STACK EMISSIONS MONITORING REPORT

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Operator & Address:
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Permit:
EPR Permit: EPR/BX4666IZ/V002

Release Point:
A7 - Special Materials Facility

Sampling Date(s):
17th November 2014

ESG Job Number:	LNO 12115
Report Date:	18th December 2014
Version:	1
Report By:	Dominic Houghton
MCERTS Number:	MM 04 529
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 - Business Manager
Technical Endorsements:	1, 2, 3 & 4
Signature:	

1015

CONTENTS

EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Qioptiq Ltd operates a manufacture of infra red materials process at St Asaph which is subject to EPR Permit EPR/BX4666IZ/V002, under the Environmental Permitting Regulations 2010.

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

The results of these tests shall be used to demonstrate compliance with a set of emission limit values for prescribed pollutants as specified in the Plant's EPR Permit, EPR/BX4666IZ/V002.

Plant

A7 - Special Materials Facility

Operator

Qioptiq Ltd
Glascoed Road
St Asaph
Denbighshire
LL17 0LL

EPR Permit: EPR/BX4666IZ/V002

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

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	**Units**	**Result**	**Calculated Uncertainty +/-**	**Limit**	**MCERTS accredited result**
Total Particulate Matter	mg/m³	0.21	0.41	1	✓
Particulate Emission Rate	g/hr	0.25	0.50	-	
Heavy Metals	mg/m³	0.00017	0.00004	-	✓
Heavy Metals Emission Rate	g/hr	0.00021	0.00005	-	
Moisture	%	0.17	0.03	-	✓
Stack Gas Temperature	°C	20.0	-	-	✓
Stack Gas Velocity	m/s	4.7	-	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	1404	-	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	1291	-	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	1289	-	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	1291	-	-	

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

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

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	**Sampling Date(s)**	**Sampling Times**	**Sampling Duration**
Total Particulate Matter Run 1	17 November 2014	12:30 - 13:30	60 minutes
Heavy Metals Run 1	17 November 2014	12:30 - 13:30	60 minutes
Stack Gas Flow Rate & Temperature Run 1	17 November 2014	12:20	-

EXECUTIVE SUMMARY

PROCESS DETAILS	
Parameter	**Process Details**
Description of process	Manufacture of infra red materials
Continuous or batch	Batch
Product Details	Infra Red Lenses
Part of batch to be monitored (if applicable)	Any
Normal load, throughput or continuous rating	Normal throughput
Fuel used during monitoring	N/A
Abatement	HEPA Filter
Plume Appearance	None visible

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	0.21 mg/m³	200 %
Heavy Metals	SRM - BS EN 14385	AE 108	1015	Yes	0.00003 mg/m³	25 %
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	0.01%	15%
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
Heavy Metals	Inductively coupled Plasma - Mass Spectrometry	ANU/SOP/117, 101,102	1015	Yes	ESG Bretby	ESG Bretby	3 months
-	-	-	-	-	-	-	-

ON-SITE TESTING							
Species	**Analytical Technique**	**Analytical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Analysis**	**Laboratory**	**Data Archive Location**	**Archive Period**
H_2O	Gravimetric	AE 105	1015	Yes	ESG Stockport	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	14	Pa	>= 5 Pa	Yes	BS EN 13284-1
Lowest Gas Velocity	4.33	m/s	-	-	-
Highest Gas Velocity	5.18	m/s	-	-	-
Ratio of Gas Velocities	1.20	: 1	< 3 : 1	Yes	BS EN 13284-1
Mean Velocity	4.73	m/s	-	-	-
Maximum angle of flow with regard to duct axis	<15	^{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	0.33	m
Width	0.25	m
Area	0.08	m^2
Port Depth	0	mm

SAMPLING LINES & POINTS			
	Isokinetic (CEN Methods)	**Isokinetic** (ISO Methods)	**Non-Iso & Gases**
Sample port size	1.5 inch Hole	-	-
Number of lines used	1	-	-
Number of points / line	1	-	-
Duct orientation	Vertical	-	-
Filtration	Out Stack	-	-
Filtration for TPM	Out Stack	-	-

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

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)	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	N/A
Handrail / obstructions do not hamper insertion of sampling equipment	No
Depth of Platform = >Stack depth / diameter + wall and port thickness + 1.5m	Yes

Sampling Platform Improvement Recommendations (if applicable)

The sampling location ports should ideally be increased to meet all the requirements as specified in EA Guidance Note M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

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

APPENDICES

CONTENTS

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

MONITORING SCHEDULE					
Species	**Method** Standard Reference Method / Alternative Method	**ESG Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Number of Samples**
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	1
Heavy Metals	SRM - BS EN 14385	AE 108	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 13-01	Horiba PG-250 Analyser	-	Laboratory Balance	LNO 00-12/00-13
Box Thermocouples	LNO 03-01	FT-IR	-	Tape Measure	LNO 24-DJH
Meter In Thermocouple	LNO 03-01	FT-IR Oven Box	-	Stopwatch	LNO 17-DJH
Meter Out Thermocouple	LNO 03-01	Bernath 3006 FID	-	Protractor	-
Control Box Timer	LNO 17-01	Signal 3030 FID	-	Barometer	LNO 08-DJH
Oven Box	LNO 13-12	Servomex	-	Digital Micromanometer	LNO 01-DJH
Probe	LNO 11-25	JCT Heated Head Filter	-	Digital Temperature Meter	LNO 03-DJH
Probe Thermocouple	LNO 10-25	Thermo FID	-	Stack Thermocouple	-
Probe	-	Stackmaster	-	Mass Flow Controller	LNO 29-67/29-65
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	LNO 29-08
S-Pitot	LNO 06-DJH	Anemometer	-	1m Heated Line (1)	-
L-Pitot	LNO 10-104	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	LNO 14-DJH	Chiller (JCT/MAK 10)	-	1m Heated Line (3)	-
Last Impinger Arm	-	Heated Line Controller (1)	-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	-	10m Heated Line (1)	-
Callipers	LNO 31-DJH	Site temperature Logger	-	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	-		-	20m Heated Line (1)	-
Inclinometer (Swirl Device)	LNO 23-DJH		-	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 +/- %
-	-	-	-	-	-

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

STACK EMISSIONS MONITORING TEAM

Team Leader	Dominic Houghton MCERTS Level 2, Technical Endorsements 1, 2, 3 & 4 MM 04 529 MCERTS Expiry Date - Dec 2016 H&S Expiry Date - Sep 2019
Technician	Mark Derbyshire MCERTS Level 1, Technical Endorsement 1 MM 07 824 MCERTS Expiry Date - Dec 2017 H&S Expiry Date - Apr 2017

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	12:30 - 13:30 17 November 2014	0.21	0.4	1	0.2
Blank	-	0.19	-	-	-

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

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

FILTER INFORMATION

SAMPLES								
Test	Filter & Probe Rinse Number	Filter Start Weight g	Filter End Weight g	Mass Gained on Filter g	Probe Rinse Start Weight g	Probe Rinse End Weight g	Mass Gained on Probe g	Combined Total Mass Gained g
Run 1	Q8181	0.15485	0.15469	-0.00016	160.08220	160.08170	-0.00050	0.00024

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	Q8180	0.15565	0.15562	-0.00003	190.35820	190.35780	-0.00040	0.00022

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	750.01
Stack static pressure, P_{static}	mm H_2O	2.04
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	750.16
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	1.6
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.0019936
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		1.193
Gas meter correction factor, Y_d		1.049891
Mean dry gas meter temperature, T_m		19.500
Mean pressure drop across orifice, ΔH	mmH_2O	41.462
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		1.158
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.1603
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		21.0
% oxygen reference condition		21
O_2 Reference Factor O_2 Ref $= \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0017 0.17
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.9
Mean of velocity heads, ΔP_{avg}	mm H_2O	1.43
Mean square root of velocity heads, $\sqrt{\Delta P}$		1.20
Mean stack gas temperature, T_s	°C	20
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	4.39

Molecular weight of dry gas, M_d		
CO_2	%	0.03
O_2	%	20.95
Total	%	20.98
N_2 (100 -Total)	%	79.02
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.82
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.08
$Q_a = (60)(A_s)(V_s)$	m³/min	21.7
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	19.9
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O_2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	19.97
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	9.90
Nozzle area, A_n	mm^2	76.99
Total sampling time, θ	min	60
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	103.8
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	0.00016
Total mass collected, M_n	g	0.00024
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	0.207
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	0.207
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		0.25

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER QUALITY ASSURANCE CHECKLIST

LEAK RATE						
Run	Mean Sampling Rate litre/min	Pre-sampling Leak Rate litre/min	Post-sampling Leak Rate litre/min	Maximum Vacuum mm Hg	Acceptable Leak Rate litre/min	Leak Tests Acceptable?
Run 1	20.88	0.04	0.04	-355.6	0.42	Yes

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	103.8	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.21	0.05	N/A - ELV <5 mg/m³

The above is based on both the Filter and rinse uncertainty
Where installations have ELVs of 5 mg/m³ or less, it may not be practical to meet the 5% of ELV requirement. Under these circumstances, a minimum one hour sample time shall used.

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	0.19	1	0.2	Yes

*For ELVs of 5 mg/m3 and lower a blank value must be <20% of the ELV

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

GF = Glass Fibre

QF = Quartz Fibre

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HEAVY METALS SOLID & VAPOUR PHASES COMBINED

TOTAL HEAVY METALS COMBINED					
Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	12:30 - 13:30 17 November 2014	0.0002	0.00003	-	0.0002
Field Blank	-	0.0002	-	-	-

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

HEAVY METALS - RUN 1 SUMMARY

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³
Arsenic	0.00003	0.20000	0.00017	-	-	-
Volume Sampled m^3		1.160			-	

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

HEAVY METALS - BLANK SUMMARY

Metals	PARTICULATE PHASE			VAPOUR PHASE		
	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³	Stack LOD mg/m³	Laboratory Result ug	Concentration mg/m³
Arsenic	0.00003	0.20000	0.00017	-	-	-
Volume Sampled m^3		1.1603			-	

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS RUN 1 — Heavy Metals

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	750.0
Stack static pressure, P_{static}	mm H_2O	2.0
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	750.2
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		1.193
Gas meter correction factor, Y_d		1.049891
Mean dry gas meter temperature, T_m		19.50
Mean pressure drop across orifice, ΔH	m	41.46
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		1.16
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	1.1603
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		21.0
% 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}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0017
	%	0.17
Moisture by FTIR	%	-

Molecular weight of dry gas, M_d		
CO_2	%	0.03
O_2	%	20.95
Total	%	20.98
N_2 (100 -Total)	%	79.02
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.82
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.9
Mean of velocity heads, ΔP_{avg}	mm H_2O	1.43
Mean square root of velocity heads, $\sqrt{\Delta P}$		1.20
Mean stack gas temperature, T_s	°C	20
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	4.39
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.08
$Q_a = (60)(A_s)(V_s)$	m^3/min	21.7
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	19.9
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	20.0
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	9.90
Nozzle area, A_n	mm^2	76.99
Total sampling time, θ	min	60
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	103.8
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	20.9	0.04	0.04	-381	0.42	Yes

Isokinetic Criterion Compliance	Isokinetic Variation %	Acceptable Isokineticity
Run 1	103.8	Yes

Filtration / Temp	Filter Material	Filter Size mm	Maximum Filtration Temperature °C	Maximum storage / transit Temperature °C
Run 1	QF	47	160	N/A

GF = Glass Fibre

QF = Quartz Fibre

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

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	12:30 - 13:30 17 November 2014	3.7948	3.7964	0.0016	0.1718	0.011	14.7

Moisture Quality Assurance							
Test Number	Sampling Duration mins	Total Volume Sampled l	Sampling Rate l/min	Start Leak Rate l/min	End Leak Rate l/min	Acceptable Leak Rate l/min	Leak Tests Acceptable?
Run 1	60	1160	20.8753	0.0400	0.0400	0.42	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.33	m
Stack Width, W	0.25	m
Stack Area, A	0.08	m^2
Average stack gas temperature	20	^oC
Stack static pressure	0.02	kPa
Barometric Pressure	100	kPa
Pitot tube calibration coefficient, K_{pt}	0.90	-

Stack Gas Composition & Molecular Weights								
Component	Molar Mass M	Density kg/m^3 p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m^3 pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m^3 pi
CO_2	44	1.963059	0.030000	0.000300	0.000589	0.029948	0.000299	0.000588
O_2	32	1.427679	20.950000	0.209500	0.299099	20.914004	0.209140	0.298585
N_2	28	1.249219	79.020000	0.790200	0.987133	78.884229	0.788842	0.985437
H_2O	18	0.803070	-	-	-	0.171818	0.001718	0.001380

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

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2868	kg/m^3
Wet Density (STP), P_{STW}	1.2860	kg/m^3
Dry Density (Actual), P_{Actual}	1.1838	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.183	kg/m^3

Where:

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

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

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

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	17 November 2014
Time of Survey	12:20
Velocity Measurement Device:	L-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	1.8	18	20	4.91	-	<15
2	0.05	1.8	18	20	4.91	-	<15
3	0.08	1.4	14	20	4.33	-	<15
4	0.12	1.6	16	20	4.63	-	<15
5	0.15	1.6	16	20	4.63	-	<15
6	0.18	1.4	14	20	4.33	-	<15
7	0.21	1.4	14	20	4.33	-	<15
8	0.25	1.4	14	20	4.33	-	<15
9	0.28	1.8	18	20	4.91	-	<15
10	0.31	1.6	16	20	4.63	-	<15
Mean	-	1.6	15	20	4.60	-	

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	0.02	2.0	20	20	5.18	-	<15
2	0.05	1.8	18	20	4.91	-	<15
3	0.08	1.6	16	20	4.63	-	<15
4	0.12	1.6	16	20	4.63	-	<15
5	0.15	1.6	16	20	4.63	-	<15
6	0.18	1.6	16	20	4.63	-	<15
7	0.21	1.8	18	20	4.91	-	<15
8	0.25	2.0	20	20	5.18	-	<15
9	0.28	1.8	18	20	4.91	-	<15
10	0.31	1.8	18	20	4.91	-	<15
Mean	-	1.8	17	20	4.85	-	

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	13.72	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	4.33	m/s	-	-
Highest Gas Velocity	5.18	m/s	-	-
Ratio of Gas Velocities	1.20	-	< 3 : 1	Yes
Maximum angle of flow with regard to duct axis	0	^{o}	< 15^{o}	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, V = K_{pt} x (1-ε) * √(2 * ΔP_{pt} / $P_{ActualW}$)		
Where: K_{pt} = Pitot tube calibration coefficient (1-ε) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**4.73**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	20	0	^{o}C
Total Pressure	100.02	101.3	kPa
Oxygen	21.0	21	%
Moisture	0.17	0.17	%

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	4.73	m/s
Stack Area (A)	0.08	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	1404	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	1291	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	1289	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	1291	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	0.33	m
Stack Width	0.25	m
Area	0.08	m^2

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

Isokinetic Sampling CEN Methods			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	50.0	0.17	<15
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
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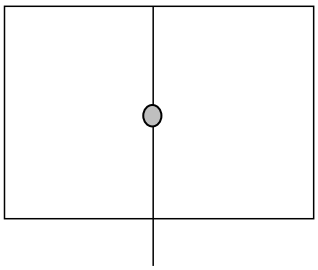

Sampling Line

○ 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 m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %	Uncollected Mass mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.001	2	0.5	1	N/A	0.24	-	-
as a %	0.09	0.68	0.50	1.00	N/A	20.68	0.19	0.022
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**	**Yes**

Run	Volume (STP) m³	Mass of particulate mg	O_2 Correction -	Leak mg/m³	Uncollected Mass mg	Combined uncertainty
Run 1	1.07	0.2400	1.00	0.000	0.0001	-
MU as mg/m^3	0.00	0.2068	-	0.000	0.0001	**0.21**
MU as %	1.31	100.0000	-	0.111	0.0529	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.41**	**mg/m³**	**200.02**	**%**

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

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - 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	Leak %
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**<5%**	**<=2%**
Run 1	0.001	2.00	0.50	1.00	0.10	-	-
as a %	0.09	0.73	0.50	1.00	-	-	0.19
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**No**	**Yes**

Run	Volume (STP) m^3	O2 Correction -	Leak mg/m^3	Lab Uncertainty mg	Combined uncertainty
Run 1	1.1477	-	0.0000	-	-
MU as mg/m^3	0.0000	-	0.0000	0.00002	**0.00002**
MU as %	1.3391	-	0.1106	12.50000	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.00004**	**mg/m^3**	**25.14**	**%**

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

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - MOISTURE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Leak
	m^3	K	kPa	% by volume	% by volume	%
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**
Run 1	0.001	2	0.5	1	N/A	-
as a %	0.09	0.68	0.50	1.00	N/A	0.19
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP)	Mass Gained	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	1.07	1600.00	1.00	1.53	57.74	-
MU as % v/v	0.00	0.01	-	0.00	0.006	**0.01**
MU as %	1.31	6.25	-	0.11	3.61	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.03**	**% v/v**	**14.67**	**%**

END OF REPORT