STACK EMISSIONS MONITORING REPORT

Unit 5 Crown Industrial Estate
Kenwood Road
Stockport
SK5 6PH
Tel: 0161 443 0980
Fax: 0161 443 0989

Your contact at ESG
Mark Woodruff Business Manager Tel: 0161 443 0982 Email: mark.woodruff@esg.co.uk

Operator & Address:
North East Lincolnshire Council Great Grimsby Crematorium Weelsby Avenue Grimsby DN32 0BA

Permit:
Defra Process Guidance Note: PG 5/2 (12)

Release Point:

Sampling Date(s):
5th - 6th February 2014

ESG Job Number:	LNO 11660
Report Date:	28th February 2014
Version:	1
Report By:	Keith Bird
MCERTS Number:	MM 07 825
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Mark Woodruff
MCERTS Number:	MM 03 164
Business Title:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Signature:	

UKAS TESTING
1015

mCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

CONTENTS

EXECUTIVE SUMMARY

Stack Emissions Monitoring Objectives
- Plant
- Operator
- Stack Emissions Monitoring Test House

Emissions Summary
Monitoring Times
Process Details
Monitoring Methods
Analytical Methods
- Sampling Methods with Subsequent Analysis
- On-Site Testing

Sampling Location
- Sampling Plane Validation Criteria
- Duct Characteristics
- Sampling Lines & Sample Points
- Sampling Platform
- Sampling Location / Platform Improvement Recommendations

Sampling and Analytical Method Deviations

APPENDICES

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team
APPENDIX 2 - Summaries, Calculations, Raw Data and Charts
APPENDIX 3 - Measurement Uncertainty Budget Calculations
APPENDIX 4 - Record of Amendments (if applicable)

EXECUTIVE SUMMARY

MONITORING OBJECTIVES

North East Lincolnshire Council operates a cremation process at Great Grimsby Crematorium which is subject to Defra Process Guidance Note PG 5/2 (12), under the Environmental Permitting Regulations 2010.

Environmental Scientifics Group Limited were commissioned by North East Lincolnshire Council 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 Defra Process Guidance Note, PG 5/2 (12).

Plant

Operator

North East Lincolnshire Council
Great Grimsby Crematorium
Weelsby Avenue
Grimsby
DN32 0BA

Defra Process Guidance Note: PG 5/2 (12)

Stack Emissions Monitoring Test House

Environmental Scientifics Group Limited - Stockport Laboratory
Unit 5 Crown Industrial Estate
Kenwood Road
Stockport
SK5 6PH
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	2.3	0.41	20	✓
Particulate Emission Rate	g/hr	3	0.5	-	
Mercury	mg/m³	0.039	0.008	0.05	✓
Mercury Emission Rate	g/hr	0.051	0.010	-	
Hydrogen Chloride	mg/m³	10.7	1.3	30	✓
Hydrogen Chloride Emission Rate	g/hr	10.9	1.3	-	
Volatile Organic Compounds	mg/m³	2.2	1.3	20	✓
Volatile Organic Compounds Emission Rate	g/hr	2.7	1.6	-	
Carbon Monoxide	mg/m³	1.6	3.5	100	✓
Carbon Monoxide Emission Rate	g/hr	1.9	4.3	-	
Oxygen	% v/v	12.5	0.3	-	✓
Moisture	%	2.3	0.09	-	✓
Stack Gas Temperature	°C	79.4	-	-	✓
Stack Gas Velocity	m/s	4.0	-	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	2139	-	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	1617	-	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	1580	-	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	1223	-	-	

ND = None Detected,
Results at or below the limit of detection are highlighted by bold italic text.
The above volumetric flow rate is an average of the data collected during the isokinetic tests. Mass emissions for non isokinetic tests are also calculated using these values.

Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	**Sampling Date(s)**	**Sampling Times**	**Sampling Duration**
Total Particulate Matter Run 1	05 February 2014	13:20 - 14:35	75 minutes
Total Particulate Matter Run 2	05 February 2014	14:55 - 16:05	70 minutes
Total Particulate Matter Run 3	06 February 2014	09:05 - 10:15	70 minutes
Mercury Run 1	06 February 2014	10:28 - 11:58	90 minutes
Hydrogen Chloride Run 1	05 February 2014	13:20 - 14:35	75 minutes
Volatile Organic Compounds Run 1	05 February 2014	13:20 - 14:35	75 minutes
Combustion Gases	05 February 2014	13:20 - 14:35	75 minutes
Stack Gas Flow Rate & Temperature Run 1	05 February 2014	12:30	-

EXECUTIVE SUMMARY

PROCESS DETAILS			
CREMATOR OPERATING INFORMATION			
Description of process	Cremation		
Continuous or batch	Batch		
Abatement	Mercury Abatement System		
Plume Appearance	Not visible from sampling location		
TEST SPECIFIC DETAILS	**Run 1**	**Run 2**	**Run 3**
Coffin Type	Standard	Standard	Standard
Sex	Male	Male	Male
Body Size	Average	Average	Average
Cremation Number	96285	96287	96290

EXECUTIVE SUMMARY

Monitoring Methods

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

MONITORING METHODS						
Species	**Method** Standard Reference Method / Alternative Method	**ESG Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Limit of Detection (LOD)**	**Calculated MU +/- %**
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	0.19 mg/m³	17.4 %
Mercury	SRM - BS EN 13211 / MID 14385	AE 107/AE 108	1015	Yes	0.00004 mg/m³	20.3 %
Hydrogen Chloride	SRM - BS EN 1911	AE 111	1015	Yes	0.002 mg/m³	12.3 %
VOCs	SRM - BS EN 12619:2013	AE 102	1015	Yes	0.4 mg/m³	60.3 %
CO	SRM - BS EN 15058	AE 102	1015	Yes	0.35 mg/m³	223.91%
O_2	AM - BS EN 14789	AE 102	1015	Yes	0.01%	2.56%
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	0.01%	4.05%
Flow Rate / Temp.	SRM - BS EN 13284-1	AE 122	1015	Yes	5 Pa	-

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 Stockport	ESG Stockport	3 months
Mercury	Inductively coupled Plasma - Mass Spectrometry	ANU/SOP/117, 101,102	1015	Yes	ESG Bretby	ESG Bretby	3 months
Hydrogen Chloride	Ion Chromatography	ASC/SOP/110/107	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**
VOCs	Flame Ionisation Detection	AE 102	1015	Yes	ESG Stockport	ESG Stockport	5 years
CO	Non Dispersive Infra Red	AE 102	1015	Yes	ESG Stockport	ESG Stockport	5 years
O_2	Zirconia Cell	AE 102	1015	Yes	ESG Stockport	ESG Stockport	5 years
H_2O	Gravimetric	AE 105	1015	Yes	ESG Stockport	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	12	Pa	>= 5 Pa	Yes	BS EN 13284-1
Lowest Gas Velocity	4.2	m/s	-	-	-
Highest Gas Velocity	4.7	m/s	-	-	-
Ratio of Gas Velocities	1.1	: 1	< 3 : 1	Yes	BS EN 13284-1
Mean Velocity	4.5	m/s	-	-	-
Maximum angle of flow with regard to duct axis	5	^{o}	< 15^{o}	Yes	BS EN 13284-1
No local negative flow	Yes	-	-	Yes	BS EN 13284-1

DUCT CHARACTERISTICS		
	Value	**Units**
Shape	Rectangular	-
Depth	0.32	m
Width	0.46	m
Area	0.15	m^2
Port Depth	90	mm

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

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

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)	N/A
Platform has vertical base boards (approximately 0.25 m high)	N/A
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 needs to be increased in size if it is to comply with the guidance stipulated in EA document M1, however it was sufficient for compliant testing to be carried out.

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

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	3
Mercury	SRM - BS EN 13211 / MID 14385	AE 107/AE 108	1015	Yes	1
Hydrogen Chloride	SRM - BS EN 1911	AE 111	1015	Yes	1
VOCs	SRM - BS EN 12619:2013	AE 102	1015	Yes	1
CO	SRM - BS EN 15058	AE 102	1015	Yes	1
O_2	AM - BS EN 14789	AE 102	1015	Yes	1
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	1
Flow Rate / Temp.	SRM - BS EN 13284-1	AE 122	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	LNO 13-05	Horiba PG-250 Analyser	LNO 21-12	Laboratory Balance	LNO 00-11 / 00-12
Box Thermocouples	LNO 03-05	FT-IR	-	Tape Measure	LNO 24-KB
Meter In Thermocouple	-	FT-IR Oven Box	-	Stopwatch	LNO 17-KB
Meter Out Thermocouple	-	Bernath 3006 FID	-	Protractor	-
Control Box Timer	LNO 17-05	Signal 3030 FID	-	Barometer	LNO 08-KB
Oven Box	LNO 09-03	Servomex	-	Digital Micromanometer	LNO 01-KB
Probe	-	JCT Heated Head Filter	-	Digital Temperature Meter	LNO 03-KB
Probe Thermocouple	-	Thermo FID	LNO 21-03	Stack Thermocouple	-
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	LNO 06-KB	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	LNO 14-KB	Chiller (JCT/MAK 10)	LNO 21-41	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	LNO 31-KB		-	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	-		-	20m Heated Line (1)	-
Inclinometer (Swirl Device)	LNO 23-KB		-	20m Heated Line (2)	-

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

CALIBRATION GASES

Gas (traceable to ISO 17025)	Cylinder I.D Number	Supplier	ppm	%	Analytical Tolerance +/- %
Oxygen	Fresh Air	BOC	-	20.95	-
Propane	HPC 746	BOC	9.9	-	2
Carbon Monoxide	HPC 777	BOC	167	-	2

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

STACK EMISSIONS MONITORING TEAM

Team Leader	Keith Bird MCERTS Level 2, Technical Endorsements 1, 2, 3 & 4 MM 07 825 MCERTS Expiry Date - Dec 2013 H&S Expiry Date - Apr 2017
Technician	Gary Orley MCERTS Trainee MM 13 1233 MCERTS Expiry Date - Mar 2018 H&S Expiry Date - Apr 2018

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	13:20 - 14:35 05 February 2014	1.6	0.38	20	1.7
Run 2	14:55 - 16:05 05 February 2014	1.7	0.36	20	1.8
Run 3	09:05 - 10:15 06 February 2014	3.7	0.28	20	5.9
Blank	-	0.16	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

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	QL 2423	0.55837	0.55839	0.00002	142.85470	142.85620	0.00150	0.00152
Run 2	Q 2424	0.55569	0.55598	0.00029	194.29620	194.29770	0.00150	0.00179
Run 3	QL 2425	0.55589	0.55931	0.00342	183.25760	183.25990	0.00230	0.00572

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	QL 2426	0.55283	0.55265	-0.00018	145.24200	145.24210	0.00010	0.00019

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	738.76
Stack static pressure, P_{static}	mm H_2O	1.02
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	738.83
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	25.5
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.031773
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		1.492
Gas meter correction factor, Y_d		1.0014
Mean dry gas meter temperature, T_m		17.800
Mean pressure drop across orifice, ΔH	mmH_2O	43.320
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		1.369
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.4010
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		14.0
% oxygen reference condition		11
O_2 Reference Factor O_2 Ref $= \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		0.70
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	0.9585
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0227 / 2.27
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.85
Mean of velocity heads, ΔP_{avg}	mm H_2O	1.00
Mean square root of velocity heads, $\sqrt{\Delta P}$		1.00
Mean stack gas temperature, T_s	°C	91
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	3.85

Molecular weight of dry gas, M_d		
CO_2	%	6.47
O_2	%	14.00
Total	%	20.47
N_2 (100 -Total)	%	79.53
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.60
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	29.33
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.15
$Q_a = (60)(A_s)(V_s)$	m^3/min	34.0
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	24.2
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O_2ref	16.97
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	24.80
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	11.94
Nozzle area, A_n	mm^2	111.98
Total sampling time, θ	min	75
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	99.0
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00008
Mass collected in probe, M_p	g	0.00150
Total mass collected, M_n	g	0.00158
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	1.128
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	1.154
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	1.648
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		1.68

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 2 — TPM

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	738.76
Stack static pressure, P_{static}	mm H_2O	1.02
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	738.83
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		1.646
Gas meter correction factor, Y_d		1.0014
Mean dry gas meter temperature, T_m		15.233
Mean pressure drop across orifice, ΔH	mmH_2O	47.464
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		1.525
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.5601
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		14
% oxygen reference condition		11
O_2 Reference Factor O_2 Ref $= \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		0.70
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	1.0673
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0227
	%	2.27
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.85
Mean of velocity heads, ΔP_{avg}	mm H_2O	1.10
Mean square root of velocity heads, $\sqrt{\Delta P}$		1.05
Mean stack gas temperature, T_s	°C	89
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	4.03

Molecular weight of dry gas, M_d		
CO_2	%	6.47
O_2	%	14.00
Total	%	20.47
N_2 (100 -Total)	%	79.53
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.60
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	29.33
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.15
$Q_a = (60)(A_s)(V_s)$	m^3/min	35.6
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	25.5
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O_2ref	17.84
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	26.08
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	11.94
Nozzle area, A_n	mm^2	111.98
Total sampling time, θ	min	70
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	112.3
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00029
Mass collected in probe, M_p	g	0.00150
Total mass collected, M_n	g	0.00179
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	1.15
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	1.17
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	1.68
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		1.80

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 3 — TPM

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	738.76
Stack static pressure, P_{static}	mm H_2O	1.02
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	738.83
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		1.836
Gas meter correction factor, Y_d		1.0014
Mean dry gas meter temperature, T_m		14.643
Mean pressure drop across orifice, ΔH	mmH_2O	62.306
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		1.707
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.7463
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		12
% oxygen reference condition		11
O_2 Reference Factor $O_2\ Ref = \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		0.90
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	1.5360
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0227
	%	2.27
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.85
Mean of velocity heads, ΔP_{avg}	mm H_2O	1.32
Mean square root of velocity heads, $\sqrt{\Delta P}$		1.15
Mean stack gas temperature, T_s	°C	58
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	4.23

Molecular weight of dry gas, M_d		
CO_2	%	6.47
O_2	%	12.00
Total	%	18.47
N_2 (100 -Total)	%	81.53
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.52
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	29.25
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.15
$Q_a = (60)(A_s)(V_s)$	m^3/min	37.3
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) +273}$	Dry	29.3
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O_2ref	26.34
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	29.94
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	11.94
Nozzle area, A_n	mm^2	111.98
Total sampling time, θ	min	70
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	109.5
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00342
Mass collected in probe, M_p	g	0.00230
Total mass collected, M_n	g	0.0057
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	3.28
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	3.35
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	3.72
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		5.88

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	19.92	0.07	0.12	-330.2	0.40	Yes
Run 2	23.55	0.04	0.09	-330.2	0.47	Yes
Run 3	26.27	0.09	0.11	-330.2	0.53	Yes

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	99.00	Yes
Run 2	112.32	Yes
Run 3	109.51	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.19	1	Yes
Run 2	0.18	1	Yes
Run 3	0.12	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	0.16	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	90	160	180	160
Run 2	QF	90	160	180	160
Run 3	QF	90	160	180	160

GF = Glass Fibre

QF = Quartz Fibre

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MERCURY SUMMARY - PARTICULATE & VAPOUR PHASES COMBINED

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	10:28 - 11:58 06 February 2014	0.039	0.00004	0.05	0.051
Field Blank	-	0.00004	-	-	-

Mercury	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mean mg/m³	Lab Result ug	Concentration mg/m³	Stack LOD mean mg/m³	Lab Result ug	Concentration mg/m³
Run 1	0.00002	0.02	0.00002	0.0000	36.10	0.039
Volume Sampled m^3		0.9214			0.9214	
Field Blank	-	0.02	0.00002	-	0.02	0.0000
Volume Sampled m^3		0.9214			0.9214	

Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS RUN 1 — Mercury

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	738.8
Stack static pressure, P_{static}	mm H_2O	1.0
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	738.8
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		1.166
Gas meter correction factor, Y_d		1.0014
Mean dry gas meter temperature, T_m		13.29
Mean pressure drop across orifice, ΔH	m	15.49
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		1.08
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.1091
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		12.5
% oxygen reference condition		11
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		0.85
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	0.921
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0227
	%	2.27
Moisture by FTIR	%	-

Molecular weight of dry gas, M_d		
CO_2	%	6.47
O_2	%	12.50
Total	%	18.97
N_2 (100 -Total)	%	81.03
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.54
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	29.27
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.85
Mean of velocity heads, ΔP_{avg}	mm H_2O	1.04
Mean square root of velocity heads, $\sqrt{\Delta P}$		1.02
Mean stack gas temperature, T_s	°C	63
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	3.78
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.15
$Q_a = (60)(A_s)(V_s)$	m^3/min	33.4
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	25.7
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O2ref	21.9
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	26.3
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	9.00
Nozzle area, A_n	mm^2	63.63
Total sampling time, θ	min	90
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	108.2
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	13.0	0.06	0.12	-254	0.26	Yes

Isokinetic Criterion Compliance	Isokinetic Variation %	Acceptable Isokineticity
Run 1	108.2	Yes

Filtration / Temp	Filter Material	Filter Size mm	Maximum Filtration Temperature °C	Maximum storage / transit Temperature °C
Run 1	QF	47	180	12

GF = Glass Fibre

QF = Quartz Fibre

HEAVY METALS ABSORBTION EFFICIENCY

Parameter		Total ug	5th Absorber ug	Absorption Efficiency	Required	Pass / Fail
Mercury	Run 1	36.12	0.87	98	95	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	13:20 - 14:35 05 February 2014	10.7	0.002	30	10.9
Field Blank	-	0.002	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

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	19.9	0.07	0.12	0.40	Yes

	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Max. Storage / Transit Temp. °C	Type of Absorbers	Absorption Solutions
Run 1	QF	47	160	12	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	10263.2	3.2	100	95	Yes

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

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	739	Pitot tube velocity constant, K_p		34.97
Stack static pressure, P_{static}	mm H_2O	1	Velocity pressure coefficient, C_p		0.85
$P_s = P_b + (P_{static}/13.6)$	mm Hg	739	Mean of velocity heads, ΔP_{avg}	mm H_2O	1.00
			Mean square root of velocity heads, $\sqrt{\Delta P}$		1.00
Vol. of water vapour collected, V_{wstd}			Mean stack gas temperature, T_s	°C	91
Moisture trap weight increase,Vlc	g	-			
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-	$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	3.9
Volume of gas metered dry, V_{mstd}			**Actual flow of stack gas, Q_a**		
Volume of gas sample through gas meter, V_m		1.4920	Area of stack, A_s	m^2	0.15
Gas meter correction factor, Y_d		1.0014	$Q_a = (60)(A_s)(V_s)$	m^3/min	34
Mean dry gas meter temperature, T_m		17.80	**Dry total flow of stack gas, Q_{std}**		
Mean pressure drop across orifice, ΔH	mmH_2O	43.32	Conversion factor (K/mm.Hg)		0.3592
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		1.37	$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) +273}$	m^3/min	24
Volume of gas metered wet, V_{mstw}			**Wet total flow of stack gas, Q_{stw}**		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.4010	$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	m^3/min	25
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	17			
% oxygen measured in gas stream, act%O_2		14.00			
% oxygen reference condition		11	**Percent isokinetic, %I**		
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		0.70	Nozzle diameter, D_n	mm	11.94
			Nozzle area, A_n	mm^2	111.98
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	0.9585	Total sampling time, θ	min	75
Moisture content, B_{wo}			$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	99
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0227			
	%	2.27	Acceptable isokinetic range 95% to 115%		Yes
Moisture by FTIR	%	-	**Hydrogen Chloride Concentration, C**		
Molecular weight of dry gas, M_d			Mass collected , M	ug	10263
CO_2		6.47	$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	7.325
O_2		14.00			
Total		20.47	$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	7.495
N_2 (100 -Total)		79.53			
			$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	10.708
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.60			
Molecular weight of wet gas, M_s			**Hydrogen Chloride Emission Rates, E**		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	29.3	$E = [(C_{wet})(Q_{stw})(60)] / 1000$	g/hr	10.90

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

VOLATILE ORGANIC COMPOUNDS SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	13:20 - 14:35 05 February 2014	2.2	0.40	20	2.7

Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

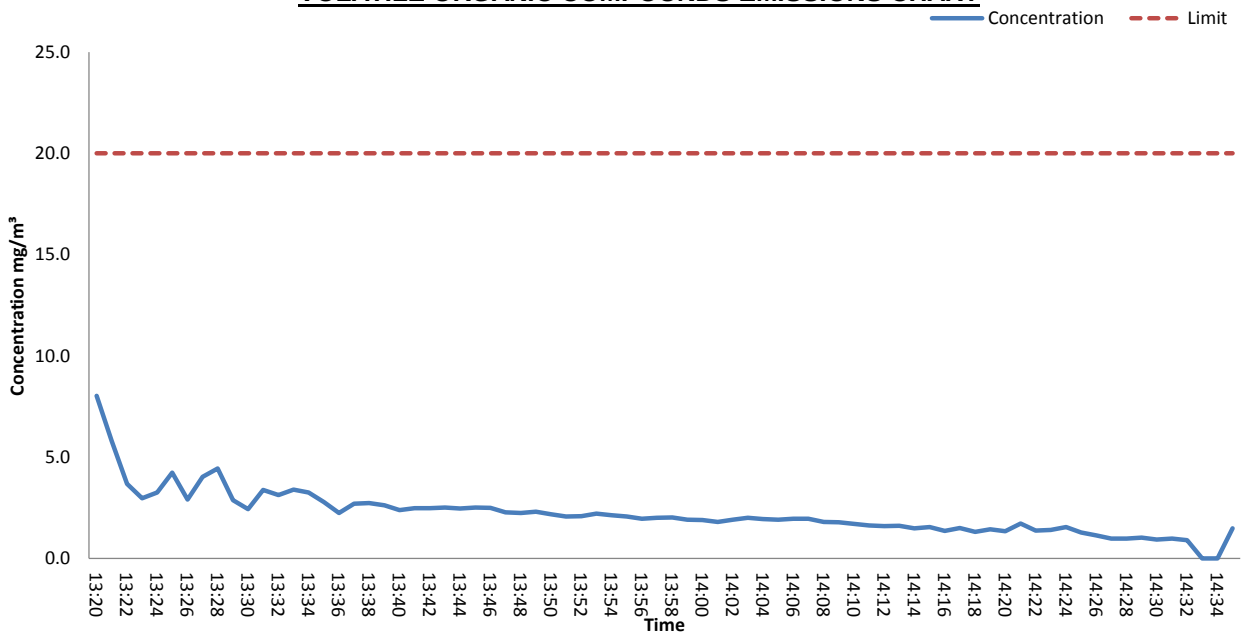
INSTRUMENTAL SPAN & ZERO CHECKS

PRE-SAMPLING CALIBRATION CHECKS								
Date	05 February 2014							
Start Time	11:20							
End Time	11:40							
Gas	Gas Conc (ppm)	Range	Instrument Zero Reading	Instrument Span Reading	Instrument Zero Reading	Zero Down line reading	Span down line reading	Leak Rate (%)
Propane	9.9	100	0	9.9	0.1	0.1	9.88	0.20

Zero and Span gas contained 10% Oxygen

POST-SAMPLING CALIBRATION CHECKS				
Date	05 February 2014			
Start Time	16:10			
End Time	16:15			
Gas	Zero down line reading	Span down line reading	Zero Drift (%)	Span Drift (%)
Propane	0.1	9.97	0.00	0.91

VOLATILE ORGANIC COMPOUNDS EMISSIONS CHART



Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

COMBUSTION GASES SUMMARY

Test	Sampling Time and Date	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
CO	13:20 - 14:35 05 February 2014	1.6	0.35	100	1.9

Test	Sampling Time and Date	Concentration %	LOD %
O_2	13:20 - 14:35 05 February 2014	12.5	0.01

Reference conditions are 273K, 101.3kPa, dry gas 11% Oxygen.

PRE-SAMPLING CALIBRATION DATA

Date	05 February 2014
Start Time	11:30
End Time	12:00

Chiller Temperature (°C)	2.1
Requirement	< 4°C
Compliant	Yes

Gas	Range (ppm / %)	Zero Reading at analyser	Span Reading at analyser	Zero Check at analyser	Zero Check down line	Span Check down line	Response Time (Secs)	Leak Rate %
CO	200	0.0	167	0.2	0.4	166.1	45	0.54
O_2	25	0.0	20.95	0.03	0.07	20.87	40	0.38

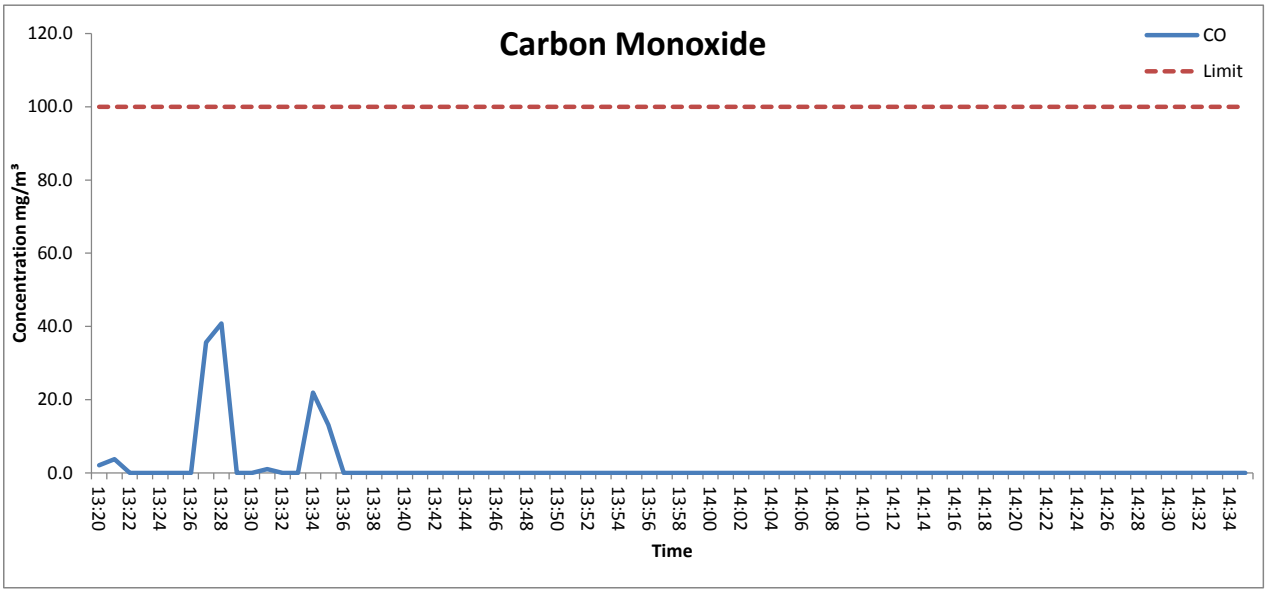
POST-SAMPLING CALIBRATION DATA

Date	05 February 2014
Start Time	16:10
End Time	16:20

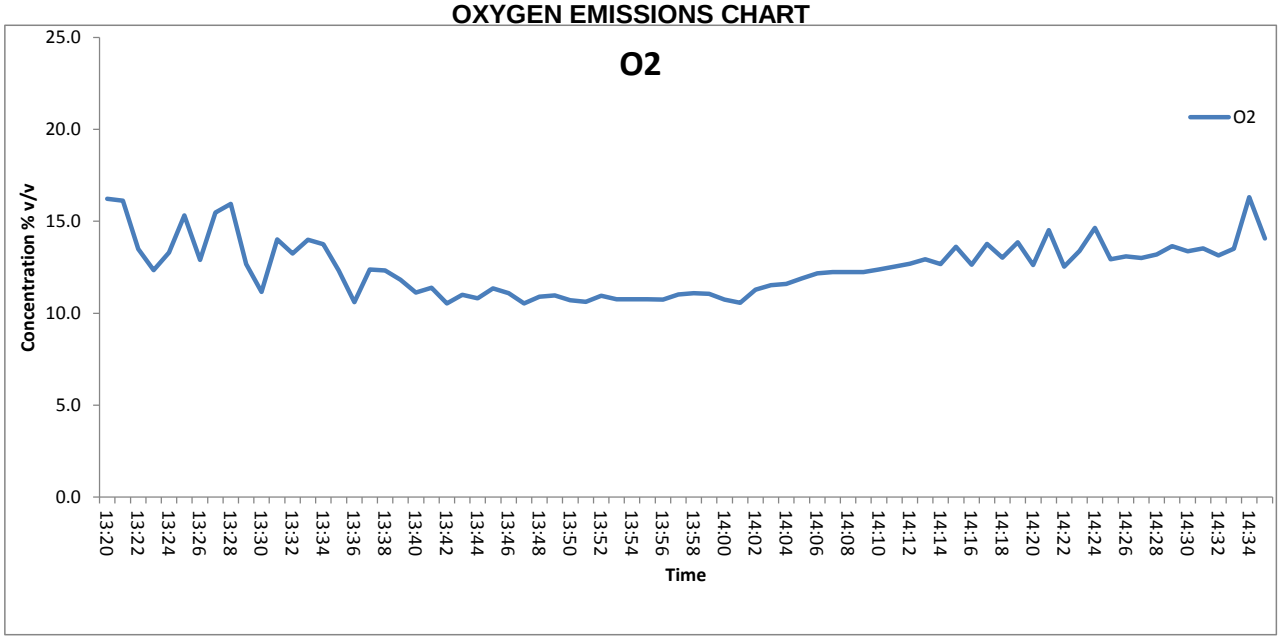
Chiller Temperature (°C)	2.1
Requirement	< 4°C
Compliant	Yes

Gas	Zero Check down line	Span Check down line	Zero Drift (%)	Span Drift (%)
CO	0.2	166	-0.10	0.05
O_2	0.04	20.88	-0.12	0.16

CARBON MONOXIDE EMISSIONS CHART



OXYGEN EMISSIONS CHART



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

DAILY OXYGEN SUMMARY

Sampling Times	Concentration %	LOD %
13:20 - 16:05 05 February 2014	14.19	0.01
10:28 - 11:58 06 February 2014	12.58	0.01

PRE SAMPLING CALIBRATION DATA

Date	Time of Analyser Checks	Range (%)	Zero Reading at analyser	Span Reading at analyser	Zero Check at analyser	Zero Check down line	Span Check down line	Leak Rate %
05 February 2014	11:30 - 12:00	25	0	20.95	0.03	0.07	20.87	-0.38
06 February 2014	08:35 - 08:45	25	0	20.95	0.02	0.06	20.96	0.05

POST SAMPLING CALIBRATION DATA

Date	Time of Analyser Checks	Zero Check down line	Span Check down line	Zero Drift (%)	Span Drift (%)
05 February 2014	16:10 - 16:20	0.04	20.88	-0.14	0.05
06 February 2014	12:00 - 12:05	0.05	20.93	-0.05	-0.14

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	13:20 - 14:35 05 February 2014	3.3233	3.3488	0.0255	2.2678	0.009	4.1

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	75	1401	19.9212	0.0700	0.1200	0.3984	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.32	m
Stack Width, W	0.46	m
Stack Area, A	0.15	m^2
Average stack gas temperature	91	^oC
Stack static pressure	0.01	kPa
Barometric Pressure	98.5	kPa
Pitot tube calibration coefficient, K_{pt}	0.85	-

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	6.420000	0.064200	0.126028	6.274406	0.062744	0.123170
O_2	32	1.427679	12.521590	0.125216	0.178768	12.237624	0.122376	0.174714
N_2	28	1.249219	81.058410	0.810584	1.012597	79.220157	0.792202	0.989633
H_2O	18	0.803070	-	-	-	2.267813	0.022678	0.018212

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

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.3174	kg/m^3
Wet Density (STP), P_{STW}	1.3057	kg/m^3
Dry Density (Actual), P_{Actual}	0.9616	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	0.953	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	05 February 2014
Time of Survey	12:30
Velocity Measurement Device:	S-Type Pitot

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	0.02	1.2	12	90	4.20	-	5
2	0.05	1.4	14	90	4.54	-	5
3	0.08	1.5	15	90	4.70	-	0
4	0.11	1.5	15	90	4.70	-	0
5	0.14	1.3	13	91	4.38	-	0
6	0.18	1.4	14	92	4.55	-	0
7	0.21	1.2	12	92	4.21	-	0
8	0.24	1.4	14	91	4.54	-	5
9	0.27	1.3	13	91	4.38	-	5
10	0.30	1.5	15	90	4.70	-	5
Mean	-	1.4	13	91	4.49	-	

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	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	

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	11.76	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	4.20	m/s	-	-
Highest Gas Velocity	4.70	m/s	-	-
Ratio of Gas Velocities	1.12	-	< 3 : 1	Yes
Maximum angle of flow with regard to duct axis	5	^{o}	< 15^{o}	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, V = K_{pt} x (1-ε) * √(2 * ΔP_{pt} / $P_{ActualW}$)		
Where: K_{pt} = Pitot tube calibration coefficient (1-ε) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**4.49**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	91	0	^{o}C
Total Pressure	98.51	101.3	kPa
Oxygen	12.5	11	%
Moisture	2.27	0.00	%

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	4.49	m/s
Stack Area (A)	0.15	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	2379	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	1736	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	1697	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	1439	m^3/hr

Where:

Q_{Actual} = Va x A x 3600

Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600

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

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

Nomenclature:

Ts = Absolute Temperature, Standard Conditions, 273 K

Ps = Absolute Pressure, Standard Conditions, 101.3 kPa

Ta = Absolute Temperature, Actual Conditions, K

Pa = Absolute Pressure, Actual Conditions, kPa

Ma = Water vapour, Actual Conditions, % Vol

Ms = Water vapour, Reference Conditions, % Vol

O_2a = Oxygen, Actual Conditions, % Vol

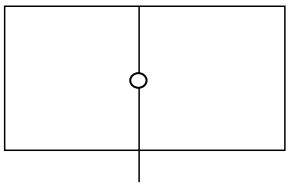
O_2s = Oxygen, Reference Conditions, % Vol

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK DIAGRAM

	Value	Units
Stack Depth	0.32	m
Stack Width	0.46	m
Area	0.15	m^2

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	50	0.16	m



Isokinetic Sampling CEN Methods			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	50.0	0.16	0
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

○ Isokinetic sampling point
● Isokinetic sampling points not used
◎ Non Isokinetic/Gases sampling point

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	0.1	0.1800	-	-
as a %	0.10	0.69	0.51	1.00	0.71	0.93898	0.60	0.001
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Run 2	0.001	2	0.5	1.00	0.1	0.190	-	-
as a %	0.09	0.69	0.51	1.00	0.71	0.890	0.38	0.001
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Run 3	0.001	2	0.5	1	0.1	0.1900	-	-
as a %	0.07	0.70	0.51	1.00	0.83	0.61849	0.42	0.001
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**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	0.88	1.5800	1.43	0.006	0.0001	-
MU as mg/m^3	0.02	0.1878	0.02	0.006	0.0001	**0.19**
MU as %	1.32	11.3924	-	0.348	0.0069	-
Run 2	0.98	1.7900	1.43	0.004	0.0001	-
MU as mg/m^3	0.02	0.1780	0.02	0.004	0.0001	**0.18**
MU as %	1.3	10.6145	-	0.221	0.0061	-
Run 3	1.42	5.7200	1.11	0.009	0.0001	-
MU as mg/m^3	0.05	0.1237	0.04	0.009	0.0001	**0.14**
MU as %	1.32	3.3217	-	0.242	0.0019	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.38**	**mg/m^3**	**23.13**	**%**
R2 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.36**	**mg/m^3**	**21.59**	**%**
R3 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.28**	**mg/m^3**	**7.50**	**%**

(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 - MERCURY

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	Leak %
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**<=2%**
Run 1	0.001	2.0	0.5	1	0.1	0.00271	-
as a %	0.11	0.70	0.51	1.00	0.80	3.00	0.92
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Run	Volume (STP) m^3	O2 Correction -	Leak mg/m^3	Lab Uncertainty mg	Combined uncertainty
Run 1	0.8552	1.1765	0.0002	-	-
MU as mg/m^3	0.0005	0.0005	0.0002	0.00392	**0.0040**
MU as %	1.3262	1.1765	0.5340	10.00000	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.01**	**mg/m^3**	**20.34**	**%**

(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 - 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	0.958488072	290.80	98.6	1.0	14	0.088418605	0.03802	-
as a %	0.10	0.69	0.51	1.00	0.71	3.00	1.07	0.60
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**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	0.8758	0.0380	1.4286	0.0372	-	-
MU as mg/m^3	0.1414	0.3222	0.1530	0.0372	0.5354	**0.6597**
MU as %	1.3203	3.0090	1.4286	0.3478	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**1.32**	**mg/m³**	**12.32**	**%**

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

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - MOISTURE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Leak
	m^3	K	kPa	% by volume	% by volume	%
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**
Run 1	0.001	2	0.5	1	0.1	-
as a %	0.10	0.69	0.51	1.00	0.71	0.60
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Run	Volume (STP)	Mass Gained	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.88	25500.00	1.43	92.52	57.74	-
MU as % v/v	0.04	0.01	0.05	0.01	0.008	**0.07**
MU as %	1.32	0.39	1.43	0.35	0.23	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.14**	**% v/v**	**4.05**	**%**

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VOLATILE ORGANIC COMPOUNDS RUN 1

Measured Concentration	2.2	mg/m^3
Limit	20	mg/m^3
Calibration Gas Concentration	15.84	mg/m^3
Range	160	mg/m^3

Performance characteristics	Value	Units	specification	MU Met?
Response time	40	seconds	<180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	75	minutes	-	-
Number of readings in measurement	75	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.70	% of value	<2 % range	Yes
Zero drift	0.00	% full scale	<2% range / 24hr	Yes
Span drift	0.91	% full scale	<2% range / 24hr	Yes
volume or pressure flow dependence	0.02	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.80	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	0.01	% full scale/10K	<3% range / 10 K	Yes
dependence on voltage	0.10	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	0.20	% of value	< 2% of span gas value	Yes
Uncertainty of calibration gas	2.0	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	0.02
Standard deviation of repeatability at span level	urs	0.02
Lack of fit	ufit	0.65
Drift	u0dr	0.07
volume or pressure flow dependence	uspres	0.00
atmopsheric pressure dependence	uapres	0.04
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	0.14
losses in the line (leak)	uleak	0.00
Uncertainty of calibration gas	ucalib	0.03
Uncertainty in factor	uf	0.05

Measurement uncertainty Measured Concentration	2.22	mg/m^3
Combined uncertainty	0.67	mg/m^3
Expanded uncertainty	1.34	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**6.69**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**1.34**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**60.29**	**% value**

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - CARBON MONOXIDE

Limit value	100	mg/m^3
Concentration @ Ref conditions	1.6	mg/m^3
Cal gas conc	208.75	mg/m^3
Analyser Full Scale	250	mg/m^3

Performance characteristics	Value	Units	specification	MU Met?
Response time	45	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	75	minutes	-	-
Number of readings in measurement	75	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.7	% of value	<2 % range	Yes
Zero drift	-0.20	% full scale	<2% range / 24hr	Yes
Span drift	0.10	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.02	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.80	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	0.01	% full scale/10K	<3% range / 10 K	Yes
dependence on voltage	0.10	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	0.54	% of value	< 2% of value	No
Uncertainty of calibration gas	1	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	0.02
Standard deviation of repeatability at span level	urs	0.02
Lack of fit	ufit	1.01
Drift	u0dr	-0.12
volume or pressure flow dependence	uspres	0.00
atmopsheric pressure dependence	uapres	0.06
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	0.22
losses in the line (leak)	uleak	0.00
Uncertainty of calibration gas	ucalib	0.01
Uncertainty in factor	uf	0.02

Measurement uncertainty (Concentration Measured)	0.9	mg/m^3
Combined uncertainty	1.0	mg/m^3
Expanded uncertainty	2.1	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**2.08**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**2.08**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**223.91**	**% value**

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXYGEN

Reference	11	%vol
Reported Concentration	12.52	%vol
Calibration gas	20.95	%vol
Analyser Full Scale	25	%vol

Performance characteristics	Value	Units	specification	MU Met?
Response time	40	seconds	< 200 s	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	75	minutes	-	-
Number of readings in measurement	75	-	-	-
Repeatability at zero	0.015	% by volume	<0.2 % range	Yes
Repeatability at span level	0.014	% by volume	<0.4 % range	Yes
Deviation from linearity	0.13	% vol	<0.3 % volume	Yes
Zero drift (during measurement period)	-0.03	% vol at zero level	<2% of volume / 24hr	Yes
Span drift (during measurement period)	0.04	% vol at span level	<2% volume/24hr	Yes
volume or pressure flow dependence	0.02	% of fs / 10l/h	<1% range	Yes
atmospheric pressure dependence	0.80	% of fs/kPa	< 1.5 % range	Yes
ambient temperature dependence	0.01	% by volume /10K	<0.3% volume 10 K	Yes
Combined interference	0.14	% range	<2% range	Yes
Dependence on voltage	0.10	% by volume /10V	< 0.1%vol /10 volt	Yes
Losses in the line (leak)	0.38	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1.00	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	-
Standard deviation of repeatability at span level	urs	0.0016
Lack of fit	ufit	0.0751
Drift	u0dr	-0.0035
volume or pressure flow dependence	uspres	0.00003
atmospheric pressure dependence	uapres	0.0122
ambient temperature dependence	utemp	0.0005
Combined interference (from mcerts)	-	0.0808
dependence on voltage	uvolt	0.0862
losses in the line (leak)	uleak	0.0276
Uncertainty of calibration gas	ucalib	0.0723

Measurement uncertainty (Concentration Measured)	12.52	%vol
Combined uncertainty	0.16	%vol
% of value	1.28	%

Expanded uncertainty expressed with a level of confidence of 95%	**2.56**	**% of value**

Expanded uncertainty expressed with a level of confidence of 95%	**0.321**	**% vol**

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXYGEN

DAY 1 - 05 February 2014

Reference	11	%vol
Measured concentration	14.19	%vol
Calibration gas	20.95	%vol
Full Scale	25	%vol

Performance characteristics	Value	Units	specification	MU Met?
Response time	40	seconds	< 200 s	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	165	minutes	-	-
Number of readings in measurement	165	-	-	-
Repeatability at zero	0.015	% by volume	<0.2 % range	Yes
Repeatability at span level	0.014	% by volume	<0.4 % range	Yes
Deviation from linearity	0.13	% vol	<0.3 % volume	Yes
Zero drift (during measurement period)	-0.14	% vol at zero level	<2% of volume / 24hr	Yes
Span drift (during measurement period)	0.05	% vol at span level	<2% volume/24hr	Yes
volume or pressure flow dependence	0.02	% of fs / 10l/h	<1% range	Yes
atmospheric pressure dependence	0.8	% of fs/kPa	< 1.5 % range	Yes
ambient temperature dependence	0.01	% by volume /10K	<0.3% volume 10 K	Yes
Combined interference	0.14	% range	<2% range	Yes
Dependence on voltage	0.1	% by volume /10V	< 0.1%vol /10 volt	Yes
Losses in the line (leak)	-0.38	% of value	< 2% of value	Yes
Uncertainty of calibration gas	2	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	-
Standard deviation of repeatability at span level	urs	0.001
Lack of fit	ufit	0.075
Drift	u0dr	-0.064
volume or pressure flow dependence	uspres	0.001
atmospheric pressure dependence	uapres	0.115
ambient temperature dependence	utemp	0.003
Combined interference (from mcerts)	-	0.020
dependence on voltage	uvolt	0.029
losses in the line (leak)	uleak	-0.031
Uncertainty of calibration gas	ucalib	0.164

Measurement uncertainty (Concentration Measured)	14.19	%vol
Combined uncertainty	0.23	%vol
% of value	1.61	%

Expanded uncertainty expressed with a level of confidence of 95%	**3.22**	**% of value**

Expanded uncertainty expressed with a level of confidence of 95%	**0.46**	**% vol**

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXYGEN

DAY 2 - 06 February 2014

Reference	11	%vol
Measured concentration	12.58	%vol
Calibration gas	20.95	%vol
Full Scale	25	%vol

Performance characteristics	Value	Units	specification	MU Met?
Response time	40	seconds	< 200 s	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	90	minutes	-	-
Number of readings in measurement	90	-	-	-
Repeatability at zero	0.015	% by volume	<0.2 % range	Yes
Repeatability at span level	0.014	% by volume	<0.4 % range	Yes
Deviation from linearity	0.13	% vol	<0.3 % volume	Yes
Zero drift (during measurement period)	-0.05	% vol at zero level	<2% of volume / 24hr	Yes
Span drift (during measurement period)	-0.14	% vol at span level	<2% volume/24hr	Yes
volume or pressure flow dependence	0.02	% of fs / 10l/h	<1% range	Yes
atmospheric pressure dependence	0.8	% of fs/kPa	< 1.5 % range	Yes
ambient temperature dependence	0.01	% by volume /10K	<0.3% volume 10 K	Yes
Combined interference	0.14	% range	<2% range	Yes
Dependence on voltage	0.1	% by volume /10V	< 0.1%vol /10 volt	Yes
Losses in the line (leak)	0.05	% of value	< 2% of value	Yes
Uncertainty of calibration gas	2	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	-
Standard deviation of repeatability at span level	urs	0.001
Lack of fit	ufit	0.075
Drift	u0dr	-0.077
volume or pressure flow dependence	uspres	0.001
atmospheric pressure dependence	uapres	0.115
ambient temperature dependence	utemp	0.003
Combined interference (from mcerts)	-	0.081
dependence on voltage	uvolt	0.029
losses in the line (leak)	uleak	0.003
Uncertainty of calibration gas	ucalib	0.145

Measurement uncertainty (Concentration Measured)	12.58	%vol
Combined uncertainty	0.23	%vol
% of value	1.84	%

Expanded uncertainty expressed with a level of confidence of 95%	**3.67**	**% of value**

Expanded uncertainty expressed with a level of confidence of 95%	**0.46**	**% vol**

Developed for the STA by R Robinson, NPL

END OF REPORT