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Stack Emissions Testing Report Commissioned by
British Crystal Ltd

Installation Name & Address
British Crystal Ltd
Unit 14
Pedmore Road Industrial Estate
Brierley Hill
West Midlands
DY5 1TJ

PPC Permit: PB 98

Stack Reference
Furnace Stack

Dates of the Monitoring Campaign
6th September 2016

Job Reference Number
CAT-2917

Report Written by
Harpreet Badwal Team Leader MCERTS Level 2 MM 03 149 TE1 TE2 TE3 TE4

Report Approved by
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Report Date
5th October 2016

Version
Version 1

Signature of Report Approver


CONTENTS

TITLE PAGE

CONTENTS

Summary of Sampling Deviations 2

EXECUTIVE SUMMARY

Monitoring Objectives 3

Monitoring Results 4

Monitoring Dates & Times 5

Process Details 6

Monitoring & Analytical Methods 7

Sampling Location 8

Plant Photos / Sample Points 9

APPENDIX 1 - Monitoring Personnel & List of Equipment

APPENDIX 2 - Raw Data, Sampling Equations & Charts

Opinions and interpretations expressed herein are outside the scope of Exova Catalyst's ISO 17025 accreditation.

MONITORING OBJECTIVES

British Crystal Ltd, Brierley Hill
Furnace Stack
6th September 2016

Overall Aim of the Monitoring Campaign

Exova Catalyst were commissioned by British Crystal Ltd to carry out stack emissions testing on the Furnace Stack at Brierley Hill.

The aim of the monitoring campaign was to demonstrate compliance with a set of emission limit values (ELVs) as specified in the Site's Permit.

Special Requirements

There were no special requirements.

Target Parameters

Total Particulate Matter | Lead |

Executive Summary

MONITORING RESULTS

British Crystal Ltd, Brierley Hill
Furnace Stack
6th September 2016

where MU = Measurement Uncertainty associated with the Result

	Concentration					Mass Emission			
Parameter	**Units**	**Result**		**MU +/-**	**Limit**	**Units**	**Result**	**MU +/-**	**Limit**
Total Particulate Matter [1]	mg/m³	13.3		38.1	20	g/hr	5.0	14.3	-
Lead [1]	mg/m³	3.3		3.5	5	g/hr	1.2	1.3	-
Oxygen	% v/v	**Dry**	20.4	0.91					
Water Vapour	% v/v	0.49		0.05					
Stack Gas Temperature	°C	59.3							
Stack Gas Velocity	m/s	13.7		0.38					
Volumetric Flow Rate (ACTUAL)	m³/hr	6195		328					
Volumetric Flow Rate (REF) [1]	m³/hr	376		19.9					

NOTE: VOLUMETRIC FLOW RATE & VELOCITY DATA TAKEN FROM THE PRELIMINARY VELOCITY TRAVERSE.

[1] Reference Conditions (REF) are: 273K, 101.3kPa, dry gas, 13% oxygen.

MONITORING DATE(S) & TIMES

British Crystal Ltd, Brierley Hill
Furnace Stack
6th September 2016

Parameter		Units	Concentration	Units	Mass Emission	Sampling Date(s)	Sampling Times	Duration mins
Total Particulate Matter	R1	mg/m³	13.3	g/hr	5.0	06/09/2016	15:43 - 16:15	32
Lead	R1	mg/m³	3.3	g/hr	1.2	06/09/2016	15:00 - 15:32	32
Oxygen	R1	% v/v	20.4			06/09/2016	15:43 - 16:15	32
Velocity & Volumetric Flow Rate	R1					06/09/2016	14:22 - 14:32	

All results are expressed at the respective reference conditions.

PROCESS DETAILS

British Crystal Ltd, Brierley Hill
Furnace Stack
6th September 2016

Standard Operating Conditions

Parameter	Value
Process Status	Normal Operation
Capacity (of 100%) and Tonnes / Hour	Standard Loading
Continuous or Batch Process	Continuous
Feedstock (if applicable)	Glass Cullets
Abatement System	None
Abatement System Running Status	N/A
Fuel	Natural Gas
Plume Appearance	None Visible

Executive Summary

MONITORING & ANALYTICAL METHODS

British Crystal Ltd, Brierley Hill
Furnace Stack
6th September 2016

	Monitoring				Analysis					
Parameter	**Standard**	**Technical Procedure**	**ISO 17025 Testing**	**Testing Lab**	**Analytical Procedure**	**Analytical Technique**	**ISO 17025 Analysis**	**Analysis Lab**	**MCERTS Testing**	**LOD (Average)**
Total Particulate Matter	EN 13284-1	CAT-TP-01	Yes	CAT	CAT-TP-03	Gravimetric	Yes	CAT	Yes	2.9 mg/m³
Lead	EN 14385	CAT-TP-06	Yes	CAT	M31	ICP-MS	Yes	RPS	Yes	0.01 mg/m³
Water Vapour	EN 14790	CAT-TP-05	Yes	CAT	CAT-TP-05	Gravimetric	Yes	CAT	Yes	0.10 % v/v
Oxygen	EN 14789	CAT-TP-39	Yes	CAT	Dry Paramagnetic Cell by Horiba PG-350E				Yes	0.10 % v/v
Velocity & Vol. Flow Rate	EN 16911-1 (MID)	CAT-TP-41	Yes	CAT	Pitot Tube and Thermocouple				Yes	1.2 m/s

ANALYSIS LABORATORIES

(with short name reference as appears in the table above)

Exova Catalyst (CAT)	ISO 17025 Accreditation Number: 4279
RPS Laboratories Ltd (RPS)	ISO 17025 Accreditation Number: 0605

SUMMARY OF SAMPLING DEVIATIONS

Parameter	Run	Deviation
Total Particulate Matter & Lead	All Runs	One out of two sampling lines was used due to sampling location restrictions, however the number of sample points used on the available line were increased to the minimum required by the Standard
Total Particulate Matter	All Runs	It is a requirement of MID 13284-1, V2.4 for the overall weighing uncertainty to be less than 5% of the ELV, unless the ELV is <5mg/m³ where a 1 hour sample is deemed to be sufficient.
Total Particulate Matter	All Runs	The blank result was higher than 10% of the ELV, however this is related to a high oxygen correction factor applied to the results. [> 100% higher]
Lead	All Runs	The detection limit for Lead in the final impinger was >5µg/m³, however this related more with the high oxygen content in the stack, rather than a high mass of Lead detected in the sample.

SUITABILITY OF SAMPLING LOCATION

Duct Characteristics

Parameter	Units	Value
Type	-	Circular
Depth	m	0.40
Width	m	-
Area	m²	0.13
Port Depth	cm	0
Orientation of Duct	-	Vertical
Sample Port Size	-	4" Hole

Location of Sampling Platform

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

Platform Details

EA Technical Guidance Note M1 / EN 15259 Platform Requirements	Value
Sufficient working area to manipulate probe and operate the measuring instruments	No
Platform has 2 levels of handrails (approx. 0.5m & 1.0m high)	Yes
Platform has vertical base boards (approx. 0.25m high)	Yes
Platform has chains / self closing gates at top of ladders	No
There are no obstructions present which hamper insertion of sampling equipment	Yes
Safe Access Available	Yes
Easy Access Available	Yes

Sampling Location / Platform Improvement Recommendations

All platforms should be designed in accordance with the requirements in the Environment Agency's Technical Guidance Note M1 and EN 15259.

EN 15259 Homogeneity Test Requirements

There is no requirement to perform a EN 15259 Homogeneity Test on this Stack.

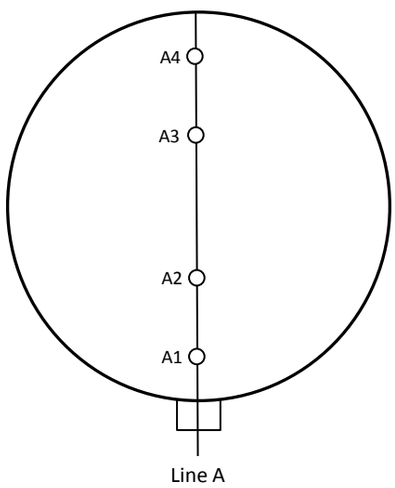
Sampling Plane Validation Criteria (from EN 15259)

Criteria in EN 15259	Units	Traverse 1		Required	Compliant
Lowest Differential Pressure	Pa	124.0		> 5 Pa	Yes
Mean Velocity	m/s	13.69		-	-
Lowest Gas Velocity	m/s	12.74		-	-
Highest Gas Velocity	m/s	15.10		-	-
Ratio of Above	: 1	1.19		< 3 : 1	Yes
Maximum Angle of Swirl	°	4		< 15°	Yes
No Local Negative Flow	-	Yes		-	Yes

PLANT PHOTOS

Photo 1

SAMPLE POINTS



where ○ = isokinetic point sampled at
● = isokinetic point not sampled at
● = combustion gases sample point
● = non-isokinetic sample point

APPENDIX CONTENTS

APPENDIX 1 - Stack Emissions Monitoring Personnel, List of Equipment & Methods and Technical Procedures Used

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK EMISSIONS MONITORING PERSONNEL

Position	Name	MCERTS Accreditation	MCERTS Number	Technical Endorsements
Team Leader	Harpreet Badwal	MCERTS Level 2	MM 03 149	TE1 TE2 TE3 TE4
Trainee	Aaron Nagha	MCERTS Trainee	Pending	None

LIST OF EQUIPMENT

Extractive Sampling	
Equipment Type	**Equipment I.D.**
Control Box DGM (1)	CAT 7.57
Control Box DGM (2)	-
Box Thermocouples (1)	CAT 3.146
Box Thermocouples (2)	-
Umbilical (1)	CAT 3.146
Umbilical (2)	-
Oven Box (1)	CAT 12.109
Oven Box (2)	-
Heated Probe (1)	CAT 5.126
Heated Probe (2)	CAT 5.127
Heated Probe (3)	CAT 5.128
S-Pitot (1)	CAT 21S.57
S-Pitot (2)	CAT 21P.38
L-Pitot	-
Site Balance	CAT 17.33
500g / 1Kg Check Weights	CAT 17.33a & b
Last Impinger Arm	CAT 4.844
Callipers	CAT 23.40
Tubes Kit Thermocouple	-

Instrumental Analysers	
Equipment Type	**Equipment I.D.**
Horiba PG-350E	CAT 39.10
Horiba PG-250	-
Servomex 4900	-
Eco Physics CLD 822Mh	-
ABB AO2020-URAS26	-
Servomex 5200MP	-
Ankersmid APS 313	CAT 4.847
Gasmet DX4000	-
Gasmet Sampling System	-
Bernath 3006 FID	-
M&C PSS	CAT 12.107
Mass Flow Controller (1)	CAT 6.61
Mass Flow Controller (2)	CAT 6.62
Mass View (1)	-
Mass View (2)	-
Hioki 5043 (V)	-
Easylogger EN-EL-12 Bit	-
Bioaerosols Temperature Logger	-
Electronic Refrigerator	-

Miscellaneous Items	
Equipment Type	**Equipment I.D.**
Digital Manometer (1)	CAT 3.142
Digital Manometer (2)	CAT 3.144
Digital Temperature Meter	-
Stopwatch	CAT 14.84
Barometer	CAT 13.40
Stack Thermocouple (1)	CAT 4.844
Stack Thermocouple (2)	CAT 4.789
Stack Thermocouple (3)	CAT 4.013
1m Heated Line (1)	-
1m Heated Line (2)	-
1m Heated Line (3)	-
5m Heated Line (1)	-
15m Heated Line (1)	-
20m Heated Line (1)	CAT 20.116
20m Heated Line (2)	-
Dual Channel Heater Controller	-
Single Channel Heater Controller	CAT 20.116
Laboratory Balance	CAT 1.18 / 1.18a
Tape Measure	CAT 16.45

METHODS & TECHNICAL PROCEDURES USED

Parameter	Standard	Technical Procedure
Total Particulate Matter	EN 13284-1	CAT-TP-01
Lead	EN 14385	CAT-TP-06
Water Vapour	EN 14790	CAT-TP-05
Oxygen	EN 14789	CAT-TP-39
Velocity & Vol. Flow Rate	EN 16911-1 (MID)	CAT-TP-41

PRELIMINARY STACK SURVEY: CALCULATIONS

General Stack Details

Stack Details (from Traverse)	Units	Value
Stack Diameter / Depth, D	m	0.40
Stack Width, W	m	-
Stack Area, A	m^2	0.13
Average Stack Gas Temperature, T_a	°C	55.1
Average Stack Gas Pressure	Pa	143
Average Stack Static Pressure, P_{static}	kPa	0.04
Average Barometric Pressure, P_b	kPa	101.0
Average Pitot Tube Calibration Coefficient, C_p	-	0.84

Stack Gas Composition & Molecular Weights

Component	Conc ppm	Conc Dry % v/v	Conc Wet % v/v	Volume Fraction r	Molar Mass M	Density kg/m³ p	Conc kg/m³ p_i
CO_2 (Estimated)	-	0.06	0.06	0.0006	44.01	1.9635	0.0012
O_2	-	20.41	20.31	0.2041	32.00	1.4277	0.2914
N_2	-	79.53	79.14	0.7953	28.01	1.2498	0.9940
Moisture (H_2O)	-	-	0.49	0.0049	18.02	0.8037	0.0040

Where: p = M / 22.41

p_i = r x p

Calculation of Stack Gas Densities

Determinand	Units	Result
Dry Density (STP), P_{STD}	kg/m³	1.287
Wet Density (STP), P_{STW}	kg/m³	1.284
Dry Density (Actual), P_{Actual}	kg/m³	1.068
Average Wet Density (Actual), $P_{ActualW}$	kg/m³	1.066

Where: P_{STD} = sum of component concentrations, kg/m³ (not including water vapour)

P_{STW} = sum of all wet concentrations / 100 x density, kg/m³ (including water vapour)

$P_{Actual} = P_{STD} \times (T_{STP} / (P_{STP})) \times ((P_{static} + P_b) / T_a)$

$P_{ActualW}$ (at each sampling point) $= P_{STW} \times (T_s / P_s) \times (P_a / T_a)$

Calculation of Stack Gas Volumetric Flowrate, Q

Duct gas flow conditions	Units	Actual	REF [1]
Temperature	°C	55.1	0.00
Total Pressure	kPa	101.0	101.3
Moisture	%	0.49	0.00
Oxygen (Dry)	%	20.4	13.0

Gas Volumetric Flowrate (from Traverse)	Units	Result
Gas Volumetric Flowrate (Actual)	m³/hr	6195
Gas Volumetric Flowrate (STP, Wet)	m³/hr	5141
Gas Volumetric Flowrate (STP, Dry)	m³/hr	5115
Gas Volumetric Flowrate REF [1]	m³/hr	376

PRELIMINARY STACK SURVEY: VELOCITY TRAVERSE TO EN 16911-1 (MID)

(1 of 1)

Parameter	Units	Value
Date of Survey	-	06/09/2016
Time of Survey	-	14:22 - 14:32
Atmospheric Pressure	kPa	101.0
Average Stack Static Pressure	Pa	38
Result of Pitot Stagnation Test	-	Pass
Are Water Droplets Present?	-	No
Device Used	S-Type Pitot with KIMO MP 210 (500Pa)	

Parameter	Units	Value
Initial Pitot Leak Check	-	Pass
Final Pitot Leak Check	-	Pass
Orientation of Duct	-	Vertical
Pitot Tube, C_p	-	0.84
Number of Lines Available	-	2
Number of Lines Used	-	1

		Sampling Line A					Sampling Line B - Restricted Access				
Traverse Point	Depth m	ΔP Pa	Temp °C	Wet Density kg/m³	Velocity m/s	Swirl °	ΔP	Temp °C	Wet Density kg/m³	Velocity m/s	Swirl °
STATIC (Units: Pa)		*38.0*									
Mean		**143.0**	**55.1**	**1.066**	**13.69**						
1	0.03	124.0	53.2	1.072	12.74	3.0					
2	0.10	136.0	55.6	1.064	13.39	2.0					
3	0.30	139.0	56.2	1.062	13.55	3.0					
4	0.37	173.0	55.5	1.064	15.10	4.0					

PRELIMINARY STACK SURVEY: VELOCITY TRAVERSE TO EN 16911-1 (MID) - MEASUREMENT UNCERTAINTY

(1 of 1)

Performance characteristics (Uncertainty Components)	Uncertainty	Value	Units
Standard Uncertainty on the coefficient of the Pitot Tube	u(k)	0.005	-
Standard Uncertainty associated with the mean local dynamic pressures	u(Δpi)	2.868	Pa
- Resolution	u(res)	0.00087	
- Calibration	u(cal)	2.129	
- Drift	u(drift)	0.083	
- Lack of Fit	u(fit)	5.012	
- Overall corrections to dynamic measurements	u(Cf)	7.226	
Standard uncertainty associated with the molar mass of the gas	u(M)	0.00003	-
- $\varphi O_2,w$	-	20.310	
- $\varphi CO_2,w$	-	0.060	
- Oxygen, dry	u(ϕO_2,d)	0.625	
- Carbon Dioxide, dry	u(ϕCO_2,d)	0.002	
- Water Vapour	u(ϕH_2O)	0.025	
- Oxygen, wet	u(ϕO_2,w)	0.622	
- Carbon Dioxide, wet	u(ϕCO_2,w)	0.002	
Standard uncertainty associated with the stack temperature	u(Tc)	1.674	K
Standard uncertainty associated with the absolute pressure in the duct	u(pc)	175.715	Pa
- Atmospheric Pressure	u(patm)	175.692	
- Static Pressure	u(pstat)	2.868	
Standard uncertainty associated with the density in the duct	u(ρ)	0.00574	-
Standard uncertainty associated with the local velocities	u(vi)	0.226	Pa
Standard uncertainty associated with the mean velocity	u(v)	0.191	m/s
Standard uncertainty associated with the mean velocity (95% Confidence)	Uc(v)	0.375	m/s
Standard uncertainty associated with the mean velocity (95% Confidence), relative	Uc,rel(v)	2.74	%
Standard uncertainty associated with the volume flow rate (95% Confidence)	Uc(qV,w)	327.8	m^3/hr
- $u^2(a)/a^2$	-	0.00053	
- $u^2(qV,w)/q^2V,w$	-	0.00073	
- $u^2(qV,w)$	-	27970	
- u(qV,w)	-	167.2	
Standard uncertainty associated with the volume flow rate (95% Confidence), relative	Uc,rel(qV,w)	5.29	%

TOTAL PARTICULATE MATTER: RESULTS SUMMARY

British Crystal Ltd, Brierley Hill
Furnace Stack

Sample Runs

Parameter	Units	Run 1		Mean
Concentration	mg/m³	13.3		13.3
Uncertainty	±mg/m³	38.1		38.1
Mass Emission	g/hr	5.0		5.0
Uncertainty	±g/hr	14.3		14.3

NOTE: Where the maximum Blank concentration is higher than the Sample concentration, the maximum Blank concentration has been reported.

Parameter	Units	Run 1		Mean
Water Vapour	% v/v	0.75		0.75
Uncertainty	±% v/v	0.06		0.06

Blank Runs

Parameter	Units	Blank 1		Maximum
Concentration	mg/m³	13.3		13.3

General Sampling Information

Parameter	Value	
Standard	EN 13284-1	
Technical Procedure	CAT-TP-01	
Probe Material	Titanium	
Filter Housing Material	Titanium	
Positioning of Filter	In Stack	
Filter Size and Material	47mm Glass Fibre	
Number of Sampling Lines Used	1 / 2	FORMAT: Number Used / Number Required
Number of Sampling Points Used	4 / 4	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1, A2, A3 & A4	

Reference Conditions

Reference Conditions are: 273K, 101.3kPa, dry gas, 13% oxygen.

TOTAL PARTICULATE MATTER: ISOKINETIC SAMPLING CALCULATIONS

Test	Units	Run 1	
Absolute pressure of stack gas, P_s			
Barometric pressure, P_b	mmHg	757.5	
Stack static pressure, P_{static}	mmH_2O	3.9	
$P_s = (P_b + (P_{static} / 13.6)$	mmHg	757.8	
Volume of water vapour collected, V_{wstd}			
Total mass collected in impingers (liquid trap)	g	0.0	
Total mass collected in impingers (silica trap)	g	3.6	
Total mass of liquid collected, V_{lc}	g	3.6	
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.0045	
Volume of gas metered dry, V_{mstd}			
Volume of gas sample through gas meter, V_m	m^3	0.6880	
Gas meter correction factor, Y_d	-	0.9920	
Average dry gas meter temperature, T_m	°C	39.8	
Average pressure drop across orifice, ΔH	mmH_2O	45.9	
$V_{mstd} = ((0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)) / (T_m + 273)$	m^3	0.5964	
Moisture content, B_{wo} & R_{wv}			
$B_{wo} = V_{wstd} / (V_{mstd} + V_{wstd})$	m^3	0.0075	
B_{wo} as a percentage	% v/v	0.75	
Reported Water Vapour, checked with Tables in EN 14790, Rwv	% v/v	0.75	
Volume of gas metered wet, V_{mstw}			
$V_{mstw} = (V_{mstd})(100/(100 - R_{wv}))$	m^3	0.6009	
Volume of gas metered at Oxygen Reference Conditions, $V_{mstd@X\%O_2}$ & $V_{mstw@X\%O_2}$			
IED & Incinerates Hazardous Material? (Yes = no positive O_2 correction)	-	No	
% wet oxygen measured in gas stream, $ACT\%O_{2w}$	% v/v	20.26	
% dry oxygen measured in gas stream, $ACT\%O_{2d}$	% v/v	20.36	
% oxygen reference condition, $REF\%O_2$	% v/v	13.00	
O_2 Reference Factor wet $(O_{2REFw}) = (21 - REF\%O_2) / (21 - ACT\%O_{2w})$	-	10.79	
O_2 Reference Factor dry $(O_{2REFd}) = (21 - REF\%O_2) / (21 - ACT\%O_{2d})$	-	12.48	
$V_{mstw@X\%oxygen} = (V_{mstw}) / (O_{2REFw})$	m^3	0.0557	
$V_{mstd@X\%oxygen} = (V_{mstd}) / (O_{2REFd})$	m^3	0.0478	
Molecular weight of dry gas stream, M_d			
CO_2 (Estimated)	% v/v	0.06	
O_2	% v/v	20.36	
Total	% v/v	20.42	
N_2	% v/v	79.58	
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$	g/gmol	28.82	
Molecular weight of stack gas (wet), M_s			
$M_s = M_d(1 - (R_{wv}/100)) + 18(R_{wv}/100)$	g/gmol	28.74	
Velocity of stack gas, V_s			
Pitot tube velocity constant, K_p	-	34.97	
Velocity pressure coefficient, C_p	-	0.84	
Average of velocity heads, ΔP_{avg}	mmH_2O	13.00	
Average square root of velocity heads, √ΔP	$\sqrt{mmH_2O}$	3.61	
Average stack gas temperature, T_s	°C	59.3	
$V_s = ((K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s} + 273)) / (\sqrt{(M_s)(P_s)})$	m/s	13.11	
Total flow of stack gas: Actual (Q_a), Wet (Q_{stw}), Dry (Q_{std}), Wet@O_{2REF} (Q_{stwO_2}), Dry@O_{2REF} (Q_{stdO_2})			
Area of stack, A_s	m^2	0.13	
$Q_a = (60)(A_s)(V_s)$	m^3/min	98.9	
Conversion factor (K/mm.Hg), C_f	-	0.3592	
$Q_{stw} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273)$	m^3/min	81.0	
$Q_{std} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273)$	m^3/min	80.4	
$Q_{stwO_2} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273) / (O_{2REFw})$	m^3/min	7.5	
$Q_{stdO_2} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273) / (O_{2REFd})$	m^3/min	6.4	
Percent isokinetic, %I			
Nozzle diameter, D_n	mm	6.01	
Nozzle area, A_n	mm^2	28.40	
Total sampling time, q	min	32	
$\%I = (4.6398E^6)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1 - (R_{wv}/100))$	%	102.6	

TOTAL PARTICULATE MATTER: SAMPLING DETAILS

Sample Runs

Parameter	Units	Run 1	
Sampling Times	-	15:43 - 16:15	
Sampling Dates	-	06/09/2016	
Sampling Device	-	ISO	
Volume Sampled (REF)	m^3	0.0478	
Filter I.D. Number	-	47-35776	
Start Filter Mass	g	0.14717	
End Filter Mass	g	0.14727	
Total Mass on Filter	g	0.00010	
Probe Rinse I.D. Number	-	PR-47-35776	
Start Probe Rinse Mass	g	2.98820	
End Probe Rinse Mass	g	2.98854	
Total Mass in Probe Rinse	g	0.00034	
Total Mass Collected	mg	0.44	
Calculated Concentration	mg/m^3	9.28	
Balance Uncertainty / LOD	mg/m^3	2.93	

Where: ISO stands for Manual Isokinetic Sampling Train

Blank Runs

Parameter	Units	Blank 1	
Blank Dates	-	06/09/2016	
Average Volume Sampled (REF)	m^3	0.0478	
Filter I.D. Number	-	47-35595	
Start Filter Mass	g	0.14691	
End Filter Mass	g	0.14754	
Total Mass on Filter	g	0.00063	
Probe Rinse I.D. Number	-	PR-47-35595	
Start Probe Rinse Mass	g	2.98947	
End Probe Rinse Mass	g	2.98947	
Total Mass in Probe Rinse	g	0.00000	
Total Mass Collected	mg	0.64	
Calculated Concentration	mg/m^3	13.33	
Balance Uncertainty / LOD	mg/m^3	2.93	

TOTAL PARTICULATE MATTER: QUALITY ASSURANCE

Sample Runs

Leak Test Results	Units	Run 1	
Mean Sampling Rate	l/min	21.3	
Pre-Sampling Leak Rate	l/min	0.09	
Post-Sampling Leak Rate	l/min	0.07	
Allowable Leak Rate	l/min	0.43	
Leak Test Acceptable	-	Yes	

Water Droplets	Units	Run 1	
Are Water Droplets Present	-	No	

MU (Concurrent Water Vapour)	Units	Run 1	
Measurement Uncertainty (MU)	%	8.0	
Allowable MU	%	20	
MU Acceptable	%	Yes	

Silica Gel (Concurrent Water Vapour)	Units	Run 1	
Less than 50% Faded	%	Yes	

Isokinetic Criterion Compliance	Units	Run 1	
Isokinetic Variation	%	102.6	
Allowable Isokinetic Range	%	95 - 115	
Isokineticity Acceptable	-	Yes	

Weighing Uncertainty Criteria	Units	Run 1	
Overall Weighing Uncertainty	± mg	0.27	
Overall Weighing Uncertainty	± mg/m³	5.65	
ELV [Daily ELV for IED]	mg/m³	20.0	
Allowable Weighing Uncertainty	mg/m³	1.00	
Weighing Uncertainty Acceptable	-	No	

Filter Temperatures	Units	Run 1	
Pre-Conditioning Temperature	°C	180	
Post-Conditioning Temperature	°C	160	
Maximum Filter Temperature	°C	60	

Test Conditions	Units	Run 1	
Ambient Temperature Recorded?	-	Yes	

TOTAL PARTICULATE MATTER: QUALITY ASSURANCE

Blank Runs

Leak Test Results	Units	Blank 1	
Expected Sampling Rate	l/min	18.0	
Pre-Sampling Leak Rate	l/min	0.08	
Post-Sampling Leak Rate	l/min	0.06	
Allowable Leak Rate	l/min	0.36	
Leak Test Acceptable	-	Yes	

Validity of Blank vs ELV	Units	Blank 1	
Allowable Blank	mg/m³	2.0	
Blank Acceptable	-	No	

Acetone / Water Rinse Blank	Units	Blank
Acetone / Water Rinse Value	mg/l	2.7
Allowable Blank	mg/l	10
Blank Acceptable	-	Yes

Method Deviations

Nature of Deviation (x = deviation applies to the associated run, wx = deviation also applies to the concurrent water vapour run)	Run Number 1	
One out of two sampling lines was used due to sampling location restrictions, however the number of sample points used on the available line were increased to the minimum required by the Standard	x	
It is a requirement of MID 13284-1, V2.4 for the overall weighing uncertainty to be less than 5% of the ELV, unless the ELV is <5mg/m³ where a 1 hour sample is deemed to be sufficient.	x	
The blank result was higher than 10% of the ELV, however this is related to a high oxygen correction factor applied to the results. [> 100% higher]	x	

TOTAL PARTICULATE MATTER: MEASUREMENT UNCERTAINTY CALCULATIONS

	Value			Standard uncertainty			
Measured Quantities	**Symbol**	**Run 1**		**Symbol**	**Units**	**Run 1**	
Sampled Volume (Actual)	V_m	0.69		uV_m	m^3	0.01	
Sampled Gas Temperature	T_m	312.8		uT_m	K	2.00	
Sampled Gas Pressure	ρ_m	101.0		$u\rho_m$	kPa	0.50	
Sampled Gas Humidity	H_m	0.00		uH_m	% v/v	1.00	
Leak	L	0.33		uL	%	-	
Mass of Particulate	m	0.44		um	mg	0.14	
Uncollected Mass	UCM	0.64		uUCM	mg	-	

	Uncertainty as a Percentage			
Measured Quantities	**Units**	**Run 1**		**Requirement of Standard**
Sampled Volume (Actual)	%	2.00		≤2%
Sampled Gas Temperature	%	0.64		≤1%
Sampled Gas Pressure	%	0.49		≤1%
Sampled Gas Humidity	%	1.00		≤1%
Leak	%	0.33		≤2%
Mass of Particulate	%	21.0		<5% of ELV
Uncollected Mass	%	-		-

	Uncertainty in Measurement Units				Sensitivity Coefficient	
Measured Quantities	**Symbol**	**Units**	**Run 1**		**Run 1**	
Sampled Volume (STP)	V_m	m^3	0.60		22.3	
Leak	L	mg/m^3	0.03		1.00	
Mass of Particulate	L_r	mg	0.44		30.1	
Uncollected Mass	UCM	mg	0.37		30.1	

	Uncertainty in Result		
Measured Quantities	**Units**	**Run 1**	
Sampled Volume (STP)	mg/m^3	0.35	
Leak	mg/m^3	0.03	
Mass of Particulate	mg/m^3	4.21	
Uncollected Mass	mg/m^3	11.0	

	Oxygen Correction Part of MU Budget		
Measured Quantities	**Units**	**Run 1**	
O_2 Correction Factor	-	12.5	
Stack Gas O_2 Content	% v/v	20.4	
MU for O_2 Correction	-	9.74	
Overall MU For O_2 Measurement	%	78.0	

Parameter	**Units**	**Run 1**	
Combined uncertainty	mg/m^3	11.8	
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m^3	23.2	
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m^3	25.4	
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m^3	38.1	
Reported Uncertainty	mg/m^3	38.1	
Expanded uncertainty (95% confidence), without Oxygen Correction	%	174.0	
Expanded uncertainty (95% confidence), with Oxygen Correction	%	190.7	
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	286.0	
Reported Uncertainty	%	286.0	

LEAD: RESULTS SUMMARY

British Crystal Ltd, Brierley Hill
Furnace Stack

Sample Runs

Parameter	Units	Run 1		Mean
Concentration	mg/m³	3.3		3.3
Uncertainty	±mg/m³	3.5		3.5
Mass Emission	g/hr	1.2		1.2
Uncertainty	±g/hr	1.3		1.3

Parameter	Units	Run 1		Mean
Water Vapour	% v/v	0.24		0.24
Uncertainty	±% v/v	0.04		0.04

Blank Runs

Parameter	Units	Blank 1		Maximum
Concentration	mg/m³	0.05		0.05

General Sampling Information

Parameter	Value	
Standard	EN 14385	
Technical Procedure	CAT-TP-06	
Name of Analytical Laboratory	RPS	
Analytical Laboratory's Procedure	M31	
ISO 17025 Accredited Analysis?	Yes	
Date of Sample Analysis	20/09/2016	
Probe Material	Titanium	
Filter Housing Material	Borosilicate Glass	
Impinger Material	Borosilicate Glass	
Absorption Solution	Nitric Peroxide	
Positioning of Filter	Out Stack	
Filter Size and Material	47mm Quartz Fibre	
Number of Sampling Lines Used	1 / 2	FORMAT: Number Used / Number Required
Number of Sampling Points Used	4 / 4	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1, A2, A3 & A4	

Reference Conditions

Reference Conditions are: 273K, 101.3kPa, dry gas, 13% oxygen.

LEAD: ISOKINETIC SAMPLING CALCULATIONS

Test	Units	Run 1	
Absolute pressure of stack gas, P_s			
Barometric pressure, P_b	mmHg	757.5	
Stack static pressure, P_{static}	mmH_2O	3.9	
$P_s = (P_b + (P_{static} / 13.6)$	mmHg	757.8	
Volume of water vapour collected, V_{wstd}			
Total mass collected in impingers (liquid trap)	g	0.1	
Total mass collected in impingers (silica trap)	g	1.2	
Total mass of liquid collected, V_{lc}	g	1.3	
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.0016	
Volume of gas metered dry, V_{mstd}			
Volume of gas sample through gas meter, V_m	m^3	0.7632	
Gas meter correction factor, Y_d	-	0.9920	
Average dry gas meter temperature, T_m	°C	37.1	
Average pressure drop across orifice, ΔH	mmH_2O	55.6	
$V_{mstd} = ((0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)) / (T_m + 273)$	m^3	0.6678	
Moisture content, B_{wo} & R_{wv}			
$B_{wo} = V_{wstd} / (V_{mstd} + V_{wstd})$	m^3	0.0024	
B_{wo} as a percentage	% v/v	0.24	
Reported Water Vapour, checked with Tables in EN 14790, Rwv	% v/v	0.24	
Volume of gas metered wet, V_{mstw}			
$V_{mstw} = (V_{mstd})(100/(100 - R_{wv}))$	m^3	0.6695	
Volume of gas metered at Oxygen Reference Conditions, $V_{mstd@X\%O_2}$ & $V_{mstw@X\%O_2}$			
IED & Incinerates Hazardous Material? (Yes = no positive O_2 correction)	-	No	
% wet oxygen measured in gas stream, $ACT\%O_{2w}$	% v/v	20.41	
% dry oxygen measured in gas stream, $ACT\%O_{2d}$	% v/v	20.52	
% oxygen reference condition, $REF\%O_2$	% v/v	13.00	
O_2 Reference Factor wet $(O_{2REFw}) = (21 - REF\%O_2) / (21 - ACT\%O_{2w})$	-	13.66	
O_2 Reference Factor dry $(O_{2REFd}) = (21 - REF\%O_2) / (21 - ACT\%O_{2d})$	-	16.52	
$V_{mstw@X\%oxygen} = (V_{mstw}) / (O_{2REFw})$	m^3	0.0490	
$V_{mstd@X\%oxygen} = (V_{mstd}) / (O_{2REFd})$	m^3	0.0404	
Molecular weight of dry gas stream, M_d			
CO_2 (Estimated)	% v/v	0.06	
O_2	% v/v	20.52	
Total	% v/v	20.58	
N_2	% v/v	79.42	
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$	g/gmol	28.83	
Molecular weight of stack gas (wet), M_s			
$M_s = M_d(1 - (R_{wv}/100)) + 18(R_{wv}/100)$	g/gmol	28.80	
Velocity of stack gas, V_s			
Pitot tube velocity constant, K_p	-	34.97	
Velocity pressure coefficient, C_p	-	0.84	
Average of velocity heads, ΔP_{avg}	mmH_2O	15.89	
Average square root of velocity heads, √ΔP	$\sqrt{mmH_2O}$	3.99	
Average stack gas temperature, T_s	°C	59.4	
$V_s = ((K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s} + 273)) / (\sqrt{(M_s)(P_s)})$	m/s	14.48	
Total flow of stack gas: Actual (Q_a), Wet (Q_{stw}), Dry (Q_{std}), Wet@O_{2REF} (Q_{stwO_2}), Dry@O_{2REF} (Q_{stdO_2})			
Area of stack, A_s	m^2	0.13	
$Q_a = (60)(A_s)(V_s)$	m^3/min	109.2	
Conversion factor (K/mm.Hg), C_f	-	0.3592	
$Q_{stw} = ((Q_a)(P_{sj})(C_f)) / ((T_s) + 273)$	m^3/min	89.4	
$Q_{std} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273)$	m^3/min	89.2	
$Q_{stwO_2} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273) / (O_{2REFw})$	m^3/min	6.5	
$Q_{stdO_2} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273) / (O_{2REFd})$	m^3/min	5.4	
Percent isokinetic, %I			
Nozzle diameter, D_n	mm	6.01	
Nozzle area, A_n	mm^2	28.40	
Total sampling time, q	min	32	
$\%I = (4.6398E^6)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1 - (R_{wv}/100))$	%	103.5	

LEAD: SAMPLING DETAILS

Sample Runs

Parameter	Units	Run 1	
Sampling Times	-	15:00 - 15:32	
Sampling Dates	-	06/09/2016	
Sampling Device	-	ISO	
Volume Sampled (REF)	m^3	0.0404	
Mass on Filter / in Rinse	µg	123.00	
Mass in Front Impingers	µg	5.87	
Mass in Back Impinger	µg	4.77	
Total Mass Collected	µg	133.64	
Calculated Concentration	mg/m^3	3.3062	
Reported Concentration	mg/m^3	3.3062	

Where: ISO stands for Manual Isokinetic Sampling Train

Blank Runs

Parameter	Units	Blank 1	
Blank Dates	-	06/09/2016	
Average Volume Sampled (REF)	m^3	0.0404	
Mass on Filter / in Rinse	µg	< 0.50	
Mass in Front Impingers	µg	0.45	
Mass in Back Impinger	µg	1.03	
Total Mass Collected	µg	1.99	
Calculated Concentration	mg/m^3	0.0491	
Reported Concentration	mg/m^3	0.0491	

LEAD: QUALITY ASSURANCE

Sample Runs

Leak Test Results	Units	Run 1	
Mean Sampling Rate	l/min	23.7	
Pre-Sampling Leak Rate	l/min	0.10	
Post-Sampling Leak Rate	l/min	0.08	
Allowable Leak Rate	l/min	0.47	
Leak Test Acceptable	-	Yes	

Absorption Efficiency	Units	Run 1	
Absorption Efficiency	%	96.4	
Allowable Absorption Efficiency	%	90	
Absorption Efficiency Acceptable	-	Yes	

Detection Limit	Units	Run 1	
Detection Limit	µg/m³	14.4	
Allowable Detection Limit	µg/m³	5	
Detection Limit Acceptable	-	No	

Water Droplets	Units	Run 1	
Are Water Droplets Present	-	No	

MU (Concurrent Water Vapour)	Units	Run 1	
Measurement Uncertainty (MU)	%	17.4	
Allowable MU	%	20	
MU Acceptable	%	Yes	

Silica Gel (Concurrent Water Vapour)	Units	Run 1	
Less than 50% Faded	%	Yes	

Isokinetic Criterion Compliance	Units	Run 1	
Isokinetic Variation	%	103.5	
Allowable Isokinetic Range	%	95 - 115	
Isokineticity Acceptable	-	Yes	

Filter Temperatures	Units	Run 1	
Maximum Filter Temperature	°C	160	

Impingers Exit Temperature	Units	Run 1	
Maximum Temperature Recorded	°C	13	
Maximum Allowable Temperature	°C	30	
Exit Temperature Acceptable	-	Yes	

Test Conditions	Units	Run 1	
Ambient Temperature Recorded?	-	Yes	

LEAD: QUALITY ASSURANCE

Blank Runs

Leak Test Results	Units	Blank 1	
Expected Sampling Rate	l/min	18.0	
Pre-Sampling Leak Rate	l/min	0.08	
Post-Sampling Leak Rate	l/min	0.09	
Allowable Leak Rate	l/min	0.36	
Leak Test Acceptable	-	Yes	

Validity of Blank vs ELV	Units	Blank 1	
Allowable Blank	mg/m³	0.50	
Blank Acceptable	-	Yes	

Method Deviations

Nature of Deviation (x = deviation applies to the associated run, wx = deviation also applies to the concurrent water vapour run)	Run Number 1	
One out of two sampling lines was used due to sampling location restrictions, however the number of sample points used on the available line were increased to the minimum required by the Standard	x	
The detection limit for Lead in the final impinger was >5µg/m³, however this related more with the high oxygen content in the stack, rather than a high mass of Lead detected in the sample.	x	

LEAD: MEASUREMENT UNCERTAINTY CALCULATIONS

	Value			Standard uncertainty			
Measured Quantities	**Symbol**	**Run 1**		**Symbol**	**Units**	**Run 1**	
Sampled Volume (Actual)	V_m	0.76		uV_m	m³	0.02	
Sampled Gas Temperature	T_m	310.1		uT_m	K	2.00	
Sampled Gas Pressure	ρ_m	101.0		$u\rho_m$	kPa	0.50	
Sampled Gas Humidity	H_m	0.00		uH_m	% v/v	1.00	
Leak	L	0.34		uL	%	-	
Laboratory Result	L_r	7.50		uL_r	%	-	

	Uncertainty as a Percentage			
Measured Quantities	**Units**	**Run 1**		**Requirement of Standard**
Sampled Volume (Actual)	%	2.00		≤2%
Sampled Gas Temperature	%	0.64		≤1%
Sampled Gas Pressure	%	0.49		≤1%
Sampled Gas Humidity	%	1.00		≤1%
Leak	%	0.34		≤2%
Laboratory Result	%	7.50		No Requirement

	Uncertainty in Measurement Units				Sensitivity Coefficient	
Measured Quantities	**Symbol**	**Units**	**Run 1**		**Run 1**	
Sampled Volume (STP)	V_m	m³	0.67		4.95	
Leak	L	mg/m³	0.0065		1.00	
Laboratory Result	L_r	mg/m³	0.2480		1.00	

	Uncertainty in Result		
Measured Quantities	**Units**	**Run 1**	
Sampled Volume (STP)	mg/m³	0.0868	
Leak	mg/m³	0.0065	
Laboratory Result	mg/m³	0.2480	

	Oxygen Correction Part of MU Budget		
Measured Quantities	**Units**	**Run 1**	
O_2 Correction Factor	-	16.5	
Stack Gas O_2 Content	% v/v	20.5	
MU for O_2 Correction	%	17.1	
Overall MU For O_2 Measurement	%	103	

Parameter	**Units**	**Run 1**	
Combined uncertainty	mg/m³	0.2628	
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m³	0.5151	
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m³	3.4528	
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m³	3.4528	
Reported Uncertainty	mg/m³	3.4528	
Expanded uncertainty (95% confidence), without Oxygen Correction	%	15.6	
Expanded uncertainty (95% confidence), with Oxygen Correction	%	104.4	
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	104.4	
Reported Uncertainty	%	104.4	

OXYGEN: RESULTS SUMMARY

British Crystal Ltd, Brierley Hill
Furnace Stack

Sample Runs

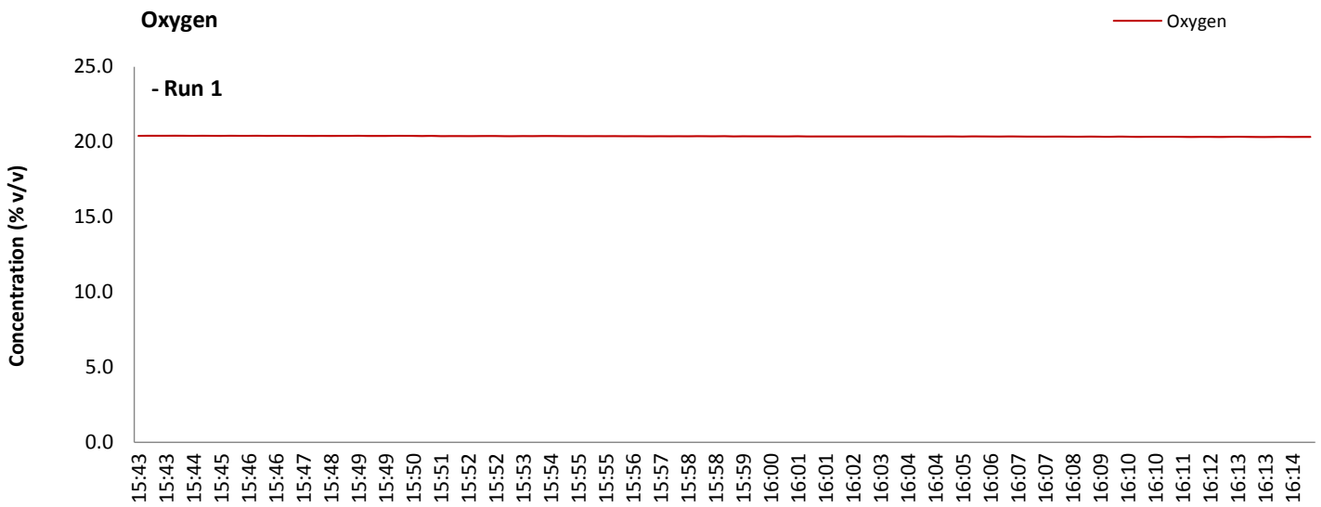
Parameter	Units	Run 1		Mean
Concentration	% v/v	20.4		20.4
Uncertainty	±% v/v	0.90		0.90

General Sampling Information

Parameter	Value	
Standard	EN 14789	
Technical Procedure	CAT-TP-39	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Span Gas Type	Synthetic Air (5 Grade)	
Span Gas Reference Number	CYL 11.0214	
Span Gas Expiry Date	29/05/2020	
Span Gas Start Pressure (bar)	100	
Gas Cylinder Concentration (% v/v)	21.5	
Span Gas Uncertainty (%)	2	
Zero Gas Type	Nitrogen (5 Grade)	
Number of Sampling Lines Used	1 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A5	

OXYGEN: DATA TREND

Graphical Trend of Data



OXYGEN: SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	
Sampling Times	-	15:43 - 16:15	
Sampling Dates	-	06/09/2016	
Instrument Range	% v/v	25.0	
Span Gas Value	% v/v	21.5	

Quality Assurance

Conditioning Unit Temperature	Units	Run 1	
Average Temperature	°C	2.0	
Allowable Temperature	< °C	4.0	
Temperature Acceptable	-	Yes	

	Zero Drift	Units	Run 1	
CAL 1	Zero Down Sampling Line (Pre)	% v/v	0.04	
	Zero Down Sampling Line (Post)	% v/v	-0.29	
	Zero Drift	% v/v	-0.33	
	Allowable Zero Drift	± % v/v	1.08	
	Zero Drift Acceptable	-	Yes	

	Span Drift	Units	Run 1	
CAL 1	Span Down Sampling Line (Pre)	% v/v	21.45	
	Span Down Sampling Line (Post)	% v/v	21.08	
	Span Drift	% v/v	-0.37	
	Allowable Span Drift	± % v/v	1.08	
	Span Drift Acceptable	-	Yes	

Test Conditions	Units	Run 1	
Run Ambient Temperature Range	°C	20 - 24	

Method Deviations

Nature of Deviation	Run Number	
(x = deviation applies to the associated run)	1	
There are no deviations associated with the sampling employed.	x	

OXYGEN: MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1		Units
Limit value	N/A		%vol
TGN M2 Allowable MU	6.0		%
Measured concentration	20.36		%vol
Range Used	25.0		%vol
Cal gas conc.	21.5		%vol

Performance characteristics	RUN 1		Units
Response time	41		seconds
Number of readings in measurement	32		-
Repeatability at zero	0.02		% full scale
Repeatability at span level	0.02		% full scale
Deviation from linearity	0.01		% of value
Zero drift	-1.54		% full scale
Span drift	-1.72		% full scale
Volume or pressure flow dependence	0.10		% of full scale
Atmospheric pressure dependence	0.19		% of value/kPa
Ambient temperature dependence	-0.21		% full scale/10K
Combined interference	0.00		% range
Dependence on voltage	0.02		% full scale/10V
Losses in the line (leak)	0.23		% of value
Uncertainty of calibration gas	2.00		% of value

Performance characteristic	RUN 1		Units
Standard deviation of repeatability at zero	use rep at span		%vol
Standard deviation of repeatability at span level	0.00		%vol
Lack of fit	0.00		%vol
Drift	-0.39		%vol
Volume or pressure flow dependence	0.00		%vol
Atmospheric pressure dependence	0.01		%vol
Ambient temperature dependence	-0.03		%vol
Combined interference (from MCERTS Certificate)	0.00		%vol
Dependence on voltage	0.00		%vol
Losses in the line (leak)	0.03		%vol
Uncertainty of calibration gas	0.24		%vol

			RUN 1		Units
Measurement uncertainty		**Result**	20.36		%vol
Combined uncertainty			0.46		%vol
Expanded uncertainty	k =	1.96	0.90		%vol

	RUN 1		Units
Expanded uncertainty (no O_2) - at 95% Confidence	4.43		% of Value
Result of Compliance with Uncertainty Requirement in M2	**COMPLIANT**		-

Requirement for SRM is that Uncertainty should be 0.5%vol absolute or 6% relative whichever is the lower, on a dry gas basis. Ref EA TGN M2.