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Stack Emissions Testing Report Commissioned by
Barden Energy Ltd

Installation Name & Address
Barden Energy Ltd
Ellel Crag Quarry
Ellel
Lancaster
Lancashire
LA2 0PY

Stack Reference
999 kW Ariterm Boiler

Dates of the Monitoring Campaign
24th August 2015

Job Reference Number
CAT-2368

Report Written by
Brian Jacob Team Leader MCERTS Level 2 MM 06 693 TE1 TE2 TE3 TE4

Report Approved by
Matthew Pendlebury Team Leader MCERTS Level 2 MM 04 535 TE1 TE2 TE3 TE4

Report Date
9th September 2015

Version
Version 1

Signature of Report Approver

CONTENTS

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MONITORING OBJECTIVES

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler
24th August 2015

Overall Aim of the Monitoring Campaign

Exova Catalyst were commissioned by Barden Energy Ltd to carry out stack emissions testing on the 999 kW Ariterm Boiler at Lancaster.

The aim of the monitoring campaign was to perform testing of an investigative nature under trial operation.

Special Requirements

There were no special requirements.

Target Parameters

Total Particulate Matter, Total VOCs (as Carbon), Oxides of Nitrogen (as NO_2), Carbon Monoxide

Executive Summary

MONITORING RESULTS

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler
24th August 2015

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	50.6		2.6	150	g/hr	78.7	6.3	2061
Total VOCs (as Carbon)	[1]	mg/m³	1.0		1.7	-	g/hr	1.6	2.7	-
Oxides of Nitrogen (as NO_2)	[1]	mg/m³	249		9.1	-	g/hr	387	27.5	-
Carbon Monoxide	[1]	mg/m³	163		5.6	-	g/hr	253	17.7	-
Carbon Dioxide		% v/v	**Dry**	14.6	0.37					
Oxygen		% v/v	**Dry**	5.53	0.27					
Water Vapour		% v/v	7.2		0.37					
Stack Gas Temperature		°C	120							
Stack Gas Velocity		m/s	10.9		0.44					
Volumetric Flow Rate (ACTUAL)		m³/hr	2416		147					
Volumetric Flow Rate (REF)	[1]	m³/hr	1557		94.5					

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

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

Executive Summary

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MONITORING DATE(S) & TIMES

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler
24th August 2015

Parameter		Units	Concentration	Units	Mass Emission	Sampling Date(s)	Sampling Times	Duration mins
Total Particulate Matter	R1	mg/m³	50.0	g/hr	77.8	24/08/2015	11:08 - 12:08	60
Total Particulate Matter	R2	mg/m³	48.9	g/hr	76.2	24/08/2015	12:14 - 13:14	60
Total Particulate Matter	R3	mg/m³	50.7	g/hr	78.9	24/08/2015	13:21 - 14:21	60
Total Particulate Matter	R4	mg/m³	53.4	g/hr	83.1	24/08/2015	14:26 - 15:26	60
Total Particulate Matter	R5	mg/m³	49.9	g/hr	77.6	24/08/2015	15:31 - 16:31	60
Total VOCs (as Carbon)	R1	mg/m³	1.03	g/hr	1.6	24/08/2015	11:08 - 16:30	322
Oxides of Nitrogen (as NO_2)	R1	mg/m³	249	g/hr	387	24/08/2015	11:08 - 16:30	322
Carbon Monoxide	R1	mg/m³	163	g/hr	253	24/08/2015	11:08 - 16:30	322
Carbon Dioxide	R1	% v/v	14.6			24/08/2015	11:08 - 16:30	322
Oxygen	R1	% v/v	5.68			24/08/2015	11:08 - 16:30	322
Velocity & Volumetric Flow Rate	R1					24/08/2015	10:15 - 10:25	

All results are expressed at the respective reference conditions.

PROCESS DETAILS

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler
24th August 2015

Standard Operating Conditions

Parameter	Value
Process Status	Normal Operation
Capacity (of 100%) and Tonnes / Hour	100% of Capacity - 999 kWe
Continuous or Batch Process	Continuous
Feedstock (if applicable)	Virgin Woodchip
Abatement System	Cyclone
Abatement System Running Status	On
Fuel	Woodchip
Plume Appearance	No Visible Plume

Executive Summary

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MONITORING & ANALYTICAL METHODS

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler
24th August 2015

	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	0.18 mg/m³
Water Vapour	EN 14790	CAT-TP-05	Yes	CAT	CAT-TP-05	Gravimetric	Yes	CAT	Yes	0.10 % v/v
Total VOCs (as Carbon)	EN 12619:2013	CAT-TP-20	Yes	CAT	Flame Ionisation Detection by Sick 3006 FID				Yes	0.32 mg/m³
Oxides of Nitrogen (as NO_2)	EN 14792	CAT-TP-21	Yes	CAT	Chemiluminescence by Horiba PG-250				Yes	0.41 mg/m³
Carbon Monoxide	EN 15058	CAT-TP-21	Yes	CAT	NDIR by Horiba PG-250				Yes	0.70 mg/m³
Carbon Dioxide	ISO 12039	CAT-TP-21	Yes	CAT	NDIR by Horiba PG-250				Yes	0.10 % v/v
Oxygen	EN 14789	CAT-TP-21	Yes	CAT	Dry Zirconia Cell by Horiba PG-250				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

SUMMARY OF SAMPLING DEVIATIONS

Parameter	Run	Deviation
All Parameters	All Runs	There are no deviations associated with the sampling employed.

SUITABILITY OF SAMPLING LOCATION

Duct Characteristics

Parameter	Units	Value
Type	-	Circular
Depth	m	0.28
Width	m	-
Area	m²	0.06
Port Depth	cm	9
Orientation of Duct	-	Vertical
Sample Port Size	-	4" BSP

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	Yes
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	Yes
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

The sampling location meets all the requirements specified in EA Guidance Note M1 and EN 15259, and therefore there are no improvement recommendations.

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	80.0		> 5 Pa	Yes
Mean Velocity	m/s	11.28		-	-
Lowest Gas Velocity	m/s	11.28		-	-
Highest Gas Velocity	m/s	11.28		-	-
Ratio of Above	: 1	1.00		< 3 : 1	Yes
Maximum Angle of Swirl	°	0		< 15°	Yes
No Local Negative Flow	-	Yes		-	Yes

Executive Summary

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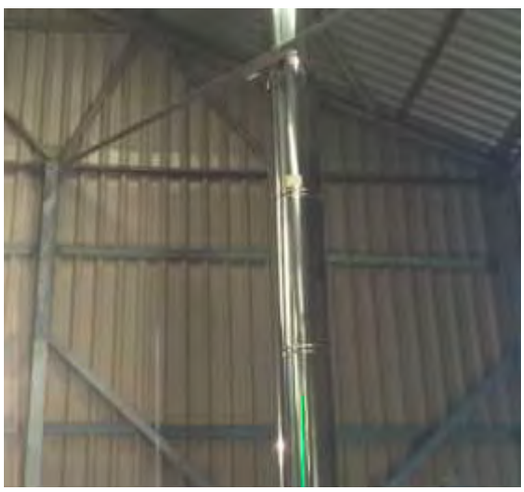
PLANT PHOTOS

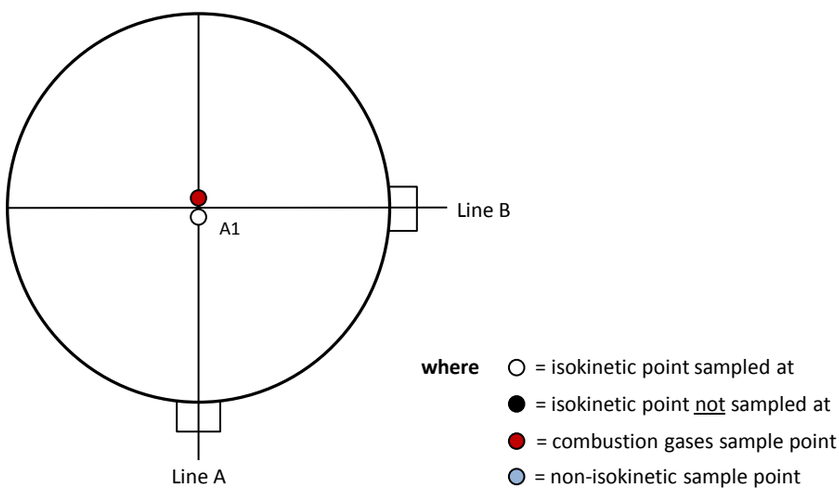
Photo 1

Photo 2

Photo 3



SAMPLE POINTS



APPENDIX CONTENTS

STACK EMISSIONS MONITORING PERSONNEL

Position	Name	MCERTS Accreditation	MCERTS Number	Technical Endorsements
Team Leader	Brian Jacob	MCERTS Level 2	MM 06 693	TE1 TE2 TE3 TE4
Technician	Darius Niknejad	MCERTS Level 1	MM 09 1036	None

LIST OF EQUIPMENT

Extractive Sampling	
Equipment Type	**Equipment I.D.**
Control Box DGM (1)	CAT 7.39
Control Box DGM (2)	-
Box Thermocouples (1)	CAT 3.10
Box Thermocouples (2)	-
Umbilical (1)	CAT 3.10
Umbilical (2)	-
Oven Box (1)	-
Oven Box (2)	-
Heated Probe (1)	-
Heated Probe (2)	-
Heated Probe (3)	-
S-Pitot (1)	CAT 21s.19
S-Pitot (2)	CAT 21p.43
L-Pitot	-
500g Check Weight	CAT 17.13
1Kg Check Weight	CAT 17.13
Last Impinger Arm	-
Callipers	CAT 23.10
Tubes Kit Thermocouple	-

Instrumental Analysers	
Equipment Type	**Equipment I.D.**
Horiba PG-250	CAT 9.9
Horiba PG-250	-
Servomex 4900	-
Eco Physics CLD 822Mh	-
ABB AO2020-URAS26	-
Servomex 5200MP	-
JCT JCC P1 Cooler	CAT 4.135
Gasmet DX4000	-
Gasmet Sampling System	-
Bernath 3006 FID	-
Ankersmid APP100	CAT 12.74
Mass Flow Controller (1)	CAT 6.3
Mass Flow Controller (2)	CAT 6.4
Mass View (1)	-
Mass View (2)	-
Easylogger EN-EL-12 Bit	CAT 11.55
Easylogger EN-EL-12 Bit	-
Bioaerosols Temperature Logger	-
Electronic Refrigerator	-

Miscellaneous Items	
Equipment Type	**Equipment I.D.**
Digital Manometer (1)	CAT 3.25
Digital Manometer (2)	-
Digital Temperature Meter	CAT 3.25
Stopwatch	CAT 14.53
Barometer	CAT 13.20
0	CAT 4.715
Stack Thermocouple (2)	-
Stack Thermocouple (3)	-
1m Heated Line (1)	-
1m Heated Line (2)	-
1m Heated Line (3)	-
5m Heated Line (1)	-
15m Heated Line (1)	-
20m Heated Line (1)	-
20m Heated Line (2)	CAT 20.69
Dual Channel Heater Controller	-
Single Channel Heater Controller	-
Laboratory Balance	CAT 1.18 / 1.18a
Tape Measure	CAT 16.14

METHODS & TECHNICAL PROCEDURES USED

Parameter	Standard	Technical Procedure
Total Particulate Matter	EN 13284-1	CAT-TP-01
Water Vapour	EN 14790	CAT-TP-05
Total VOCs (as Carbon)	EN 12619:2013	CAT-TP-20
Oxides of Nitrogen (as NO_2)	EN 14792	CAT-TP-21
Carbon Monoxide	EN 15058	CAT-TP-21
Carbon Dioxide	ISO 12039	CAT-TP-21
Oxygen	EN 14789	CAT-TP-21
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	0.28
Stack Width, W	m	-
Stack Area, A	m²	0.06
Average Stack Gas Temperature, T_a	°C	117
Average Stack Gas Pressure	Pa	80.0
Average Stack Static Pressure, P_{static}	kPa	-0.03
Average Barometric Pressure, P_b	kPa	101.3
Average Pitot Tube Calibration Coefficient, C_p	-	0.86

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	-	14.59	13.55	0.1459	44.01	1.9635	0.2865
O_2	-	5.53	5.14	0.0553	32.00	1.4277	0.0790
N_2	-	79.87	74.15	0.7987	28.01	1.2498	0.9983
Moisture (H_2O)	-	-	7.16	0.0716	18.02	0.8037	0.0575

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	1.364
Wet Density (STP), P_{STW}	kg/m³	1.324
Dry Density (Actual), P_{Actual}	kg/m³	0.954
Average Wet Density (Actual), $P_{ActualW}$	kg/m³	0.926

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	117	0.00
Total Pressure	kPa	101.3	101.3
Moisture	%	7.2	0.00

Gas Volumetric Flowrate (from Traverse)	Units	Result
Gas Volumetric Flowrate (Actual)	m³/hr	2501
Gas Volumetric Flowrate (STP, Wet)	m³/hr	1750
Gas Volumetric Flowrate (STP, Dry)	m³/hr	1625
Gas Volumetric Flowrate REF [1]	m³/hr	1625

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

(1 of 1)

Parameter	Units	Value
Date of Survey	-	24/08/2015
Time of Survey	-	10:15 - 10:25
Atmospheric Pressure	kPa	101.3
Average Stack Static Pressure	Pa	-29
Result of Pitot Stagnation Test	-	Pass
Are Water Droplets Present?	-	No
Device Used	S-Type Pitot with KIMO MP 200 (500Pa)	

Parameter	Units	Value
Initial Pitot Leak Check	-	Pass
Final Pitot Leak Check	-	Pass
Orientation of Duct	-	Vertical
Pitot Tube, C_p	-	0.86
Number of Lines Available	-	2
Number of Lines Used	-	1

		Sampling Line A					Sampling Line B				
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)		*-29.0*									
Mean		**80.0**	**117.0**	**0.926**	**11.28**						
1	0.14	80.0	117.0	0.926	11.28	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(Δpi)	1.495	Pa
- Resolution	u(res)	0.00087	
- Calibration	u(cal)	0.666	
- Drift	u(drift)	0.083	
- Lack of Fit	u(fit)	0.485	
- Overall corrections to dynamic measurements	u(Cf)	1.236	
Standard uncertainty associated with the molar mass of the gas	u(M)	0.00008	-
- $\varphi O_2,w$	-	5.139	
- $\varphi CO_2,w$	-	13.548	
- Oxygen, dry	u(ϕO_2,d)	0.169	
- Carbon Dioxide, dry	u(ϕCO_2,d)	0.447	
- Water Vapour	u(ϕH_2O)	0.365	
- Oxygen, wet	u(ϕO_2,w)	0.159	
- Carbon Dioxide, wet	u(ϕCO_2,w)	0.418	
Standard uncertainty associated with the stack temperature	u(Tc)	1.990	K
Standard uncertainty associated with the absolute pressure in the duct	u(pc)	175.698	Pa
- Atmospheric Pressure	u(patm)	175.692	
- Static Pressure	u(pstat)	1.495	
Standard uncertainty associated with the density in the duct	u(ρ)	0.00499	-
Standard uncertainty associated with the local velocities	u(vi)	0.233	Pa
Standard uncertainty associated with the mean velocity	u(v)	0.233	m/s
Standard uncertainty associated with the mean velocity (95% Confidence)	Uc(v)	0.457	m/s
Standard uncertainty associated with the mean velocity (95% Confidence), relative	Uc,rel(v)	4.05	%
Standard uncertainty associated with the volume flow rate (95% Confidence)	Uc(qV,w)	151.9	m^3/hr
- $u^2(a)/a^2$	-	0.00053	
- $u^2(qV,w)/q^2V,w$	-	0.00096	
- $u^2(qV,w)$	-	6003	
- u(qV,w)	-	77.5	
Standard uncertainty associated with the volume flow rate (95% Confidence), relative	Uc,rel(qV,w)	6.07	%

TOTAL PARTICULATE MATTER: RESULTS SUMMARY

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Run 5	Mean
Concentration	mg/m³	50.0	48.9	50.7	53.4	49.9	50.6
Uncertainty	±mg/m³	2.5	2.5	2.6	2.8	2.6	2.6
Mass Emission	g/hr	77.8	76.2	78.9	83.1	77.6	78.7
Uncertainty	±g/hr	6.1	6.0	6.3	6.7	6.2	6.3

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Run 5	Mean
Water Vapour	% v/v	5.11	8.18	8.50	6.40	7.60	7.16
Uncertainty	±% v/v	0.26	0.42	0.45	0.34	0.40	0.37

Blank Runs

Parameter	Units	Blank 1		Maximum
Concentration	mg/m³	0.18		0.18

NOTE: Where the Balance Uncertainty / Limit of Detection is higher than the Blank concentration, the Balance Uncertainty / Limit of Detection concentration has been reported.

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 / 1	FORMAT: Number Used / Number Required
Number of Sampling Points Used	1 / 1	FORMAT: Number Used / Number Required
Sample Point I.D.'s	A1	

Reference Conditions

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

TOTAL PARTICULATE MATTER: ISOKINETIC SAMPLING CALCULATIONS

Test	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Absolute pressure of stack gas, P_s						
Barometric pressure, P_b	mmHg	759.8	759.8	759.8	759.8	759.8
Stack static pressure, P_{static}	mmH_2O	-2.9	-2.9	-2.9	-2.9	-2.9
$P_s = (P_b + (P_{static} / 13.6)$	mmHg	759.5	759.5	759.5	759.5	759.5
Volume of water vapour collected, V_{wstd}						
Total mass collected in impingers (liquid trap)	g	38.5	54.1	52.3	34.8	36.5
Total mass collected in impingers (silica trap)	g	-4.8	-0.1	2.9	2.3	10.6
Total mass of liquid collected, V_{lc}	g	33.7	54.0	55.2	37.1	47.1
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.0420	0.0673	0.0688	0.0462	0.0587
Volume of gas metered dry, V_{mstd}						
Volume of gas sample through gas meter, V_m	m^3	0.8330	0.8160	0.8080	0.7430	0.7850
Gas meter correction factor, Y_d	-	1.0110	1.0110	1.0110	1.0110	1.0110
Average dry gas meter temperature, T_m	°C	22.2	25.8	28.7	31.0	31.1
Average pressure drop across orifice, ΔH	mmH_2O	22.8	21.1	18.3	18.0	17.6
$V_{mstd} = ((0.3592)(V_m)(P_b + (\Delta H/13.6))(Y_d)) / (T_m + 273)$	m^3	0.7803	0.7549	0.7403	0.6755	0.7134
Moisture content, B_{wo} & R_{wv}						
$B_{wo} = V_{wstd} / (V_{mstd} + V_{wstd})$	m^3	0.0511	0.0818	0.0850	0.0640	0.0760
B_{wo} as a percentage	% v/v	5.11	8.18	8.50	6.40	7.60
Reported Water Vapour, checked with Tables in EN 14790, Rwv	% v/v	5.11	8.18	8.50	6.40	7.60
Volume of gas metered wet, V_{mstw}						
$V_{mstw} = (V_{mstd})(100/(100 - R_{wv}))$	m^3	0.8222	0.8222	0.8091	0.7217	0.7721
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	No	No	No	No
% wet oxygen measured in gas stream, $ACT\%O_{2w}$	% v/v	N/A	N/A	N/A	N/A	N/A
% dry oxygen measured in gas stream, $ACT\%O_{2d}$	% v/v	N/A	N/A	N/A	N/A	N/A
% oxygen reference condition, $REF\%O_2$	% v/v	N/A	N/A	N/A	N/A	N/A
O_2 Reference Factor wet $(O_{2REFw}) = (21 - REF\%O_2) / (21 - ACT\%O_{2w})$	-	N/A	N/A	N/A	N/A	N/A
O_2 Reference Factor dry $(O_{2REFd}) = (21 - REF\%O_2) / (21 - ACT\%O_{2d})$	-	N/A	N/A	N/A	N/A	N/A
$V_{mstw@X\%oxygen} = (V_{mstw}) / (O_{2REFw})$	m^3	N/A	N/A	N/A	N/A	N/A
$V_{mstd@X\%oxygen} = (V_{mstd}) / (O_{2REFd})$	m^3	N/A	N/A	N/A	N/A	N/A
Molecular weight of dry gas stream, M_d						
CO_2	% v/v	15.00	14.00	15.00	15.00	15.00
O_2	% v/v	6.12	5.60	5.46	5.11	5.11
Total	% v/v	21.12	19.60	20.46	20.11	20.11
N_2	% v/v	78.88	80.40	79.54	79.89	79.89
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$	g/gmol	30.64	30.46	30.62	30.60	30.60
Molecular weight of stack gas (wet), M_s						
$M_s = M_d(1 - (R_{wv}/100)) + 18(R_{wv}/100)$	g/gmol	30.00	29.44	29.55	29.80	29.65
Velocity of stack gas, V_s						
Pitot tube velocity constant, K_p	-	34.97	34.97	34.97	34.97	34.97
Velocity pressure coefficient, C_p	-	0.85	0.85	0.85	0.85	0.85
Average of velocity heads, ΔP_{avg}	mmH_2O	8.80	8.50	7.28	7.10	6.95
Average square root of velocity heads, √ΔP	$\sqrt{mmH_2O}$	2.97	2.92	2.70	2.66	2.64
Average stack gas temperature, T_s	°C	119.1	121.9	120.3	119.8	120.0
$V_s = ((K_p)(C_p)(\sqrt{\Delta P})(\sqrt{T_s} + 273)) / (\sqrt{(M_s)(P_s)})$	m/s	11.57	11.52	10.61	10.43	10.35
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	0.06	0.06	0.06	0.06	0.06
$Q_a = (60)(A_s)(V_s)$	m^3/min	42.7	42.6	39.2	38.6	38.3
Conversion factor (K/mm.Hg), C_f	-	0.3592	0.3592	0.3592	0.3592	0.3592
$Q_{stw} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273)$	m^3/min	29.7	29.4	27.2	26.8	26.6
$Q_{std} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273)$	m^3/min	28.2	27.0	24.9	25.1	24.5
$Q_{stwO_2} = ((Q_a)(P_s)(C_f)) / ((T_s) + 273) / (O_{2REFw})$	m^3/min	N/A	N/A	N/A	N/A	N/A
$Q_{stdO_2} = ((Q_a)(P_s)(C_f)(1 - (R_{wv}/100))) / ((T_s) + 273) / (O_{2REFd})$	m^3/min	N/A	N/A	N/A	N/A	N/A
Percent isokinetic, %I						
Nozzle diameter, D_n	mm	5.98	5.98	5.98	5.98	5.98
Nozzle area, A_n	mm^2	28.06	28.06	28.06	28.06	28.06
Total sampling time, q	min	60	60	60	60	60
$\%I = (4.6398E^6)(T_s+273)(V_{mstd}) / (P_s)(V_s)(A_n)(q)(1 - (R_{wv}/100))$	%	101.1	102.3	108.8	98.6	106.3

TOTAL PARTICULATE MATTER: SAMPLING DETAILS

Sample Runs

Parameter	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Sampling Times	-	11:08 - 12:08	12:14 - 13:14	13:21 - 14:21	14:26 - 15:26	15:31 - 16:31
Sampling Dates	-	24/08/2015	24/08/2015	24/08/2015	24/08/2015	24/08/2015
Sampling Device	-	ISO	ISO	ISO	ISO	ISO
Volume Sampled (REF)	m^3	0.7803	0.7549	0.7403	0.6755	0.7134
Filter I.D. Number	-	47-28171	47-28172	47-28173	47-28174	47-28175
Start Filter Mass	g	0.14024	0.13952	0.13931	0.14082	0.13951
End Filter Mass	g	0.17575	0.17415	0.17412	0.17441	0.17250
Total Mass on Filter	g	0.03551	0.03463	0.03481	0.03359	0.03299
Probe Rinse I.D. Number	-	PR-47-28171	PR-47-28172	PR-47-28173	PR-47-28174	PR-47-28175
Start Probe Rinse Mass	g	2.99832	3.06516	3.02662	3.00851	3.26634
End Probe Rinse Mass	g	3.00179	3.06748	3.02932	3.01097	3.26893
Total Mass in Probe Rinse	g	0.00347	0.00232	0.00270	0.00246	0.00259
Total Mass Collected	mg	38.98	36.95	37.51	36.05	35.58
Calculated Concentration	mg/m^3	49.95	48.95	50.67	53.36	49.88
Balance Uncertainty / LOD	mg/m^3	0.17	0.17	0.18	0.19	0.18

Where: ISO stands for Manual Isokinetic Sampling Train

Blank Runs

Parameter	Units	Blank 1	
Blank Dates	-	24/08/2015	
Average Volume Sampled (REF)	m^3	0.7329	
Filter I.D. Number	-	47-28199	
Start Filter Mass	g	0.14021	
End Filter Mass	g	0.14027	
Total Mass on Filter	g	0.00006	
Probe Rinse I.D. Number	-	PR-47-28199	
Start Probe Rinse Mass	g	2.99629	
End Probe Rinse Mass	g	2.99629	
Total Mass in Probe Rinse	g	0.00000	
Total Mass Collected	mg	0.06	
Calculated Concentration	mg/m^3	0.08	
Balance Uncertainty / LOD	mg/m^3	0.18	

TOTAL PARTICULATE MATTER: QUALITY ASSURANCE

Sample Runs

Leak Test Results	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Mean Sampling Rate	l/min	14.0	13.7	13.6	12.5	13.2
Pre-Sampling Leak Rate	l/min	0.10	0.12	0.10	0.11	0.14
Post-Sampling Leak Rate	l/min	0.12	0.10	0.15	0.15	0.14
Allowable Leak Rate	l/min	0.28	0.27	0.27	0.25	0.26
Leak Test Acceptable	-	Yes	Yes	Yes	Yes	Yes

Water Droplets	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Are Water Droplets Present	-	No	No	No	No	No

MU (Concurrent Water Vapour)	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Measurement Uncertainty (MU)	%	5.1	5.1	5.2	5.3	5.3
Allowable MU	%	20	20	20	20	20
MU Acceptable	%	Yes	Yes	Yes	Yes	Yes

Silica Gel (Concurrent Water Vapour)	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Less than 50% Faded	%	Yes	Yes	Yes	Yes	No

Isokinetic Criterion Compliance	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Isokinetic Variation	%	101.1	102.3	108.8	98.6	106.3
Allowable Isokinetic Range	%	95 - 115	95 - 115	95 - 115	95 - 115	95 - 115
Isokineticity Acceptable	-	Yes	Yes	Yes	Yes	Yes

Weighing Uncertainty Criteria	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Overall Weighing Uncertainty	± mg	0.24	0.24	0.24	0.24	0.24
Overall Weighing Uncertainty	± mg/m³	0.31	0.32	0.33	0.36	0.34
ELV [Daily ELV for IED]	mg/m³	150	150	150	150	150
Allowable Weighing Uncertainty	mg/m³	7.50	7.50	7.50	7.50	7.50
Weighing Uncertainty Acceptable	-	Yes	Yes	Yes	Yes	Yes

Filter Temperatures	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Pre-Conditioning Temperature	°C	180	180	180	180	180
Post-Conditioning Temperature	°C	160	160	160	160	160
Maximum Filter Temperature	°C	119	122	120	120	120

Test Conditions	Units	Run 1	Run 2	Run 3	Run 4	Run 5
Ambient Temperature Recorded?	-	Yes	Yes	Yes	Yes	Yes

TOTAL PARTICULATE MATTER: QUALITY ASSURANCE

Blank Runs

Leak Test Results	Units	Blank 1	
Expected Sampling Rate	l/min	15.0	
Pre-Sampling Leak Rate	l/min	0.10	
Post-Sampling Leak Rate	l/min	0.11	
Allowable Leak Rate	l/min	0.30	
Leak Test Acceptable	-	Yes	

Validity of Blank vs ELV	Units	Blank 1	
Allowable Blank	mg/m^3	15.0	
Blank Acceptable	-	Yes	

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	2	3	4	5
There are no deviations associated with the sampling employed.	wx	wx	wx	wx	wx

TOTAL PARTICULATE MATTER: MEASUREMENT UNCERTAINTY CALCULATIONS

		Value						Standard uncertainty					
Measured Quantities	**Symbol**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Symbol**	**Units**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**
Sampled Volume (Actual)	V_m	0.83	0.82	0.81	0.74	0.79	uV_m	m^3	0.02	0.02	0.02	0.01	0.02
Sampled Gas Temperature	T_m	295.2	298.8	301.7	304.0	304.1	uT_m	K	2.00	2.00	2.00	2.00	2.00
Sampled Gas Pressure	ρ_m	101.3	101.3	101.3	101.3	101.3	$u\rho_m$	kPa	0.50	0.50	0.50	0.50	0.50
Sampled Gas Humidity	H_m	0.00	0.00	0.00	0.00	0.00	uH_m	% v/v	1.00	1.00	1.00	1.00	1.00
Leak	L	0.85	0.73	1.10	1.20	1.06	uL	%	-	-	-	-	-
Mass of Particulate	m	39.0	37.0	37.5	36.0	35.6	um	mg	0.13	0.13	0.13	0.13	0.13
Uncollected Mass	UCM	0.06	0.06	0.06	0.06	0.06	uUCM	mg	-	-	-	-	-

		Uncertainty as a Percentage					
Measured Quantities	**Units**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Requirement of Standard**
Sampled Volume (Actual)	%	2.00	2.00	2.00	2.00	2.00	≤2%
Sampled Gas Temperature	%	0.68	0.67	0.66	0.66	0.66	≤1%
Sampled Gas Pressure	%	0.49	0.49	0.49	0.49	0.49	≤1%
Sampled Gas Humidity	%	1.00	1.00	1.00	1.00	1.00	≤1%
Leak	%	0.85	0.73	1.10	1.20	1.06	≤2%
Mass of Particulate	%	0.11	0.11	0.12	0.13	0.12	<5% of ELV
Uncollected Mass	%	-	-	-	-	-	-

		Uncertainty in Measurement Units						Sensitivity Coefficient				
Measured Quantities	**Symbol**	**Units**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**
Sampled Volume (STP)	V_m	m^3	0.78	0.75	0.74	0.68	0.71	64.0	64.8	68.4	79.0	69.9
Leak	L	mg/m^3	0.25	0.21	0.32	0.37	0.30	1.00	1.00	1.00	1.00	1.00
Mass of Particulate	L_r	mg	39.0	37.0	37.5	36.0	35.6	1.28	1.32	1.35	1.48	1.40
Uncollected Mass	UCM	mg	0.03	0.03	0.03	0.03	0.03	1.28	1.32	1.35	1.48	1.40

		Uncertainty in Result				
Measured Quantities	**Units**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**
Sampled Volume (STP)	mg/m^3	1.25	1.23	1.29	1.36	1.27
Leak	mg/m^3	0.25	0.21	0.32	0.37	0.30
Mass of Particulate	mg/m^3	0.17	0.17	0.18	0.19	0.18
Uncollected Mass	mg/m^3	0.04	0.05	0.05	0.05	0.05

		Oxygen Correction Part of MU Budget				
Measured Quantities	**Units**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**
O_2 Correction Factor	-	N/A	N/A	N/A	N/A	N/A
Stack Gas O_2 Content	% v/v	N/A	N/A	N/A	N/A	N/A
MU for O_2 Correction	-	N/A	N/A	N/A	N/A	N/A
Overall MU For O_2 Measurement	%	N/A	N/A	N/A	N/A	N/A

Parameter	**Units**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**
Combined uncertainty	mg/m^3	1.29	1.26	1.34	1.43	1.32
Expanded uncertainty (95% confidence), without Oxygen Correction	mg/m^3	2.5	2.5	2.6	2.8	2.6
Expanded uncertainty (95% confidence), with Oxygen Correction	mg/m^3	N/A	N/A	N/A	N/A	N/A
Expanded uncertainty (95% confidence), estimated with Method Deviations	mg/m^3	2.5	2.5	2.6	2.8	2.6
Reported Uncertainty	mg/m^3	2.5	2.5	2.6	2.8	2.6
Expanded uncertainty (95% confidence), without Oxygen Correction	%	5.0	5.1	5.2	5.2	5.2
Expanded uncertainty (95% confidence), with Oxygen Correction	%	N/A	N/A	N/A	N/A	N/A
Expanded uncertainty (95% confidence), estimated with Method Deviations	%	5.0	5.1	5.2	5.2	5.2
Reported Uncertainty	%	5.0	5.1	5.2	5.2	5.2

TOTAL VOCs (as CARBON): RESULTS SUMMARY

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler

Sample Runs

Parameter	Units	Run 1		Mean
Concentration	mg/m³	1.0		1.0
Uncertainty	±mg/m³	1.7		1.7
Mass Emission	g/hr	1.6		1.6
Uncertainty	±g/hr	2.7		2.7

General Sampling Information

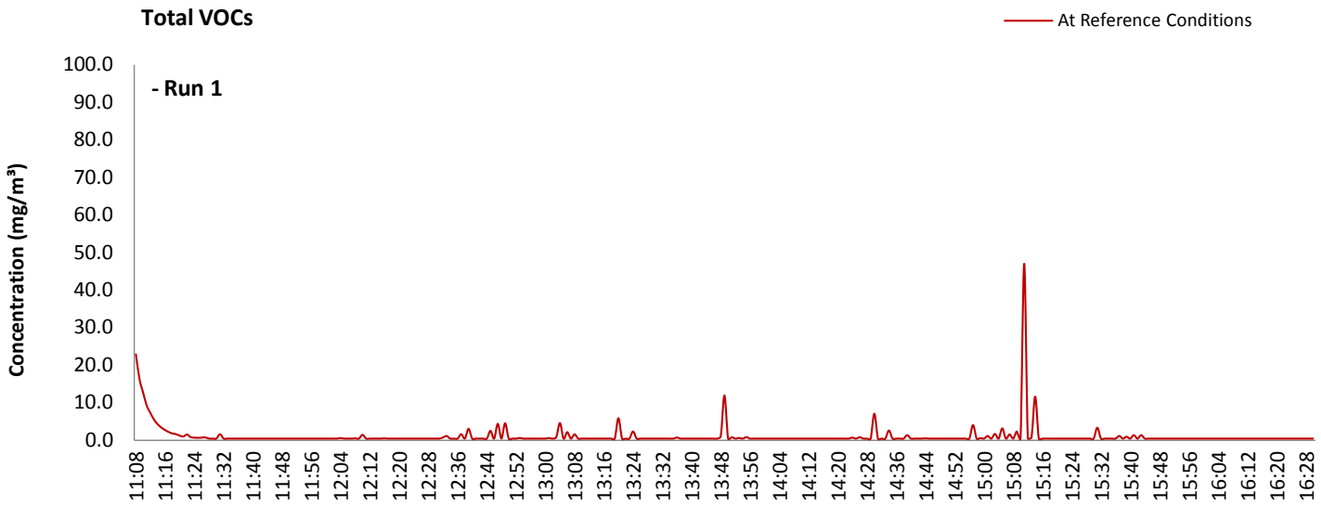
Parameter	Value	
Standard	EN 12619:2013	
Technical Procedure	CAT-TP-20	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Span Gas Type	Propane in 5% O_2 in N_2 (5 Grade)	
Span Gas Reference Number	CYL 1.0135 in N_2 | CYL 1.1085 in AIR	
Span Gas Expiry Date	23/12/2019 | 15/07/2020	
Span Gas Start Pressure (bar)	100 | 100	
Gas Cylinder Concentration (ppm)	79.85 | 80.8	
Span Gas Set Point (ppm)	80.72	This is the blended concentration of both propane cylinders
Span Gas Uncertainty (%)	2 | 2	
Zero Gas Type	5% O_2 in N_2 (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	A1	

Reference Conditions

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

TOTAL VOCs (as CARBON): DATA TREND

Graphical Trend of Data



TOTAL VOCs (as CARBON): SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	
Sampling Times	-	11:08 - 16:30	
Sampling Dates	-	24/08/2015	
Instrument Range	ppm	100	
Span Gas Value	ppm	80.7	

Quality Assurance

	Zero Drift	Units	Run 1	
CAL 1	Zero Down Sampling Line (Pre)	ppm	0.20	
	Zero Down Sampling Line (Post)	ppm	-0.70	
	Zero Drift	ppm	-0.90	
	Allowable Zero Drift	± ppm	4.04	
	Zero Drift Acceptable	-	Yes	

	Span Drift	Units	Run 1	
CAL 1	Span Down Sampling Line (Pre)	ppm	79.8	
	Span Down Sampling Line (Post)	ppm	78.3	
	Span Drift	ppm	-1.50	
	Allowable Span Drift	± ppm	4.04	
	Span Drift Acceptable	-	Yes	

Test Conditions	Units	Run 1	
Run Ambient Temperature Range	°C	14 - 15	

Method Deviations

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

TOTAL VOCs (as CARBON): MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1		Units
Limit value	-		mg/m³ (REF)
TGN M2 Allowable MU	15.0		%
Measured concentration	1.03		mg/m³ (STP, dry)
Range Used	100.0		ppm
Range Used [A]	160.6		mg/m³
Cal gas conc.	80.7		ppm
Conversion	1.61		ppm to mg/m³
MCERTS Range [B]	15.0		mg/m³
Lower of [A] or [B]	15.0		mg/m³
Cal gas conc.	129.6		mg/m³

Performance characteristics	RUN 1		Units
Response time	45		seconds
Number of readings in measurement	322		-
Repeatability at zero	2.00		% full scale
Repeatability at span level	0.00		% full scale
Deviation from linearity	0.16		% of value
Zero drift	-1.13		% full scale
Span drift	-1.88		% full scale
Volume or pressure flow dependence	1.60		% of full scale
Atmospheric pressure dependence	0.30		% of value/kPa
Ambient temperature dependence	1.40		% full scale/10K
Combined interference	0.45		% range
Dependence on voltage	0.50		% full scale/10V
Losses in the line (leak)	1.11		% of value
Uncertainty of calibration gas	2.83		% of value

Performance characteristic	RUN 1		Units
Standard deviation of repeatability at zero	use rep at span		mg/m³
Standard deviation of repeatability at span level	0.00		mg/m³
Lack of fit	0.01		mg/m³
Drift	-0.86		mg/m³
Volume or pressure flow dependence	0.00		mg/m³
Atmospheric pressure dependence	0.01		mg/m³
Ambient temperature dependence	0.20		mg/m³
Combined interference (from MCERTS Certificate)	0.04		mg/m³
Dependence on voltage	0.06		mg/m³
Losses in the line (leak)	0.01		mg/m³
Uncertainty of calibration gas	0.02		mg/m³

			RUN 1		Units
Measurement uncertainty		**Result**	1.03		mg/m³
Combined uncertainty			0.88		mg/m³
Expanded uncertainty	k =	1.96	1.73		mg/m³
Uncertainty corrected to std conds. (O_2)			1.73		mg/m³ (REF)

	RUN 1		Units
Expanded uncertainty (no O_2) - at 95% Confidence	168.37		% of Value
Expanded uncertainty (no O_2) - at 95% Confidence	N/A		% at ELV
Overall Allowable uncertainty (no O_2) - at 95% Confidence	N/A		% at ELV
Result of Compliance with Uncertainty Requirement in M2	N/A		-

	RUN 1		Units
Expanded uncertainty (with O_2) - at 95% Confidence	N/A		% of Value
Expanded uncertainty (with O_2) - at 95% Confidence	N/A		% at ELV
Overall Allowable uncertainty (with O_2) - at 95% Confidence	N/A		% at ELV
Result of Compliance with Uncertainty Requirement in M2	**N/A**		-

Requirement for SRM is that Uncertainty should be <15% of the value at the ELV, on a dry gas basis, or if O_2 correction is applied less than 15% + the uncertainty associated with the O_2 correction (using sqrt of sum squares to add uncertainty components). Ref EA TGN M2.

OXIDES OF NITROGEN (as NO_2): RESULTS SUMMARY

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler

Sample Runs

Parameter	Units	Run 1		Mean
Concentration	mg/m³	249		249
Uncertainty	±mg/m³	9.1		9.1
Mass Emission	g/hr	387		387
Uncertainty	±g/hr	27.5		27.5

General Sampling Information

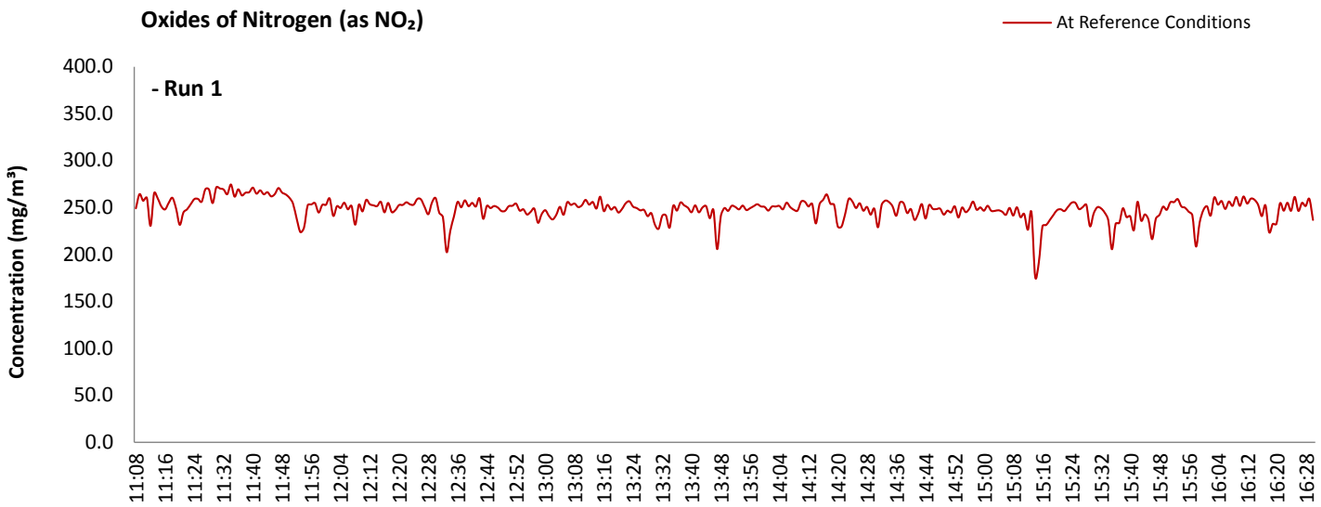
Parameter	Value	
Standard	EN 14792	
Technical Procedure	CAT-TP-21	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Date & Result of Last Converter Check	31/10/2014 - 95.7%	
Span Gas Type	Nitrogen Monoxide	
Span Gas Reference Number	CYL 4.0155	
Span Gas Expiry Date	15/07/2019	
Span Gas Start Pressure (bar)	200	
Gas Cylinder Concentration (ppm)	404.89	NOTE: Dilution performed to achieve correct span value
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	B1	

Reference Conditions

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

OXIDES OF NITROGEN (as NO_2): DATA TREND

Graphical Trend of Data



OXIDES OF NITROGEN (as NO_2): SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	
Sampling Times	-	11:08 - 16:30	
Sampling Dates	-	24/08/2015	
Instrument Range	ppm	100	
Span Gas Value	ppm	80.0	

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)	ppm	0.20	
	Zero Down Sampling Line (Post)	ppm	0.90	
	Zero Drift	ppm	0.70	
	Allowable Zero Drift	± ppm	4.00	
	Zero Drift Acceptable	-	Yes	

	Span Drift	Units	Run 1	
CAL 1	Span Down Sampling Line (Pre)	ppm	80.2	
	Span Down Sampling Line (Post)	ppm	81.4	
	Span Drift	ppm	1.20	
	Allowable Span Drift	± ppm	4.00	
	Span Drift Acceptable	-	Yes	

Test Conditions	Units	Run 1	
Run Ambient Temperature Range	°C	14 - 15	

Method Deviations

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

OXIDES OF NITROGEN (as NO_2): MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1		Units
Limit value	-		mg/m³ (REF)
TGN M2 Allowable MU	10.0		%
Measured concentration	248.65		mg/m³ (STP, dry)
Ration NO / NO_2	5		%
Range Used	100.0		ppm
Range Used [A]	205.2		mg/m³
Cal gas conc.	80.0		ppm
Conversion	2.05		ppm to mg/m³
MCERTS Range [B]	125.0		mg/m³
Lower of [A] or [B]	125.0		mg/m³
Cal gas conc.	164.2		mg/m³

Performance characteristics	RUN 1		Units
Response time	60		seconds
Number of readings in measurement	322		-
Repeatability at zero	0.40		% full scale
Repeatability at span level	0.40		% full scale
Deviation from linearity	0.14		% of value
Zero drift	0.87		% full scale
Span drift	1.50		% full scale
Volume or pressure flow dependence	0.40		% of full scale
Atmospheric pressure dependence	0.30		% of value/kPa
Ambient temperature dependence	0.18		% full scale/10K
Combined interference	0.60		% range
Dependence on voltage	0.40		% full scale/10V
Converter efficiency	95.7		%
Losses in the line (leak)	0.00		% of value
Uncertainty of calibration gas blending	1.40		% 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		mg/m³
Standard deviation of repeatability at span level	0.02		mg/m³
Lack of fit	0.10		mg/m³
Drift	2.98		mg/m³
Volume or pressure flow dependence	0.00		mg/m³
Atmospheric pressure dependence	0.11		mg/m³
Ambient temperature dependence	0.03		mg/m³
Combined interference (from MCERTS Certificate)	0.43		mg/m³
Dependence on voltage	0.05		mg/m³
Converter efficiency	0.31		mg/m³
Losses in the line (leak)	0.00		mg/m³
Uncertainty of calibration gas blending	2.01		mg/m³
Uncertainty of calibration gas	2.87		mg/m³

			RUN 1		Units
Measurement uncertainty		**Result**	248.65		mg/m³
Combined uncertainty			4.65		mg/m³
Expanded uncertainty	k =	1.96	9.12		mg/m³
Uncertainty corrected to std conds. (O_2)			9.12		mg/m³ (REF)

	RUN 1		Units
Expanded uncertainty (no O_2) - at 95% Confidence	3.67		% of Value
Expanded uncertainty (no O_2) - at 95% Confidence	N/A		% at ELV
Overall Allowable uncertainty (no O_2) - at 95% Confidence	N/A		% at ELV
Result of Compliance with Uncertainty Requirement in M2	**N/A**		-

	RUN 1		Units
Expanded uncertainty (with O_2) - at 95% Confidence	N/A		% of Value
Expanded uncertainty (with O_2) - at 95% Confidence	N/A		% at ELV
Overall Allowable uncertainty (with O_2) - at 95% Confidence	N/A		% at ELV
Result of Compliance with Uncertainty Requirement in M2	**N/A**		-

Requirement for SRM is that Uncertainty should be <10% of the value at the ELV, on a dry gas basis, or if O_2 correction is applied less than 10% + the uncertainty associated with the O_2 correction (using sqrt of sum squares to add uncertainty components). Ref EA TGN M2.

CARBON MONOXIDE: RESULTS SUMMARY

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler

Sample Runs

Parameter	Units	Run 1		Mean
Concentration	mg/m³	163		163
Uncertainty	±mg/m³	5.6		5.6
Mass Emission	g/hr	253		253
Uncertainty	±g/hr	17.7		17.7

General Sampling Information

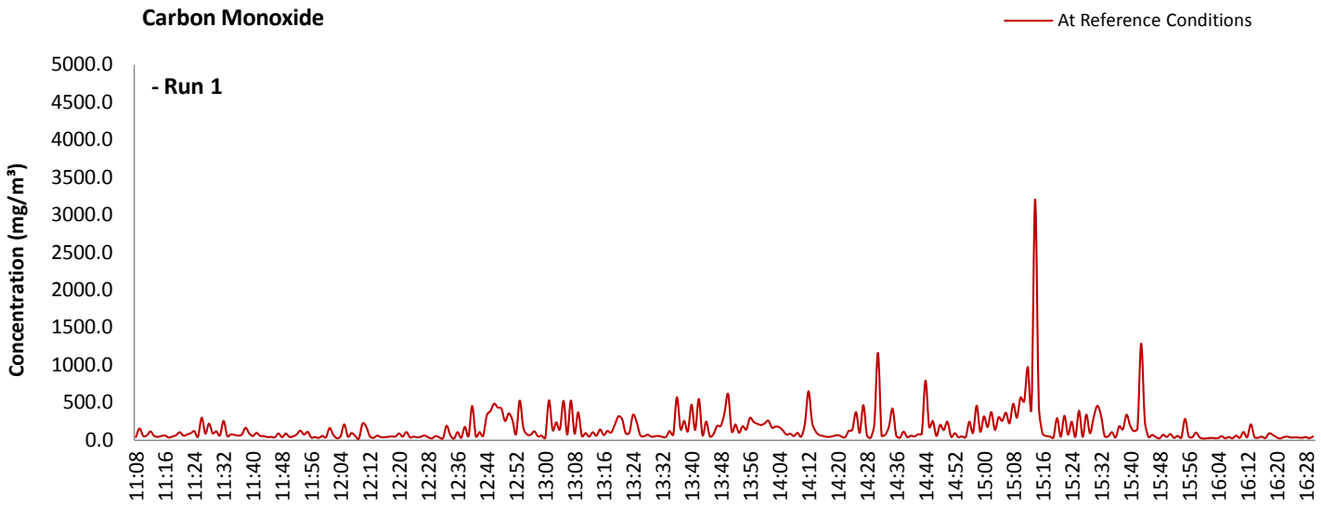
Parameter	Value	
Standard	EN 15058	
Technical Procedure	CAT-TP-21	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Span Gas Type	Carbon Monoxide	
Span Gas Reference Number	CYL 2.0105	
Span Gas Expiry Date	09/01/2020	
Span Gas Start Pressure (bar)	50	
Gas Cylinder Concentration (ppm)	399.25	NOTE: Dilution performed to achieve correct span value
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	B1	

Reference Conditions

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

CARBON MONOXIDE: DATA TREND

Graphical Trend of Data



CARBON MONOXIDE: SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	
Sampling Times	-	11:08 - 16:30	
Sampling Dates	-	24/08/2015	
Instrument Range	ppm	200	
Span Gas Value	ppm	160.0	

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)	ppm	0.20	
	Zero Down Sampling Line (Post)	ppm	-1.00	
	Zero Drift	ppm	-1.20	
	Allowable Zero Drift	± ppm	8.00	
	Zero Drift Acceptable	-	Yes	

	Span Drift	Units	Run 1	
CAL 1	Span Down Sampling Line (Pre)	ppm	159	
	Span Down Sampling Line (Post)	ppm	158	
	Span Drift	ppm	-1.00	
	Allowable Span Drift	± ppm	8.00	
	Span Drift Acceptable	-	Yes	

Test Conditions	Units	Run 1	
Run Ambient Temperature Range	°C	14 - 15	

Method Deviations

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

CARBON MONOXIDE: MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1		Units
Limit value	-		mg/m³ (REF)
TGN M2 Allowable MU	6.0		%
Measured concentration	162.65		mg/m³ (STP, dry)
Range Used	200.0		ppm
Range Used [A]	249.8		mg/m³
Cal gas conc.	160.0		ppm
Conversion	1.25		ppm to mg/m³
MCERTS Range [B]	95.0		mg/m³
Lower of [A] or [B]	95.0		mg/m³
Cal gas conc.	199.9		mg/m³

Performance characteristics	RUN 1		Units
Response time	60		seconds
Number of readings in measurement	322		-
Repeatability at zero	0.40		% full scale
Repeatability at span level	0.40		% full scale
Deviation from linearity	0.35		% of value
Zero drift	-0.75		% full scale
Span drift	-0.63		% full scale
Volume or pressure flow dependence	0.40		% of full scale
Atmospheric pressure dependence	0.30		% of value/kPa
Ambient temperature dependence	0.05		% full scale/10K
Combined interference	0.73		% range
Dependence on voltage	0.40		% full scale/10V
Losses in the line (leak)	0.63		% of value
Uncertainty of calibration gas blending	1.40		% 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		mg/m³
Standard deviation of repeatability at span level	0.02		mg/m³
Lack of fit	0.19		mg/m³
Drift	-1.46		mg/m³
Volume or pressure flow dependence	0.00		mg/m³
Atmospheric pressure dependence	0.08		mg/m³
Ambient temperature dependence	0.01		mg/m³
Combined interference (from MCERTS Certificate)	0.40		mg/m³
Dependence on voltage	0.05		mg/m³
Losses in the line (leak)	0.59		mg/m³
Uncertainty of calibration gas blending	1.31		mg/m³
Uncertainty of calibration gas	1.88		mg/m³

			RUN 1		Units
Measurement uncertainty		**Result**	162.65		mg/m³
Combined uncertainty			2.85		mg/m³
Expanded uncertainty	k =	1.96	5.58		mg/m³
Uncertainty corrected to std conds. (O_2)			5.58		mg/m³ (REF)

	RUN 1		Units
Expanded uncertainty (no O_2) - at 95% Confidence	3.43		% of Value
Expanded uncertainty (no O_2) - at 95% Confidence	N/A		% at ELV
Overall Allowable uncertainty (no O_2) - at 95% Confidence	N/A		% at ELV
Result of Compliance with Uncertainty Requirement in M2	**N/A**		-

	RUN 1		Units
Expanded uncertainty (with O_2) - at 95% Confidence	N/A		% of Value
Expanded uncertainty (with O_2) - at 95% Confidence	N/A		% at ELV
Overall Allowable uncertainty (with O_2) - at 95% Confidence	N/A		% at ELV
Result of Compliance with Uncertainty Requirement in M2	**N/A**		-

Requirement for SRM is that Uncertainty should be <6% of the value at the ELV, on a dry gas basis, or if O_2 correction is applied less than 6% + the uncertainty associated with the O_2 correction (using sqrt of sum squares to add uncertainty components). Ref EA TGN M2.

CARBON DIOXIDE: RESULTS SUMMARY

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler

Sample Runs

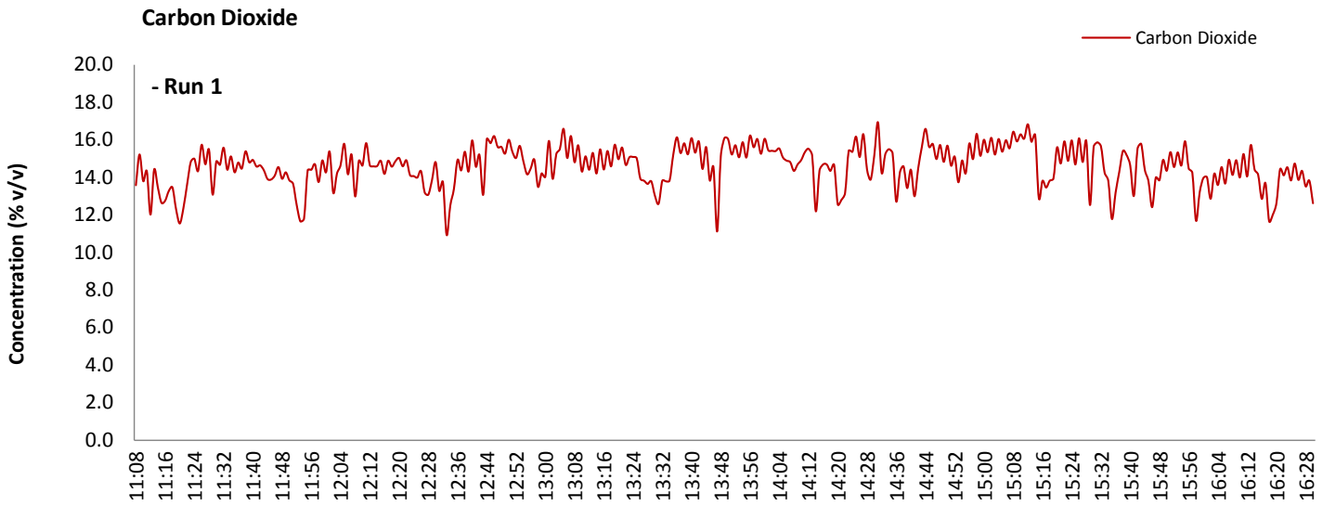
Parameter	Units	Run 1		Mean
Concentration	% v/v	14.6		14.6
Uncertainty	±% v/v	0.37		0.37

General Sampling Information

Parameter	Value	
Standard	ISO 12039	
Technical Procedure	CAT-TP-21	
Probe Material	Stainless Steel	
Filtration Type / Size	0.1µm Glass Fibre	
Heated Head Filter Used	Yes	
Heated Line Temperature	180°C	
Span Gas Type	Carbon Dioxide	
Span Gas Reference Number	CYL 6.0023	
Span Gas Expiry Date	20/06/2019	
Span Gas Start Pressure (bar)	120	
Gas Cylinder Concentration (% v/v)	16.09	
Span Gas Uncertainty (%)	2.00	
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	B1	

CARBON DIOXIDE: DATA TREND

Graphical Trend of Data



CARBON DIOXIDE: SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	
Sampling Times	-	11:08 - 16:30	
Sampling Dates	-	24/08/2015	
Instrument Range	% v/v	20.0	
Span Gas Value	% v/v	16.09	

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	0.03	
	Zero Down Sampling Line (Post)	% v/v	0.03	
	Zero Drift	% v/v	0.00	
	Allowable Zero Drift	± % v/v	0.80	
	Zero Drift Acceptable	-	Yes	

	Span Drift	Units	Run 1	
CAL 1	Span Down Sampling Line (Pre)	% v/v	16.09	
	Span Down Sampling Line (Post)	% v/v	15.99	
	Span Drift	% v/v	-0.10	
	Allowable Span Drift	± % v/v	0.80	
	Span Drift Acceptable	-	Yes	

Test Conditions	Units	Run 1	
Run Ambient Temperature Range	°C	14 - 15	

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	

CARBON DIOXIDE: MEASUREMENT UNCERTAINTY CALCULATIONS

Performance characteristics	RUN 1		Units
Limit value	N/A		%vol
TGN M2 Allowable MU	25.0		%
Measured concentration	14.59		%vol
Range Used	20.0		%vol
Cal gas conc.	16.1		%vol

Performance characteristics	RUN 1		Units
Response time	160		seconds
Number of readings in measurement	322		-
Repeatability at zero	0.40		% full scale
Repeatability at span level	0.40		% full scale
Deviation from linearity	0.28		% of value
Zero drift	0.00		% full scale
Span drift	-0.62		% full scale
Volume or pressure flow dependence	0.40		% of full scale
Atmospheric pressure dependence	0.30		% of value/kPa
Ambient temperature dependence	0.01		% full scale/10K
Combined interference	0.00		% range
Dependence on voltage	0.40		% full scale/10V
Losses in the line (leak)	0.00		% 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	0.02		%vol
Lack of fit	0.03		%vol
Drift	-0.05		%vol
Volume or pressure flow dependence	0.00		%vol
Atmospheric pressure dependence	0.02		%vol
Ambient temperature dependence	0.00		%vol
Combined interference (from MCERTS Certificate)	0.00		%vol
Dependence on voltage	0.05		%vol
Losses in the line (leak)	0.00		%vol
Uncertainty of calibration gas	0.17		%vol

			RUN 1		Units
Measurement uncertainty		**Result**	14.59		%vol
Combined uncertainty			0.19		%vol
Expanded uncertainty	k =	1.96	0.37		%vol

	RUN 1		Units
Expanded uncertainty (no O_2) - at 95% Confidence	2.52		% of Value
Result of Compliance with Uncertainty Requirement in M2	**COMPLIANT**		-

Requirement is that Uncertainty should be <25% relative, on a dry gas basis. Ref EA TGN M2 (other analyser).

OXYGEN: RESULTS SUMMARY

Barden Energy Ltd, Lancaster
999 kW Ariterm Boiler

Sample Runs

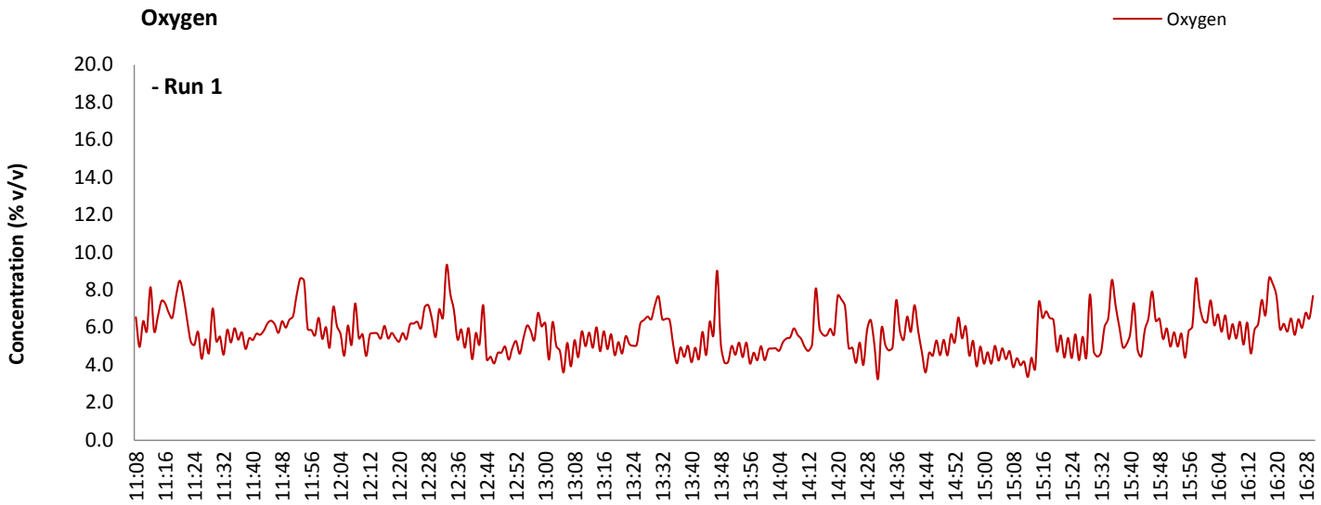
Parameter	Units	Run 1		Mean
Concentration	% v/v	5.68		5.68
Uncertainty	±% v/v	0.27		0.27

General Sampling Information

Parameter	Value	
Standard	EN 14789	
Technical Procedure	CAT-TP-21	
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 11.0212	
Span Gas Expiry Date	29/05/2020	
Span Gas Start Pressure (bar)	100	
Gas Cylinder Concentration (% v/v)	21.2	NOTE: Dilution performed to achieve correct span value
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	B1	

OXYGEN: DATA TREND

Graphical Trend of Data



OXYGEN: SAMPLING DETAILS & QUALITY ASSURANCE

Sampling Details

Parameter	Units	Run 1	
Sampling Times	-	11:08 - 16:30	
Sampling Dates	-	24/08/2015	
Instrument Range	% v/v	25.0	
Span Gas Value	% v/v	21.2	

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	
CAL 1	Zero Down Sampling Line (Post)	% v/v	0.09	
CAL 1	Zero Drift	% v/v	0.05	
	Allowable Zero Drift	± % v/v	1.06	
	Zero Drift Acceptable	-	Yes	

	Span Drift	Units	Run 1	
CAL 1	Span Down Sampling Line (Pre)	% v/v	21.20	
CAL 1	Span Down Sampling Line (Post)	% v/v	21.17	
CAL 1	Span Drift	% v/v	-0.03	
	Allowable Span Drift	± % v/v	1.06	
	Span Drift Acceptable	-	Yes	

Test Conditions	Units	Run 1	
Run Ambient Temperature Range	°C	14 - 15	

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	5.68		%vol
Range Used	25.0		%vol
Cal gas conc.	21.2		%vol

Performance characteristics	RUN 1		Units
Response time	60		seconds
Number of readings in measurement	322		-
Repeatability at zero	0.04		% full scale
Repeatability at span level	0.04		% full scale
Deviation from linearity	0.19		% of value
Zero drift	0.24		% full scale
Span drift	-0.14		% full scale
Volume or pressure flow dependence	0.20		% of full scale
Atmospheric pressure dependence	0.30		% of value/kPa
Ambient temperature dependence	-0.07		% full scale/10K
Combined interference	0.56		% range
Dependence on voltage	0.02		% full scale/10V
Losses in the line (leak)	0.00		% of value
Uncertainty of calibration gas			% 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	0.03		%vol
Drift	0.02		%vol
Volume or pressure flow dependence	0.00		%vol
Atmospheric pressure dependence	0.02		%vol
Ambient temperature dependence	-0.01		%vol
Combined interference (from MCERTS Certificate)	0.08		%vol
Dependence on voltage	0.00		%vol
Losses in the line (leak)	0.00		%vol
Uncertainty of calibration gas	0.07		%vol

			RUN 1		Units
Measurement uncertainty		**Result**	5.68		%vol
Combined uncertainty			0.14		%vol
Expanded uncertainty	k =	1.96	0.27		%vol

	RUN 1		Units
Expanded uncertainty (no O_2) - at 95% Confidence	4.80		% 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.