	0.21	-	-	-

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

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	0.02	0.02	0.04	Yes

Filtration	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Type of Absorbers	Absorption Solutions
Run 1	QF	47	150	Quartz	NaOH

GF = Glass Fibre

QF = Quartz Fibre

HYDROGEN FLUORIDE ABSORPTION EFFICIENCY

Parameter	Total ug	IMP 2 ug	Absorption Efficiency %	Acceptable Absorption Efficiency %	Absorption Efficiency Acceptable ?
Run 1	24.4	ND	Not Determined	95	Not Determined

ND: Non Detected

PRELIMINARY STACK SURVEY

Stack Diameter / Depth, D	1.40	m
Stack Width, W	-	m
Stack Area, A	1.54	m^2
Average stack gas temperature	82	^oC
Pitot static pressure	0.48	kPa
Barometric Pressure	101	kPa
Pitot tube calibration coefficient, K_{pt}	0.81	-

Stack Gas Composition & Molecular Weights

Component	Molar Mass M	Density kg/m3 p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m3 pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m3 pi
CO_2	44	1.9631	15.80	0.158	0.31	15.66	0.16	0.31
O_2	32	1.4277	20.95	0.210	0.30	20.77	0.21	0.30
N_2	28	1.2492	63.25	0.633	0.79	62.69	0.63	0.78
H_2O	18	0.8031	-	-	-	0.88	0.01	0.01

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

Calculation of Stack Gas Densities

Determinand	Result	Units
Dry Density (STP), P_{STD}	1.3994	kg/m^3
Wet Density (STP), P_{STW}	1.3942	kg/m^3
Dry Density (Actual), P_{Actual}	1.0781	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.074	kg/m^3

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	15th September 2009
Time of Survey	10:01
Velocity Measurement Device:	S-Type

Sampling Line A							
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	0.07	17.6	172	82	14.52	-	0
2	0.21	17.6	172	82	14.52	-	0
3	0.35	17.8	174	82	14.60	-	0
4	0.49	17.8	174	82	14.60	-	0
5	0.63	17.7	173	82	14.56	-	0
6	0.77	17.4	171	82	14.44	-	0
7	0.91	17.5	172	82	14.48	-	0
8	1.05	17.6	172	82	14.52	-	0
9	1.19	17.6	172	82	14.52	-	0
10	1.33	17.3	170	82	14.39	-	0
Mean	-	17.59	172	82	14.51	-	

Sampling Line B							
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	0.07	17.7	173	82	14.56	-	0
2	0.21	17.8	174	82	14.60	-	0
3	0.35	17.8	174	82	14.60	-	0
4	0.49	18.1	177	82	14.72	-	0
5	0.63	18.0	176	82	14.68	-	0
6	0.77	17.9	175	82	14.64	-	0
7	0.91	17.9	175	82	14.64	-	0
8	1.05	17.6	172	82	14.52	-	0
9	1.19	17.4	171	82	14.44	-	0
10	1.33	17.5	172	82	14.48	-	0
Mean	-	17.77	174	82	14.59	-	

PRELIMINARY STACK SURVEY (CONTINUED)

TRAVERSE 1 CONTINUED

Sampling Line C							
Traverse Point	Distance into duct (m)	ΔP pt mmH_2O	ΔP pt Pa	Temp ^{o}C	Velocity m/s	O_3 % Vol	Angle of Swirl ^{o}
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 ^{o}C	Velocity m/s	O_3 % Vol	Angle of Swirl ^{o}
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	169.54	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	14.39	m/s	-	-
Highest Gas Velocity	14.72	m/s	-	-
Ratio of Above	1.02	-	< 3 : 1	Yes
Angle of flow with regard to duct axis	0	°	< 15°	Yes
No local negative flow	-	-	-	Yes

Other Sampling Method Criteria	Result	Units	Requirement	Compliant
Mean Velocity	14.55	m/s	-	-
Standard Deviation of Velocity from Mean	0.59	%	< 10%	Yes
Mean Oxygen	20.95	%	-	-
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* of H_2O) / (1 + (p*i* 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} x (1-ε) * √(2 * ΔP_{pt} / $P_{ActualW}$)

Calculation based on BS 1042:Section 2.1:1983 (Section 7 - Velocity Computation)

Where:

K_{pt} = Pitot tube calibration coefficient

(1-ε) = Compressibility correction factor, assumed at a constant 0.998

Average Stack Gas Velocity, Va **14.55** 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	82	0	^{o}C
Total Pressure	101.5	101.3	kPa
Oxygen	21.0	21	%
Moisture	0.88	0.88	%

Gas Volumetric Flowrate	Result	Units
Gas Volumetric Flowrate (Actual), Q_{Actual}	80648	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	62130	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	61584	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	62130	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

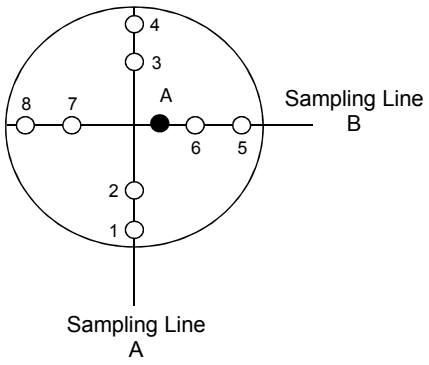
Ms = Water vapour, Reference Conditions, % Vol

O_2a = Oxygen, Actual Conditions, % Vol

O_2s = Oxygen, Reference Conditions, % Vol

STACK DIAGRAM

	Value	Units
Stack Depth	1.40	m
Stack Width	-	m
Area	1.54	m^2



Non-Isokinetic Sampling

Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	40	0.56	m

Isokinetic Sampling CEN Methods

Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	6.7	0.09	2
2	25.0	0.35	3
3	75.0	1.05	2
4	93.3	1.31	4
5	6.7	0.09	2
6	25.0	0.35	3
7	75.0	1.05	1
8	93.3	1.31	1
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

APPENDIX 3 - Calibrateable Equipment Checklist & Calibration Gases

CALIBRATEABLE EQUIPMENT CHECKLIST

Extractive Sampling		Instrumental Analyser/s		Miscellaneous	
Equipment	**Equipment I.D.**	**Equipment**	**Equipment I.D.**	**Equipment**	**Equipment I.D.**
Control Box DGM	LAB 13-12	Horiba PG-250 Analyser	-	Laboratory Balance	LAB 0001
Box Thermocouples	LAB 03-12	Horiba PG-200 Cooler	-	Tapemeasure	LAB 24-06
Meter In Thermocouple	-	JCT JCC P-1 Cooler	-	Stopwatch	-
Meter Out Thermocouple	-	Testo 350 Analyser	-	Protractor	LAB 08-01
Control Box Timer	LAB 17-12	Testo 339 Cooler	-	Barometer	LAB 08-01
Umbilical	LAB 03-29	FT-IR	-	Digital Micromanometer	LAB 01-07
Oven Box	LAB 09-16	FT-IR Oven Box	-	Digital Temperature Meter	LAB 03-34
Probe	LAB 1013	Bernath 3006 FID	-	Stack Thermocouple	LAB 11-08
S-Pitot	LAB 05-08	Signal 3010 MINIFID	-	Drycal	-
L-Pitot	-	Signal 3030 FID	-	Mass Flow Controller	-
Site Balance	LAB 14-09	Servomex	-	Mass Flow Control Box	-
Last Impinger Arm	-	JCT Heated Head Filter	-	1m Heated Line	-
Calipers	LAB 0058	Stackmaster Heated Filter	-	5m Heated Line (1)	-
Small DGM	-		-	5m Heated Line (2)	-
			-	10m Heated Line (1)	-
			-	10m Heated Line (2)	-
			-	15m Heated Line (1)	-
			-	15m Heated Line (2)	-
			-	20m Heated Line (1)	-

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

APPENDIX 4 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume m^3	Sampled Gas Temp K	Sampled Gas Pressure KPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Mass of Particulate mg	Leak %	Uncollected Mass mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.001	2	1	1	N/A	0.29120	-	-
as a %	0.16	0.69	0.99	1.00	N/A	1.37750	0.55	0.00
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP) m^3	Mass of particulate mg	O2 Correction -	Leak mg/m^3	Uncollected Mass mg	Combined uncertainty
Run 1	0.58	21.1400	1.00	0.110	0.00	-
MU as mg/m^3	0.15	0.2092	-	0.068	0.00	**0.73**
MU as %	1.57	1.3775	-	0.317	0.00	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**1.47**	**mg/m^3**	**4.23**	**%**

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

Developed for the STA by R Robinson, NPL

APPENDIX 4 - Measurement Uncertainty Budget Calculations

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	Mass of Heavy Metals %	Leak %
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**<5%**	**<=2%**
Run 1	0.71	273.00	105.80	0.00	-	2.88	0.81	-
as a %	0.14	0.73	0.95	1.00	-	3.00	-	0.38
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**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	0.7400	0.8054	-	0.0025	-	-
MU as mg/m^3	0.0178	0.0344	-	0.0025	0.1137	**0.1201**
MU as %	1.5647	3.0228	-	0.2206	10.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.24**	**mg/m^3**	**21.13**	**%**

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

Developed for the STA by R Robinson, NPL

APPENDIX 4 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - ISOKINETIC HYDROGEN CHLORIDE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Concentration in impinger	Mass of Hydrogen Chloride	Leak
	m^3	K	KPa	% by volume	% by volume	mg	%	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**<5%**	**<=2%**
Run 1	0.61005628	290.00	105.8	0	-	0.009911111	0.00223	-
as a %	0.16	0.69	0.95	1.00	-	3.00	3.03	0.55
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	0.5998	0.0022	-	0.0018	-	-
MU as mg/m^3	0.0088	0.0172	-	0.0018	0.0000	**0.0194**
MU as %	1.5482	3.0327	-	0.3171	0.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.04**	**mg/m^3**	**6.84**	**%**

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

Developed for the STA by R Robinson, NPL

APPENDIX 4 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - NON-ISOKINETIC HYDROGEN FLUORIDE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Concentration in impinger	Mass of Hydrogen Fluoride	Leak
	m^3	K	KPa	% by volume	% by volume	mg	%	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**<5% of limit value**	**<=2%**
Run 1	0.001	2.000	1.000	1.000	0.100	0.003	0.001	-
as a %	1.652	0.707	0.131	1.000	-	3.000	3.028	1.000
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	0.4392	0.0244	-	0.0023	-	-
MU as mg/m^3	0.0051	0.0123	-	0.0023	0.0203	**0.0244**
MU as %	1.2524	3.0279	-	0.5774	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.05**	**mg/m^3**	**12.01**	**%**

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

Developed for the STA by R Robinson, NPL

APPENDIX 4 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - MOISTURE

Run	Sampled	Sampled Gas	Sampled Gas	Sampled Gas	Oxygen	Leak	Uncollected
	m^3	K	KPa	% by volume	% by volume	%	mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.001	2	1	1	N/A	-	-
as a %	0.16	0.69	0.99	1.00	N/A	0.55	2.33
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**

Run	Volume (STP)	Mass Gained	O2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.58	4300.00	1.00	22.35	57.74	-
MU as % v/v	0.01	0.02	-	0.00	0.012	**0.03**
MU as %	1.57	2.33	-	0.32	1.34	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.06**	**% v/v**	**6.26**	**%**

APPENDIX 5 - Waste Oil Analysis

WASTE OIL ANALYSIS

Parameter	Concentration mg/kg	Limit
Cadmium	1	-
Nickel	2	-
Lead	23	-
Chromium	10	-
Copper	1	-
Vanadium	1	-
Chloride	150	-
Fluoride	47	-
Sulphur	0.39	1%
Total PCB's	< 5	5 mg/Kg