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Stack Emissions Testing Report Commissioned by
Brierley British Crystal

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

PPC Permit: PB 98 Variation 200839393

Stack Reference
Furnace Stack

Dates of the Monitoring Campaign
23rd January 2019

Job Reference Number
CAT-4637

Report Written by
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Report Date
18th February 2019

Version
Version 1

Signature of Report Approver

CONTENTS

TITLE PAGE

CONTENTS

EXECUTIVE SUMMARY

Monitoring Objectives	3
Monitoring Results	4
Monitoring Dates & Times	5
Process Details	6
Monitoring & Analytical Methods	7
Summary of Sampling Deviations	7
Sampling Location	8
Plant Photos / Sample Points	9

APPENDIX 1 - Monitoring Personnel & List of Equipment

APPENDIX 2 - Raw Data, Sampling Equations & Charts

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Executive Summary

(Page 1 of 7)

MONITORING OBJECTIVES

Brierley British Crystal, Brierley Hill

Furnace Stack

23rd January 2019

Overall Aim of the Monitoring Campaign

Exova Catalyst were commissioned by Brierley British Crystal 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

(Page 2 of 7)

MONITORING RESULTS

Brierley British Crystal, Brierley Hill

Furnace Stack

23rd January 2019

where MU = Measurement Uncertainty associated with the Result

Parameter	Concentration				Mass Emission			
	Units	Result	MU +/-	Limit	Units	Result	MU +/-	Limit
Total Particulate Matter ¹	mg/m ³	9.4	35.1	20	g/hr	2.4	8.9	-
Lead ¹	mg/m ³	1.0	1.6	5	g/hr	0.25	0.40	-
Oxygen	% v/v	Dry 20.6	0.52					
Water Vapour	% v/v	1.7	0.13					
Stack Gas Temperature	°C	40.4						
Stack Gas Velocity	m/s	13.8	0.38					
Volumetric Flow Rate (ACTUAL)	m ³ /hr	6266	332					
Volumetric Flow Rate (REF) ¹	m ³ /hr	253	13					

NOTE: VOLUMETRIC FLOW RATE & VELOCITY DATA TAKEN FROM AN AVERAGE OF ALL OF THE ISOKINETIC RUNS.

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

Executive Summary

(Page 3 of 7)

MONITORING DATE(S) & TIMES

Brierley British Crystal, Brierley Hill
Furnace Stack
23rd January 2019

Parameter	Units	Concentration	Units	Mass Emission	Sampling Date(s)	Sampling Times	Duration mins	
Total Particulate Matter	R1	mg/m ³	9.4	g/hr	2.4	23/01/2019	09:57 - 10:29	32
Lead	R1	mg/m ³	1.0	g/hr	0.25	23/01/2019	10:44 - 11:16	32
Oxygen	R1	% v/v	20.6		23/01/2019	09:57 - 10:29	32	
Oxygen	R2	% v/v	20.4		23/01/2019	10:44 - 11:16	32	
Velocity Traverse	R1				23/01/2019	09:31 - 09:40		

All results are expressed at the respective reference conditions.

Executive Summary

(Page 4 of 7)

PROCESS DETAILS

Brierley British Crystal, Brierley Hill

Furnace Stack

23rd January 2019

Standard Operating Conditions

Parameter	Value
Process Status	Normal Operation
Capacity (of 100%) and Tonnes / Hour	Standard Operating Capacity
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

(Page 5 of 7)

MONITORING & ANALYTICAL METHODS

Brierley British Crystal, Brierley Hill
Furnace Stack
23rd January 2019

Parameter	Monitoring				Analysis					MCERTS Testing	LOD (Average)
	Standard	Technical Procedure	ISO 17025 Testing	Testing Lab	Analytical Procedure	Analytical Technique	ISO 17025 Analysis	Analysis Lab			
Total Particulate Matter	EN 13284-1	CAT-TP-01	Yes	CAT	CAT-TP-03	Gravimetric	Yes	CAT	Yes	5.35 mg/m ³	
Lead	EN 14385	CAT-TP-06	Yes	CAT	CAT-AP-07	ICP-MS	Yes	CAT	Yes	0.018 mg/m ³	
Water Vapour	EN 14790	CAT-TP-05	Yes	CAT	CAT-TP-05	Gravimetric	Yes	CAT	Yes	0.1 % v/v	
Oxygen	EN 14789	CAT-TP-39	Yes	CAT	Dry Paramagnetic Cell by Horiba PG-350E				Yes	0.1 %	
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
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SUMMARY OF SAMPLING DEVIATIONS

Parameter	Run	Deviation
All Parameters	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/m ³ 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 it should be noted that the results were of an extremely low order. [25 - 50% higher]
Lead	All Runs	The detection limit for some of the metals was >5µg/m ³ , however it should be noted that the results were of an extremely low order.

Executive Summary

(Page 6 of 7)

SUITABILITY OF SAMPLING LOCATION

Duct Characteristics

Parameter	Units	Value
Type	-	Circular
Depth	m	0.40
Width	m	-
Area	m ²	0.13
Port Depth	cm	0
Orientation of Duct	-	Vertical
Number of Ports	-	2
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	No

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	123.0	> 5 Pa	Yes
Mean Velocity	m/s	13.41	-	-
Lowest Gas Velocity	m/s	12.59	-	-
Highest Gas Velocity	m/s	14.07	-	-
Ratio of Above	: 1	1.12	< 3 : 1	Yes
Maximum Angle of Swirl	°	0.00	< 15°	Yes
No Local Negative Flow	-	Yes	-	Yes

Executive Summary

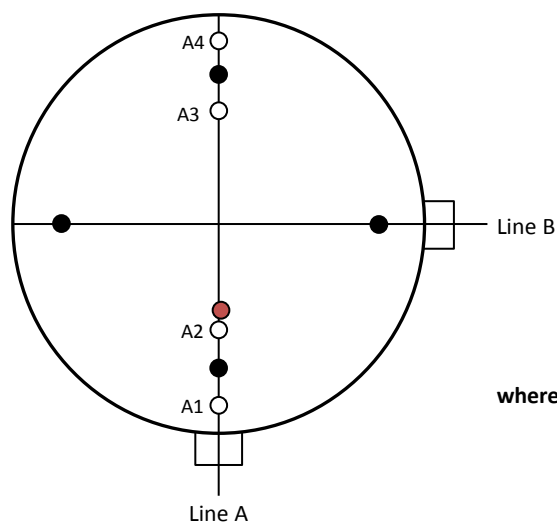
(Page 7 of 7)

PLANT PHOTOS

Photo 1



SAMPLE POINTS



- where
- = isokinetic point sampled at
 - = isokinetic point not sampled at
 - (red) = combustion gases sample point
 - (blue) = non-isokinetic sample point



APPENDICES

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
Technician	Lee Heaton	MCERTS Level 1	MM 17 1433	None

LIST OF EQUIPMENT

Extractive Sampling		Instrumental Analysers		Miscellaneous Items	
Equipment Type	Equipment I.D.	Equipment Type	Equipment I.D.	Equipment Type	Equipment I.D.
Control Box DGM (1)	CAT 7.67	Horiba PG-350E	CAT 39.10	Digital Manometer (1)	CAT 3.142
Control Box DGM (2)	-	Horiba PG-250	-	Digital Manometer (2)	CAT 3.144
Box Thermocouples (1)	CAT 3.164	Servomex 4900	-	Digital Temperature Meter	-
Box Thermocouples (2)	-	Eco Physics CLD 822Mh	-	Stopwatch	CAT 14.84
Umbilical (1)	CAT 3.146	ABB AO2020-URAS26	-	Barometer	CAT 13.40
Umbilical (2)	-	Testo 350 XL	-	Stack Thermocouple (1)	CAT 4.1034
Oven Box (1)	CAT 12.109	Ankersmid APS 313	CAT 4.847	Stack Thermocouple (2)	CAT 4.1048
Oven Box (2)	-	Gasmet DX4000	-	Stack Thermocouple (3)	CAT 4.1135
Heated Probe (1)	CAT 5.126	Gasmet Sampling System	-	1m Heated Line (1)	-
Heated Probe (2)	CAT 5.127	Bernath 3006 FID	-	1m Heated Line (2)	-
Heated Probe (3)	CAT 5.128	M&C PSS	CAT 12.107	1m Heated Line (3)	-
S-Pitot (1)	CAT 21S.57	Mass Flow Controller (1)	CAT 6.61	5m Heated Line (1)	-
S-Pitot (2)	CAT 21P.110	Mass Flow Controller (2)	CAT 6.62	15m Heated Line (1)	-
L-Pitot	-	Mass View (1)	-	20m Heated Line (1)	CAT 20.116
Site Balance	CAT 17.33	Mass View (2)	-	20m Heated Line (2)	-
500g / 1Kg Check Weights	CAT 17.33 a & b	Hioki 5043 (V)	-	Dual Channel Heater Controller	-
Last Impinger Arm	CAT 4.007	Easylogger EN-EL-12 Bit	-	Single Channel Heater Controller	CAT 20.116
Callipers	CAT 23.40	Bioaerosols Temperature Logger	-	Laboratory Balance	CAT 1.18 / 1.18a
Tubes Kit Thermocouple	-	Electronic Refrigerator	-	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	38.3
Average Stack Gas Pressure	Pa	140.0
Average Stack Static Pressure, P _{static}	kPa	0.041
Average Barometric Pressure, P _b	kPa	98.4
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/m ³ ρ	Conc kg/m ³ ρ _i
CO ₂ (Estimated)	-	0.06	0.06	0.0006	44.01	1.9635	0.00118
O ₂	-	20.55	20.21	0.2055	32.00	1.4277	0.29345
N ₂	-	79.39	78.04	0.7939	28.01	1.2498	0.99219
Moisture (H ₂ O)	-	-	1.69	0.0169	18.02	0.8037	0.01361

Where: $\rho = M / 22.41$

$\rho_i = r \times \rho$

Calculation of Stack Gas Densities

Determinand	Units	Result
Dry Density (STP), P _{STD}	kg/m ³	1.287
Wet Density (STP), P _{STW}	kg/m ³	1.279
Dry Density (Actual), P _{Actual}	kg/m ³	1.097
Average Wet Density (Actual), P _{ActualW}	kg/m ³	1.090

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)

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

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

Calculation of Stack Gas Volumetric Flowrate, Q

Duct gas flow conditions	Units	Actual	REF ¹
Temperature	°C	38.3	0.0
Total Pressure	kPa	98.4	101.3
Moisture	%	1.69	0.00
Oxygen (Dry)	%	20.6	13.0

Gas Volumetric Flowrate (from Traverse)	Units	Result
Gas Volumetric Flowrate (Actual)	m ³ /hr	6067
Gas Volumetric Flowrate (STP, Wet)	m ³ /hr	5171
Gas Volumetric Flowrate (STP, Dry)	m ³ /hr	5083
Gas Volumetric Flowrate REF ¹	m ³ /hr	283

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

(1 of 1)

Parameter	Units	Value
Date of Survey	-	23/01/2019
Time of Survey	-	09:31 - 09:40
Atmospheric Pressure	kPa	98.4
Average Stack Static Pressure	Pa	41
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	-	2

Traverse Point	Depth m	ΔP Pa	Sampling Line A				Sampling Line B				
			Temp °C	Wet Density kg/m ³	Velocity m/s	Swirl °	Temp °C	Wet Density kg/m ³	Velocity m/s	Swirl °	
<i>STATIC (Units: Pa)</i>		43.0					39.0				
Mean		144.5	38.0	1.091	13.62		135.5	38.5	1.089	13.19	
1	0.06	135.0	38.0	1.091	13.17	0.0	148.0	38.0	1.091	13.79	0.0
2	0.34	154.0	38.0	1.091	14.07	0.0	123.0	39.0	1.087	12.59	0.0

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	$u(\Delta p_i)$	2.816	Pa
- Resolution	$u(res)$	0.00087	
- Calibration	$u(cal)$	2.041	
- Drift	$u(drift)$	0.083	
- Lack of Fit	$u(fit)$	4.804	
- Overall corrections to dynamic measurements	$u(C_f)$	6.929	
Standard uncertainty associated with the molar mass of the gas	$u(M)$	0.00003	-
- $\phi_{O_2,w}$	-	20.206	
- $\phi_{CO_2,w}$	-	0.059	
- Oxygen, dry	$u(\phi_{O_2,d})$	0.629	
- Carbon Dioxide, dry	$u(\phi_{CO_2,d})$	0.002	
- Water Vapour	$u(\phi_{H_2O})$	0.086	
- Oxygen, wet	$u(\phi_{O_2,w})$	0.619	
- Carbon Dioxide, wet	$u(\phi_{CO_2,w})$	0.002	
Standard uncertainty associated with the stack temperature	$u(T_c)$	1.588	K
Standard uncertainty associated with the absolute pressure in the duct	$u(p_c)$	175.703	Pa
- Atmospheric Pressure	$u(p_{atm})$	175.692	
- Static Pressure	$u(p_{stat})$	1.991	
Standard uncertainty associated with the density in the duct	$u(\rho)$	0.00589	-
Standard uncertainty associated with the local velocities	$u(v_i)$	0.221	Pa
Standard uncertainty associated with the mean velocity	$u(\underline{v})$	0.187	m/s
Standard uncertainty associated with the mean velocity (95% Confidence)	$U_c(v)$	0.367	m/s
Standard uncertainty associated with the mean velocity (95% Confidence), relative	$U_{c,rel}(v)$	2.74	%
Standard uncertainty associated with the volume flow rate (95% Confidence)	$U_c(qV,w)$	321.0	m ³ /hr
- $u^2(a)/a^2$	-	0.00053	
- $u^2(qV,w)/q^2V,w$	-	0.00073	
- $u^2(qV,w)$	-	26824	
- $u(qV,w)$	-	163.8	
Standard uncertainty associated with the volume flow rate (95% Confidence), relative	$U_{c,rel}(qV,w)$	5.29	%

TOTAL PARTICULATE MATTER: RESULTS SUMMARY

Brierley British Crystal, Brierley Hill
Furnace Stack

Sample Runs

Parameter	Units	Run 1	Mean
Concentration	mg/m ³	9.4	9.4
Uncertainty	±mg/m ³	35.1	35.1
Mass Emission	g/hr	2.4	2.4
Uncertainty	±g/hr	8.9	8.9

Parameter	Units	Run 1	Mean
Water Vapour	% v/v	2.6	2.6
Uncertainty	±% v/v	0.21	0.21

Blank Runs

Parameter	Units	Blank 1	Maximum
Concentration	mg/m ³	7.1	7.1

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
Number of Sampling Points Used	4/4
Sample Point I.D.'s	A1, A2, A3 & A4

FORMAT: Number Used / Number Required

FORMAT: Number Used / Number Required

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	738.0	
Stack static pressure, P _{static}	mmH ₂ O	4.4	
$P_s = (P_b + (P_{static} / 13.6))$	mmHg	738.3	
Volume of water vapour collected, V_{wstd}			
Total mass collected in impingers (liquid trap)	g	8.0	
Total mass collected in impingers (silica trap)	g	5.9	
Total mass of liquid collected, V _{lc}	g	13.9	
$V_{wstd} = (0.001246)(V_{lc})$	m ³	0.0173	
Volume of gas metered dry, V_{mstd}			
Volume of gas sample through gas meter, V _m	m ³	0.7050	
Gas meter correction factor, Y _d	-	0.9920	
Average dry gas meter temperature, T _m	°C	11.3	
Average pressure drop across orifice, ΔH	mmH ₂ O	47.7	
$V_{mstd} = ((0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)) / (T_m + 273)$	m ³	0.6553	
Moisture content, B_{w0} & R_{wv}			
$B_{w0} = V_{wstd} / (V_{mstd} + V_{wstd})$	m ³	0.0257	
B _{w0} as a percentage	% v/v	2.57	
Reported Water Vapour, checked with Tables in EN 14790, R _{wv}	% v/v	2.57	
Volume of gas metered wet, V_{mstw}			
$V_{mstw} = (V_{mstd})(100/(100 - R_{wv}))$	m ³	0.6726	
Volume of gas metered at Oxygen Reference Conditions, V_{mstd@X%O₂} & V_{mstw@X%O₂}			
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	20.61	
% 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})	-	10.86	
O ₂ Reference Factor dry (O _{2REFd}) = (21 - REF%O ₂) / (21 - ACT%O _{2d})	-	20.62	
$V_{mstw@X\%oxygen} = (V_{mstw}) / (O_{2REFw})$	m ³	0.0620	
$V_{mstd@X\%oxygen} = (V_{mstd}) / (O_{2REFd})$	m ³	0.0318	
Molecular weight of dry gas stream, M_d			
CO ₂ (Estimated)	% v/v	0.56	
O ₂	% v/v	20.61	
Total	% v/v	21.17	
N ₂	% v/v	78.83	
$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2)$	g/gmol	28.91	
Molecular weight of stack gas (wet), M_s			
$M_s = M_d(1 - (R_{wv}/100)) + 18(R_{wv}/100)$	g/gmol	28.63	
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 ₂ O	14.83	
Average square root of velocity heads, √ΔP	√mmH ₂ O	3.85	
Average stack gas temperature, T _s	°C	41.6	
$V_s = ((K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s + 273})) / (V(M_s)(P_s))$	m/s	13.83	
Total flow of stack gas: Actual (Q_a), Wet (Q_{stw}), Dry (Q_{std}), Wet@O_{2REF} (Q_{stwO₂}), Dry@O_{2REF} (Q_{stdO₂})			
Area of stack, A _s	m ²	0.13	
$Q_a = (60)(A_s)(V_s)$	m ³ /min	104.3	
Conversion factor (K/mm.Hg), C _f	-	0.3592	
$Q_{stw} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273)$	m ³ /min	87.9	
$Q_{std} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273)$	m ³ /min	85.6	
$Q_{stwO_2} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273) / (O_{2REFw})$	m ³ /min	8.1	
$Q_{stdO_2} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273) / (O_{2REFd})$	m ³ /min	4.2	
Percent isokinetic, %I			
Nozzle diameter, D _n	mm	6.02	
Nozzle area, A _n	mm ²	28.44	
Total sampling time, q	min	32	
$\%I = (4.6398E^6)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1 - (R_{wv}/100))$	%	105.7	

TOTAL PARTICULATE MATTER: SAMPLING DETAILS

Sample Runs

Parameter	Units	Run 1
Sampling Times	-	09:57 - 10:29
Sampling Dates	-	23/01/2019
Sampling Device	-	ISO
Volume Sampled (REF)	m ³	0.0318
Filter I.D. Number	-	47-56718
Start Filter Mass	g	0.15565
End Filter Mass	g	0.15570
Total Mass on Filter	g	0.00005
Probe Rinse I.D. Number	-	PR-47-56718
Start Probe Rinse Mass	g	3.10867
End Probe Rinse Mass	g	3.10892
Total Mass in Probe Rinse	g	0.00025
Total Mass Collected	mg	0.30
Calculated Concentration	mg/m ³	9.44
Balance Uncertainty / LOD	mg/m ³	5.35

Where: ISO stands for Manual Isokinetic Sampling Train

Blank Runs

Parameter	Units	Blank 1
Blank Dates	-	23/01/2019
Average Volume Sampled (REF)	m ³	0.0318
Filter I.D. Number	-	47-56710
Start Filter Mass	g	0.15379
End Filter Mass	g	0.15390
Total Mass on Filter	g	0.00011
Probe Rinse I.D. Number	-	PR-47-56710
Start Probe Rinse Mass	g	3.09308
End Probe Rinse Mass	g	3.09320
Total Mass in Probe Rinse	g	0.00012
Total Mass Collected	mg	0.23
Calculated Concentration	mg/m ³	7.13
Balance Uncertainty / LOD	mg/m ³	5.35

TOTAL PARTICULATE MATTER: QUALITY ASSURANCE

(PAGE 1 OF 2)

Sample Runs

Leak Test Results	Units	Run 1
Mean Sampling Rate	l/min	21.9
Pre-Sampling Leak Rate	l/min	0.05
Post-Sampling Leak Rate	l/min	0.05
Allowable Leak Rate	l/min	0.44
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	%	20.0
MU Acceptable	%	Yes

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

Isokinetic Criterion Compliance	Units	Run 1
Isokinetic Variation	%	105.7
Allowable Isokinetic Range	%	95 - 115
Isokineticity Acceptable	-	Yes

Weighing Uncertainty Criteria	Units	Run 1
Overall Weighing Uncertainty	± mg	0.32
Overall Weighing Uncertainty	± mg/m ³	10.09
ELV [Daily ELV for IED]	mg/m ³	20.00
Allowable Weighing Uncertainty	mg/m ³	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	43

Test Conditions	Units	Run 1
Ambient Temperature Recorded?	-	Yes

TOTAL PARTICULATE MATTER: QUALITY ASSURANCE

(PAGE 2 OF 2)

Blank Runs

Leak Test Results	Units	Blank 1
Expected Sampling Rate	l/min	20.0
Pre-Sampling Leak Rate	l/min	0.05
Post-Sampling Leak Rate	l/min	0.05
Allowable Leak Rate	l/min	0.40
Leak Test Acceptable	-	Yes

Validity of Blank vs ELV	Units	Blank 1
Allowable Blank	mg/m ³	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	Run Number	
	(x = deviation applies to the associated run, wx = deviation also applies to the concurrent water vapour run)	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	wx	
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/m ³ where a 1 hour sample is deemed to be sufficient.	wx	
The blank result was higher than 10% of the ELV, however it should be noted that the results were of an extremely low order. [25 - 50% higher]	x	

TOTAL PARTICULATE MATTER: MEASUREMENT UNCERTAINTY CALCULATIONS

Measured Quantities	Value		Standard uncertainty		
	Symbol	Run 1	Symbol	Units	Run 1
Sampled Volume (Actual)	V _m	0.7050	uV _m	m ³	0.0141
Sampled Gas Temperature	T _m	284.3	uT _m	K	2.0
Sampled Gas Pressure	p _m	98.5	up _m	kPa	0.5
Sampled Gas Humidity	H _m	0.0	uH _m	% v/v	1.0
Leak	L	0.23	uL	%	-
Mass of Particulate	m	0.30	um	mg	0.17
Uncollected Mass	UCM	0.23	uUCM	mg	-

Measured Quantities	Uncertainty as a Percentage		Requirement of Standard
	Units	Run 1	
Sampled Volume (Actual)	%	2.00	≤2%
Sampled Gas Temperature	%	0.70	≤1%
Sampled Gas Pressure	%	0.51	≤1%
Sampled Gas Humidity	%	1.00	≤1%
Leak	%	0.23	≤2%
Mass of Particulate	%	26.75	<5% of ELV
Uncollected Mass	%	-	-

Measured Quantities	Uncertainty in Measurement Units			Sensitivity Coefficient	
	Symbol	Units	Run 1	Run 1	
Sampled Volume (STP)	V _m	m ³	0.6553	14.41	
Leak	L	mg/m ³	0.012	1.00	
Mass of Particulate	L _r	mg	0.300	31.47	
Uncollected Mass	UCM	mg	0.13	31.47	

Measured Quantities	Uncertainty in Result	
	Units	Run 1
Sampled Volume (STP)	mg/m ³	0.239
Leak	mg/m ³	0.0125
Mass of Particulate	mg/m ³	5.3501
Uncollected Mass	mg/m ³	4.1185

Measured Quantities	Oxygen Correction Part of MU Budget	
	Units	Run 1
O ₂ Correction Factor	-	20.62
Stack Gas O ₂ Content	% v/v	20.61
MU for O ₂ Correction	-	26.58
Overall MU For O ₂ Measurement	%	128.90

Parameter	Units	Run 1
Combined uncertainty	mg/m ³	6.76
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m ³	13.24
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m ³	17.98
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m ³	35.07
Reported Uncertainty	mg/m ³	35.07
Expanded uncertainty (95% confidence), without Oxygen Correction	%	140.3
Expanded uncertainty (95% confidence), with Oxygen Correction	%	190.5
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	371.4
Reported Uncertainty	%	371.4

LEAD: RESULTS SUMMARY

Brierley British Crystal, Brierley Hill
Furnace Stack

Sample Runs

Parameter	Units	Run 1	Mean
Concentration	mg/m ³	1.0	1.0
Uncertainty	±mg/m ³	1.6	1.6
Mass Emission	g/hr	0.25	0.25
Uncertainty	±g/hr	0.40	0.40

Parameter	Units	Run 1	Mean
Water Vapour	% v/v	0.81	0.81
Uncertainty	±% v/v	0.06	0.06

Blank Runs

Parameter	Units	Blank 1	Maximum
Concentration	mg/m ³	< 0.02	< 0.02

General Sampling Information

Parameter	Value
Standard	EN 14385
Technical Procedure	CAT-TP-06
Name of Analytical Laboratory	CAT
Analytical Laboratory's Procedure	CAT-AP-07
ISO 17025 Accredited Analysis?	Yes
Date of Sample Analysis	07/02/2019 & 12/02/2019
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
Number of Sampling Points Used	4/4
Sample Point I.D.'s	A1, A2, A3 & A4

FORMAT: Number Used / Number Required

FORMAT: Number Used / Number Required

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	738.0	
Stack static pressure, P _{static}	mmH ₂ O	4.4	
$P_s = (P_b + (P_{static} / 13.6))$	mmHg	738.3	
Volume of water vapour collected, V_{wstd}			
Total mass collected in impingers (liquid trap)	g	2.5	
Total mass collected in impingers (silica trap)	g	1.8	
Total mass of liquid collected, V _{lc}	g	4.3	
$V_{wstd} = (0.001246)(V_{lc})$	m ³	0.0054	
Volume of gas metered dry, V_{mstd}			
Volume of gas sample through gas meter, V _m	m ³	0.7180	
Gas meter correction factor, Y _d	-	0.9920	
Average dry gas meter temperature, T _m	°C	17.0	
Average pressure drop across orifice, ΔH	mmH ₂ O	50.0	
$V_{mstd} = ((0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)) / (T_m + 273)$	m ³	0.6543	
Moisture content, B_{wv} & R_{wv}			
$B_{wv} = V_{wstd} / (V_{mstd} + V_{wstd})$	m ³	0.0081	
B _{wv} as a percentage	% v/v	0.81	
Reported Water Vapour, checked with Tables in EN 14790, R _{wv}	% v/v	0.81	
Volume of gas metered wet, V_{mstw}			
$V_{mstw} = (V_{mstd})(100/(100 - R_{wv}))$	m ³	0.6597	
Volume of gas metered at Oxygen Reference Conditions, V_{mstd@X%O₂} & V_{mstw@X%O₂}			
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	20.61	
% 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})	-	10.86	
O ₂ Reference Factor dry (O _{2REFd}) = (21 - REF%O ₂) / (21 - ACT%O _{2d})	-	20.62	
$V_{mstw@X\%oxygen} = (V_{mstw}) / (O_{2REFw})$	m ³	0.0608	
$V_{mstd@X\%oxygen} = (V_{mstd}) / (O_{2REFd})$	m ³	0.0317	
Molecular weight of dry gas stream, M_d			
CO ₂ (Estimated)	% v/v	0.56	
O ₂	% v/v	20.61	
Total	% v/v	21.17	
N ₂	% v/v	78.83	
$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2)$	g/gmol	28.91	
Molecular weight of stack gas (wet), M_s			
$M_s = M_d(1 - (R_{wv}/100)) + 18(R_{wv}/100)$	g/gmol	28.83	
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 ₂ O	15.13	
Average square root of velocity heads, √ΔP	√mmH ₂ O	3.89	
Average stack gas temperature, T _s	°C	39.1	
$V_s = ((K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s + 273})) / (\sqrt{M_s}(P_s))$	m/s	13.87	
Total flow of stack gas: Actual (Q_a), Wet (Q_{stw}), Dry (Q_{std}), Wet@O_{2REF} (Q_{stwO₂}), Dry@O_{2REF} (Q_{stdO₂})			
Area of stack, A _s	m ²	0.13	
$Q_a = (60)(A_s)(V_s)$	m ³ /min	104.6	
Conversion factor (K/mm.Hg), C _f	-	0.3592	
$Q_{stw} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273)$	m ³ /min	88.9	
$Q_{std} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273)$	m ³ /min	88.1	
$Q_{stwO_2} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273) / (O_{2REFw})$	m ³ /min	8.2	
$Q_{stdO_2} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273) / (O_{2REFd})$	m ³ /min	4.3	
Percent isokinetic, %I			
Nozzle diameter, D _n	mm	6.02	
Nozzle area, A _n	mm ²	28.44	
Total sampling time, q	min	32	
$\%I = (4.6398E^6)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1 - (R_{wv}/100))$	%	102.5	

LEAD: SAMPLING DETAILS

Sample Runs

Parameter	Units	Run 1
Sampling Times	-	10:44 - 11:16
Sampling Dates	-	23/01/2019
Sampling Device	-	ISO
Volume Sampled (REF)	m ³	0.0317
Mass on Filter / in Rinse	µg	26.65
Mass in Front Impingers	µg	1.20
Mass in Back Impinger	µg	4.13
Total Mass Collected	µg	31.98
Calculated Concentration	mg/m ³	1.0078
Reported Concentration	mg/m ³	1.0078

Where: ISO stands for Manual Isokinetic Sampling Train

Blank Runs

Parameter	Units	Blank 1
Blank Dates	-	23/01/2019
Average Volume Sampled (REF)	m ³	0.0317
Mass on Filter / in Rinse	µg	< 0.50
Mass in Front Impingers	µg	< 0.04
Mass in Back Impinger	µg	< 0.02
Total Mass Collected	µg	< 0.56
Calculated Concentration	mg/m ³	< 0.0177
Reported Concentration	mg/m ³	< 0.0177

LEAD: QUALITY ASSURANCE

(PAGE 1 OF 2)

Sample Runs

Leak Test Results	Units	Run 1
Mean Sampling Rate	l/min	22.3
Pre-Sampling Leak Rate	l/min	0.05
Post-Sampling Leak Rate	l/min	0.05
Allowable Leak Rate	l/min	0.45
Leak Test Acceptable	-	Yes

Absorption Efficiency	Units	Run 1
Absorption Efficiency	%	87.1
Allowable Absorption Efficiency	%	N/A
Absorption Efficiency Acceptable	-	Yes

Where the emissions are < 30% of the ELV, MID 14385 does not require the absorption efficiency requirement to be applied

Detection Limit	Units	Run 1
Detection Limit	µg/m ³	18.1
Allowable Detection Limit	µg/m ³	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)	%	7.5
Allowable MU	%	20.0
MU Acceptable	%	Yes

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

Isokinetic Criterion Compliance	Units	Run 1
Isokinetic Variation	%	102.5
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	11
Maximum Allowable Temperature	°C	30
Exit Temperature Acceptable	-	Yes

Test Conditions	Units	Run 1
Ambient Temperature Recorded?	-	Yes

LEAD: QUALITY ASSURANCE

(PAGE 2 OF 2)

Blank Runs

Leak Test Results	Units	Blank 1
Expected Sampling Rate	l/min	20.0
Pre-Sampling Leak Rate	l/min	0.05
Post-Sampling Leak Rate	l/min	0.05
Allowable Leak Rate	l/min	0.40
Leak Test Acceptable	-	Yes

Validity of Blank vs ELV	Units	Blank 1
Allowable Blank	mg/m ³	0.500
Blank Acceptable	-	Yes

Method Deviations

Nature of Deviation	Run Number	
	(x = deviation applies to the associated run, wx = deviation also applies to the concurrent water vapour run)	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	wx	
The detection limit for some of the metals was >5µg/m ³ , however it should be noted that the results were of an extremely low order.	x	

LEAD: MEASUREMENT UNCERTAINTY CALCULATIONS

Measured Quantities	Value		Standard uncertainty		
	Symbol	Run 1	Symbol	Units	Run 1
Sampled Volume (Actual)	V _m	0.7180	uV _m	m ³	0.0144
Sampled Gas Temperature	T _m	290.0	uT _m	K	2.0
Sampled Gas Pressure	p _m	98.5	up _m	kPa	0.5
Sampled Gas Humidity	H _m	0.0	uH _m	% v/v	1.0
Leak	L	0.22	uL	%	-
Laboratory Result	L _r	7.10	uL _r	%	-

Measured Quantities	Uncertainty as a Percentage		Requirement of Standard
	Units	Run 1	
Sampled Volume (Actual)	%	2.00	≤2%
Sampled Gas Temperature	%	0.69	≤1%
Sampled Gas Pressure	%	0.51	≤1%
Sampled Gas Humidity	%	1.00	≤1%
Leak	%	0.22	≤2%
Laboratory Result	%	7.10	No Requirement

Measured Quantities	Uncertainty in Measurement Units			Sensitivity Coefficient	
	Symbol	Units	Run 1	Run 1	
Sampled Volume (STP)	V _m	m ³	0.6543	1.54	
Leak	L	mg/m ³	0.0013	1.00	
Laboratory Result	L _r	mg/m ³	0.0716	1.00	

Measured Quantities	Uncertainty in Result	
	Units	Run 1
Sampled Volume (STP)	mg/m ³	0.0258
Leak	mg/m ³	0.0013
Laboratory Result	mg/m ³	0.0716

Measured Quantities	Oxygen Correction Part of MU Budget	
	Units	Run 1
O ₂ Correction Factor	-	20.62
Stack Gas O ₂ Content	% v/v	20.61
MU for O ₂ Correction	%	26.58
Overall MU For O ₂ Measurement	%	128.90

Parameter	Units	Run 1
Combined uncertainty	mg/m ³	0.0761
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m ³	0.1491
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m ³	1.3076
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m ³	1.5691
Reported Uncertainty	mg/m ³	1.5691
Expanded uncertainty (95% confidence), without Oxygen Correction	%	14.8
Expanded uncertainty (95% confidence), with Oxygen Correction	%	129.7
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	155.7
Reported Uncertainty	%	155.7

OXYGEN: RESULTS SUMMARY

Brierley British Crystal, Brierley Hill
Furnace Stack

Sample Runs

Parameter	Units	Run 1	Run 2	Mean
Concentration	% v/v	20.6	20.4	20.5
Uncertainty	±% v/v	0.53	0.52	0.52

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	No
Heated Line Temperature	Orsat Used
Span Gas Type	Synthetic Air (5 Grade)
Span Gas Reference Number	CYL 11.0318
Span Gas Expiry Date	23/11/2022
Span Gas Start Pressure (bar)	150
Gas Cylinder Concentration (% v/v)	21.1
Span Gas Uncertainty (%)	2
Zero Gas Type	Nitrogen (5 Grade)
Number of Sampling Lines Used	1/1
Number of Sampling Points Used	1/1
Sample Point I.D.'s	A2

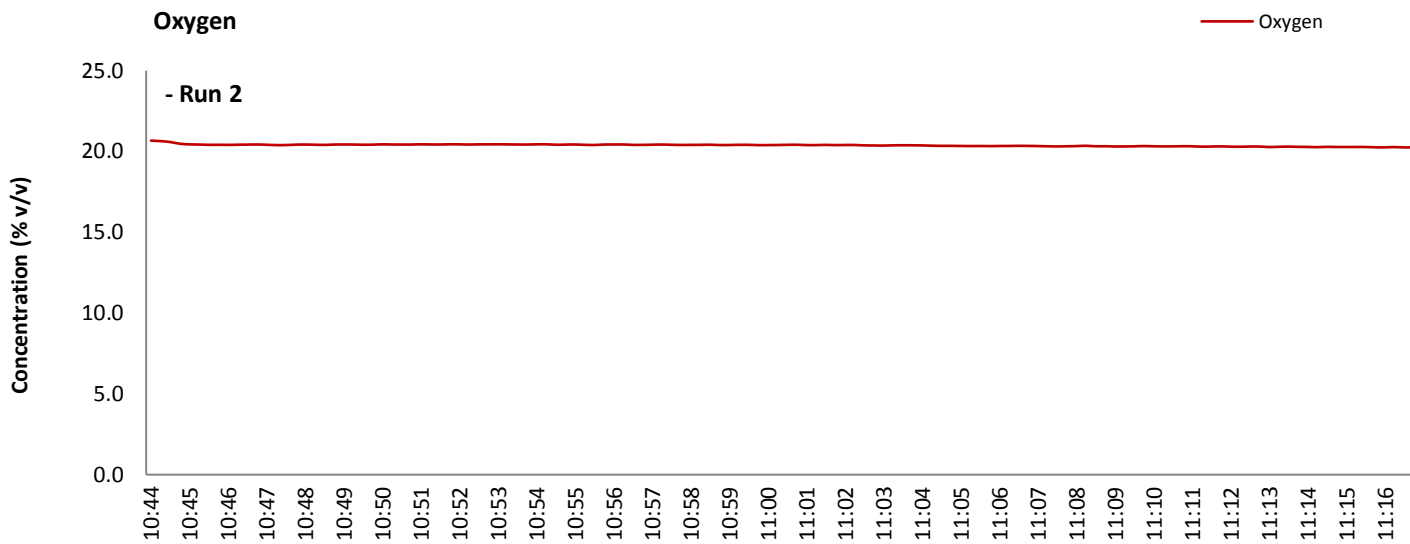
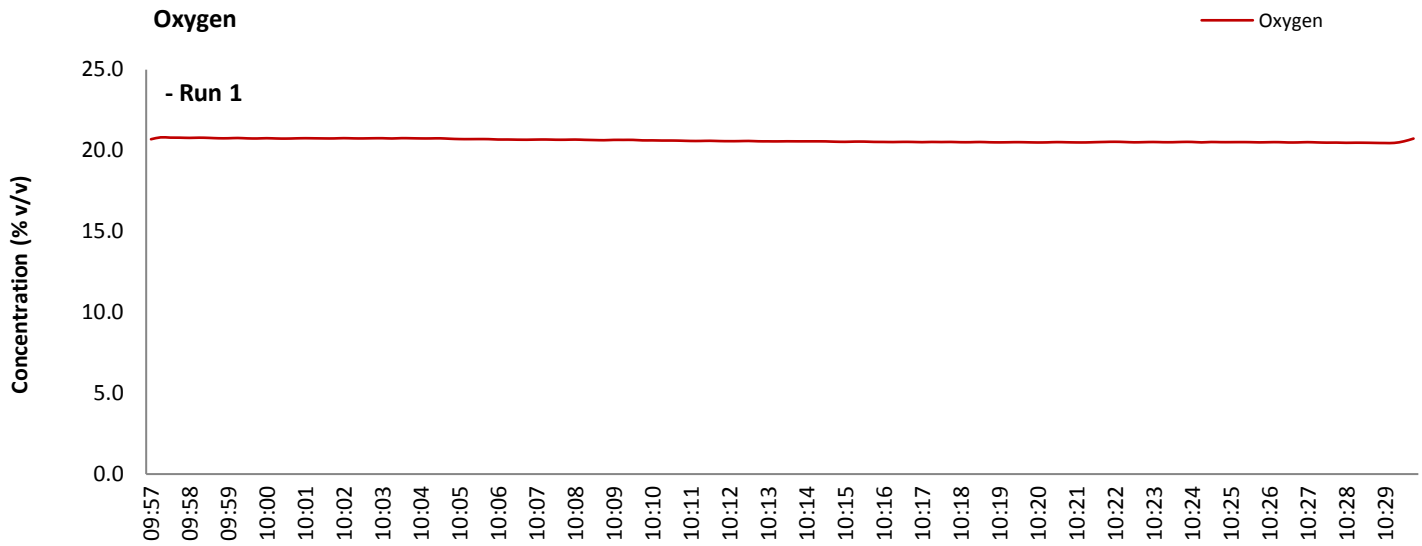
NOTE: Dilution performed to achieve correct span value

FORMAT: Number Used / Number Required

FORMAT: Number Used / Number Required

OXYGEN: DATA TREND

Graphical Trend of Data



OXYGEN: SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	Run 2
Sampling Times	-	09:57 - 10:29	10:44 - 11:16
Sampling Dates	-	23/01/2019	23/01/2019
Instrument Range	% v/v	25	25
Span Gas Value	% v/v	13.0	13.0

Quality Assurance

Conditioning Unit Temperature	Units	Run 1	Run 2
Average Temperature	°C	N/A	N/A
Allowable Temperature	< °C	N/A	N/A
Temperature Acceptable	-	N/A	N/A

Zero Drift	Units	Run 1	Run 2	
CAL 1	Zero at Analyser (Pre)	% v/v	0.00	0.00
	Zero at Analyser (Post)	% v/v	-0.03	-0.03
	Zero Drift	% v/v	-0.03	-0.03
	Allowable Zero Drift	± % v/v	0.65	0.65
	Zero Drift Acceptable	-	Yes	Yes

Span Drift	Units	Run 1	Run 2	
CAL 1	Span at Analyser (Pre)	% v/v	13.00	13.03
	Span at Analyser (Post)	% v/v	12.90	12.90
	Span Drift	% v/v	-0.10	-0.10
	Allowable Span Drift	± % v/v	0.65	0.65
	Span Drift Acceptable	-	Yes	Yes

Test Conditions	Units	Run 1	Run 2
Run Ambient Temperature Range	°C	2 - 7	2 - 7

Method Deviations

Nature of Deviation	Run Number		
	1	2	
(x = deviation applies to the associated run)			
There are no deviations associated with the sampling employed.	x	x	

OXYGEN: MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1	RUN 2	Units
Limit value	N/A	N/A	%vol
TGN M2 Allowable MU	6.0	6.0	%
Measured concentration	20.61	20.38	%vol
Range Used	25.0	25.0	%vol
Cal gas conc.	21.1	21.1	%vol

Performance characteristics	RUN 1	RUN 2	Units
Response time	41	41	seconds
Number of readings in measurement	32	32	-
Repeatability at zero	0.02	0.02	% full scale
Repeatability at span level	0.02	0.02	% full scale
Deviation from linearity	0.02	0.02	% of value
Zero drift	-0.23	-0.23	% full scale
Span drift	-0.77	-0.77	% full scale
Volume or pressure flow dependence	0.10	0.10	% of full scale
Atmospheric pressure dependence	0.19	0.19	% of value/kPa
Ambient temperature dependence	-0.21	-0.21	% full scale/10K
Combined interference	0.00	0.00	% range
Dependence on voltage	0.02	0.02	% full scale/10V
Losses in the line (leak)	0.00	0.00	% of value
Uncertainty of calibration gas	2.00	2.00	% of value

Performance characteristic	RUN 1	RUN 2	Units
Standard deviation of repeatability at zero	use rep at span	use rep at span	%vol
Standard deviation of repeatability at span level	0.00	0.00	%vol
Lack of fit	0.00	0.00	%vol
Drift	-0.12	-0.12	%vol
Volume or pressure flow dependence	0.00	0.00	%vol
Atmospheric pressure dependence	0.01	0.01	%vol
Ambient temperature dependence	-0.03	-0.03	%vol
Combined interference (from MCERTS Certificate)	0.00	0.00	%vol
Dependence on voltage	0.00	0.00	%vol
Losses in the line (leak)	0.00	0.00	%vol
Uncertainty of calibration gas	0.24	0.24	%vol

Measurement uncertainty	Result	RUN 1	RUN 2	Units
Combined uncertainty		20.61	20.38	%vol
Expanded uncertainty	k = 1.96	0.27	0.27	%vol
		0.53	0.52	%vol

	RUN 1	RUN 2	Units
Expanded uncertainty (no O ₂) - at 95% Confidence	2.55	2.56	% of Value
Result of Compliance with Uncertainty Requirement in M2	COMPLIANT	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.