2499

EMISSIONS MONITORING SURVEY

Prepared for:

Dwr Cymru Welsh Water.

Afan Combined Heat and Power Facility
Afan Waste Treatment Works
Port Talbot Steelworks
SA13 1RA

Permit Number	**: EPR/ZP3032KQ**
Variation Number	**: EPR/ZP3032KQ/V004**
Installation	**: Afan CHP Facility**
Visit Details	**: Compliance – August 2023**
Job Number	**: P5579**
Report Number	**: R001**
Report Issue Date	**: 14th September 2023**
Survey Dates	**: 16th – 17th August 2023**

Prepared by:

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Report Issue:		**FINAL**	
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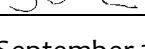
		Signature:	
Date:	12th September 2023	***Date:***	14th September 2023

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MCERTS requirements mean that comparison of results with emissions limit values is not permitted within this report.

TABLE OF CONTENTS

PART 1 - EXECUTIVE SUMMARY

1 Monitoring Objectives

Environmental Compliance Ltd (ECL) was commissioned by **Dwr Cymru Welsh Water** to undertake an emission monitoring survey at their **Afan CHP Facility**. This report presents the findings of the study.

The monitoring at this installation was carried out in accordance with our quotation reference **DHFB/P5579/Q001,** for compliance check monitoring of emissions to air. The substances requested for monitoring at each emissions point are listed below:

Substances to be monitored	Emission Point Identification	
	A3 & A4	**A5**
	Boiler 1 & 2	**Biogas Flare**
Velocity / Flowrate	● U	
Oxides of Nitrogen (as NO_2)	● U	● U
Sulphur Dioxide	● U	● U
Carbon Monoxide	● U	● U
Oxygen	● U	● U

● Denotes the substances to be monitored.

U **Denotes UKAS accreditation is held for monitoring that substance, but does not mean that it has been claimed which will depend on whether the testing could be completed in accordance with the Standard Reference Method.**

Special Requirements: *"Normal Operating Conditions."*

1.1 Monitoring Results

Emission Point Reference	Substance to be Monitored	Emission Limit Value	Periodic Monitoring Result	Units	Uncertainty %	Reference Conditions 273 K, 101.3 kPa	Date of Sampling	Start and End Times	Monitoring Method Reference	Accreditation Claimed For Test Result	Tick if non-conforming test (see Section 2	Operating Status
A3 – Boiler 1	Volumetric Flowrate	…	1.61592	m^3/sec	3	Stack Conditions	16/08/2023	13:16 – 13:40	BS EN 16911-1:2013 & MID	UKAS / MCERTS		Normal
	Volumetric Flowrate	…	0.77088	m^3/sec	5	Dry & 3% O2			BS EN 16911-1:2013 & MID	UKAS / MCERTS		
	Oxides of Nitrogen (as NO_2)	170	122.56	mg/m^3	2	Dry & 3% O2		13:45 – 14:45	BS EN 14792: 2017	UKAS / MCERTS		
	Carbon Monoxide	75	6.07	mg/m^3	2	Dry & 3% O2			BS EN 15058: 2017	UKAS / MCERTS		
	Sulphur Dioxide	160	11.05	mg/m^3	3	Dry & 3% O2			CEN / TS 17021:2017	UKAS / MCERTS		
	Oxygen (Zirconia Cell)	…	6.45	%	2	& Dry Gas			BS EN 14789: 2017	UKAS / MCERTS		

Emission Point Reference	Substance to be Monitored	Emission Limit Value	Periodic Monitoring Result	Units	Uncertainty %	Reference Conditions 273 K, 101.3 kPa	Date of Sampling	Start and End Times	Monitoring Method Reference	Accreditation Claimed For Test Result	Tick if non-conforming test (see Section 2	Operating Status
A4 – Boiler 2	Volumetric Flowrate	…	1.63570	m^3/sec	3	Stack Conditions	17/08/2023	08:37 – 08:58	BS EN 16911-1:2013 & MID	UKAS / MCERTS		Normal
	Volumetric Flowrate	…	0.63800	m^3/sec	6	Dry & 3% O2			BS EN 16911-1:2013 & MID	UKAS / MCERTS		
	Oxides of Nitrogen (as NO_2)	170	124.44	mg/m^3	2	Dry & 3% O2		09:00 – 10:00	BS EN 14792: 2017	UKAS / MCERTS		
	Carbon Monoxide	75	11.01	mg/m^3	2	Dry & 3% O2			BS EN 15058: 2017	UKAS / MCERTS		
	Sulphur Dioxide	160	12.11	mg/m^3	3	Dry & 3% O2			CEN / TS 17021:2017	UKAS / MCERTS		
	Oxygen (Zirconia Cell)	…	8.63	%	2	& Dry Gas			BS EN 14789: 2017	UKAS / MCERTS		

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
Visit Details : Compliance – August 2023
Survey Dates : 16th – 17th August 2023
Report Issue Date : 14th September 2023

Emission Point Reference	Substance to be Monitored	Emission Limit Value	Periodic Monitoring Result	Units	Uncertainty %	Reference Conditions 273 K, 101.3 kPa	Date of Sampling	Start and End Times	Monitoring Method Reference	Accreditation Claimed For Test Result	Tick if non-conforming test (see Section 2	Operating Status
A5 – Flare Stack	Oxides of Nitrogen (as NO_2)	150	79.92	mg/m^3	2	Dry & 3% O2	17/08/2023	14:05 – 15:05	BS EN 14792: 2017	UKAS / MCERTS		Normal
	Carbon Monoxide	50	48.47	mg/m^3	3	Dry & 3% O2			BS EN 15058: 2017	UKAS / MCERTS		
	Sulphur Dioxide $^{\$}$	339	2.22	mg/m^3	13	Dry & 3% O2			BS EN 14791:2017	UKAS / MCERTS		
	Oxygen (Paramagnetic)	...	12.90	%	2	& Dry Gas			BS EN 14789: 2017	UKAS / MCERTS		

Notes

The volumetric flowrate shown above is that from the initial pitot traverse.
Any other flow measurements made during isokinetic sampling and/ or repeat traverses are shown later in the tables section.

The uncertainty figures presented in Table 1.1 for NO_x, CO, SO2 & O_2 are "measurement uncertainty" figures, which do not take into account the variability of the measured sample values. The "uncertainty of measurement results" figures, which do include this contribution, are presented in the appendices of the report for these determinands.

Emission Limit Value	The emission limit value is that stated in the permit and will be expressed as a concentration or a mass emission.
Periodic Monitoring Result	The result given is expressed in the same terms and units as the emission limit value.
Uncertainty	The uncertainty associated with the quoted result is at the 95% confidence interval. The Uncertainty results **DO NOT** take into account the effect of the sample location limitations.
Reference Conditions	All results are expressed at 273 K and 101.3kPa. The oxygen and moisture corrections are stated.
Monitoring Method Reference	The method stated is in accordance with the Environment Agency Technical Guidance Note M2, or other method approved by the Environment Agency.
Accreditation for use of Method	**The details indicate the accreditation for the use of the complete monitoring method, e.g. MCERTs, UKAS. If use of the method is not accredited " NA" is stated.**
Operating Status	The details indicate the feedstock and the loading rate of the plant during monitoring.
$^{\$}$	Chemical Analysis on sample reagents was performed by an External Laboratory as detailed in Section 4
NU	UKAS Accreditation Held but UKAS Accreditation cannot be claimed for the test as sampling did not comply with the Standard Reference Method (SRM), see section 2 & 5
NA	**Method is NOT UKAS Accredited.**

1.2 Operating Information

Any operating information and CEMS data below has been supplied by the client.

Emission Point Reference	Process Type	Process Duration	Fuel	Feedstock	Abatement	Load	Comparison of Operator CEMS and Periodic Monitoring Results					
							Parameter	Date	Time	CEMS Results	Periodic Monitoring Results	Units
A3 - Boiler 1	Continuous	N/A	Natural Gas	N/A	N/A	Normal	...	...	...	NP	...	...
A4 - Boiler 2	Continuous	N/A	Natural Gas	N/A	N/A	Normal	...	...	...	NP	...	...
A5 – Flare Stack	Continuous	N/A	Biogas	N/A	N/A	Normal	...	...	...	NP	...	...

Notes:

Process Type	State whether the process is a continuous or batch process.
Process Duration	If a batch process, state the duration, frequency and details of the portion of the batch sampled. If continuous state "NA"
Fuel	If applicable, state the fuel type If not applicable state "NA"
Feedstock	State the feedstock type
Abatement	State the type and whether operational during monitoring. If not applicable state "NA"
Load	State the normal load, throughput or rating of the plant
CEMS Data	Enter this data for each CEM installed if it is has been provided by operator otherwise state “NP” (NOT PROVIDED)

2 Monitoring Deviations

The objective of the survey was to measure the concentrations of pollutants from the processes / locations as detailed in Section 1. This survey meets the requirements of the site's **PPC Permit Number: EPR/ZP3032KQ** where UKAS and MCERTS accreditation has and could be claimed for the testing in the monitoring results table.

There were no modifications to the sampling procedures (TPDs) listed in section 4.

There were substance deviations from the original and agreed emissions monitoring schedule, as follows.

Sampling from **CHP 1 & CHP 2** was included in the scope of the quotation and SSP, but this was not completed due to process operating issues.

A5 Flare Stack – Due to the nature of the process and sampling location, it was not possible to undertake an initial Velocity & Temperature profile of the gas stream while the process was in operation.

There were no non-conforming tests.

The Uncertainty of the reported concentrations for these pollutant results DOES NOT take into account the effect of non-conformities or sample location limitations

Homogeneity tests have not been completed for pollutants at the following locations:

- A3 (Boiler 1) - Not applicable to this location as the duct area is <1m^2 and not requested by client.
- A4 (Boiler 2) - Not applicable to this location as the duct area is <1m^2 and not requested by client.
- A5 (Flare Stack) - Not requested by client.

PART 2 – SUPPORTING INFORMATION

3 SAMPLING STAFF DETAILS

Site Sampling Team

Names of Site Team	Dates on Site	MCERTS No.	LEVEL	Technical Endorsements
Peter Brockway	16th – 17th August 2023	MM 17 1459	2	TE1, TE2, TE3, TE4
Llion Preskett Hughes		MM 22 1689	1	…

Report Reviewer

Name	MCERTS No.	LEVEL	Technical Endorsements
Andy Barnes	MM 03 235	2	TE1, TE2, TE3, TE4

Technical Endorsement Key:-

TE1 – **Isokinetic** Particulates, Temperature & Velocity Profiles, Oxygen.
TE2 – **Isokinetic** Extractive Pollutants:- Metals, Dioxin & Furans, PAHs, PCBs, HCl, HF.
TE3 – **Non-Isokinetic** Extractive Pollutants:- Speciated VOCs, HF, HCl, Cyanide.
TE4 – **Continuous Analysers** (Combustion Gases):- TVOC, CO, NOx, SO2.

4 SAMPLING PROTOCOLS / METHODOLOGIES

Details of the substances monitored, the standard methods used and the Environmental Compliance Limited Technical Procedures used during this survey are shown in the table below. Detailed sampling protocols are included in a separate document which will be sent with the report.

In all cases, where analysis of collected samples was required, the analysis was by a subcontract laboratory. Details of the sub-contract laboratory are shown on the analysis certificates in this report. The UKAS/MCERTs accreditation status of the analysis is also indicated on the certificates.

Any required modifications to the Technical Procedure Documents (TPDs) specified below will be detailed in section 2 of this report.

Determinand	External Reference Method	ECL Technical Procedure Number
Velocity and Flowrate	BS EN 16911-1:2013 & MID	ECL/ TPD/ 022A
Oxygen (PG250)	BS EN 14789: 2017	ECL / TPD / 033C
Carbon Monoxide (PG250)	BS EN 15058: 2017	ECL / TPD / 033C
Oxides of Nitrogen (PG250)	BS EN 14792: 2017	ECL / TPD / 033C
Sulphur Dioxide (PG250)	PD CEN/TS 17021:2017	ECL / TPD / 033C
Oxygen (PG350 E)	BS EN 14789: 2017	ECL / TPD / 033D
Carbon Monoxide (PG350E)	BS EN 15058: 2017	ECL / TPD / 033D
Oxides of Nitrogen (PG350 E)	BS EN 14792: 2017	ECL / TPD / 033D
Sulphur Dioxide	BS EN 14791:2017	ECL / TPD / 039
Moisture	BS EN 14790: 2017	ECL / TPD / 082

5 SAMPLE POINT DESCRIPTIONS

The homogeneity test is applicable to combustion processes, but may also be requested by the regulator for non-combustion processes.

Homogeneity testing has not been completed at these locations. The test is not usually required for stacks with sampling plane areas of <1m^2 (below 1.13m in diameter for circular ducts).

The Uncertainty of the reported concentrations for these pollutant results DOES NOT take into account the effect of non-conformities or sample location limitations.

The sample locations that were monitored are detailed below:

A3 Boiler 1

The stack diameter is 0.55m and the sample platform width back from the sample port is circa 3.0m.

Two sample ports are located on the stack at 90 degrees to each other and are located on the same plane.

These sample ports are located at a height of approximately 1.5m from the working sample platform.

Access to the sample platform was attained by means of permanent steps accessed from inside the Boiler House building.

A4 Boiler 2

The stack diameter is 0.55m and the sample platform width back from the sample port is circa 3.0m.

Two sample ports are located on the stack at 90 degrees to each other and are located on the same plane.

These sample ports are located at a height of approximately 1.5m from the working sample platform.

Access to the sample platform was attained by means of permanent steps accessed from inside the Boiler House building.

A5 Flare Stack

The stack diameter is 3.0m and the sample platform width back from the sample port is circa 3.0m.

Two sample ports are located on the stack at 90 degrees to each other and are located on the same plane.

These sample ports are located at a height of approximately 1.5m from the working sample platform.

Access to the sample platform was attained by means of temporary scaffold, accessed from outside the Boiler House building.

EQUIPMENT IDs
(Pre site checklist from SSP)

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
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Report Ref : P5579 : R001

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Survey Dates : 16th – 17th August 2023
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PRE SITE EQUIPMENT CHECKLIST/ EQUIPMENT USED

(Completed before departure to site and when on site in full)

Equipment	Equip. Type	ID No:	ID No:	ID No:	ID No:	ID No:	ID No:	ID No:	ID No:
MST console/pump	E001	U001							
MST Nozzle set									
MST "S" Type Pitot		602							
MST Probe									
MST Hot Box									
MST Impinger Arm		979							
Barometer		1220							
Site Balance		1225							
Site Check weights		1226							
		1227							
Horiba	E002	271	1065						
Heated Probe / Filter		921	1348						
Chiller		1345							
MFC									
Heated Line		432	433	1184	1185				
FID	E003								
Heated Line									
Heated Probe / Filter									
Testo	E004								
FTIR	E005								
Heated Probe / Filter									
Heated Line									
Stackmite	E006								
"L" Type Pitot									
Digital Manometer									
Stack Thermocouple		1194							
Thermocouple Reader									
Nozzle Set									
Workhorse Pumps	E007								
Stack Thermocouple									
Tube Thermocouple									
Meter Thermocouple									
High Vac Gauge									
Dioxin Thermocouple									

Quantity of Ice Required / Used for Survey	2	Bags (2kg bags)

FIGURES

Dwr Cymru Welsh Water
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Figure 1 – Combustion Gases

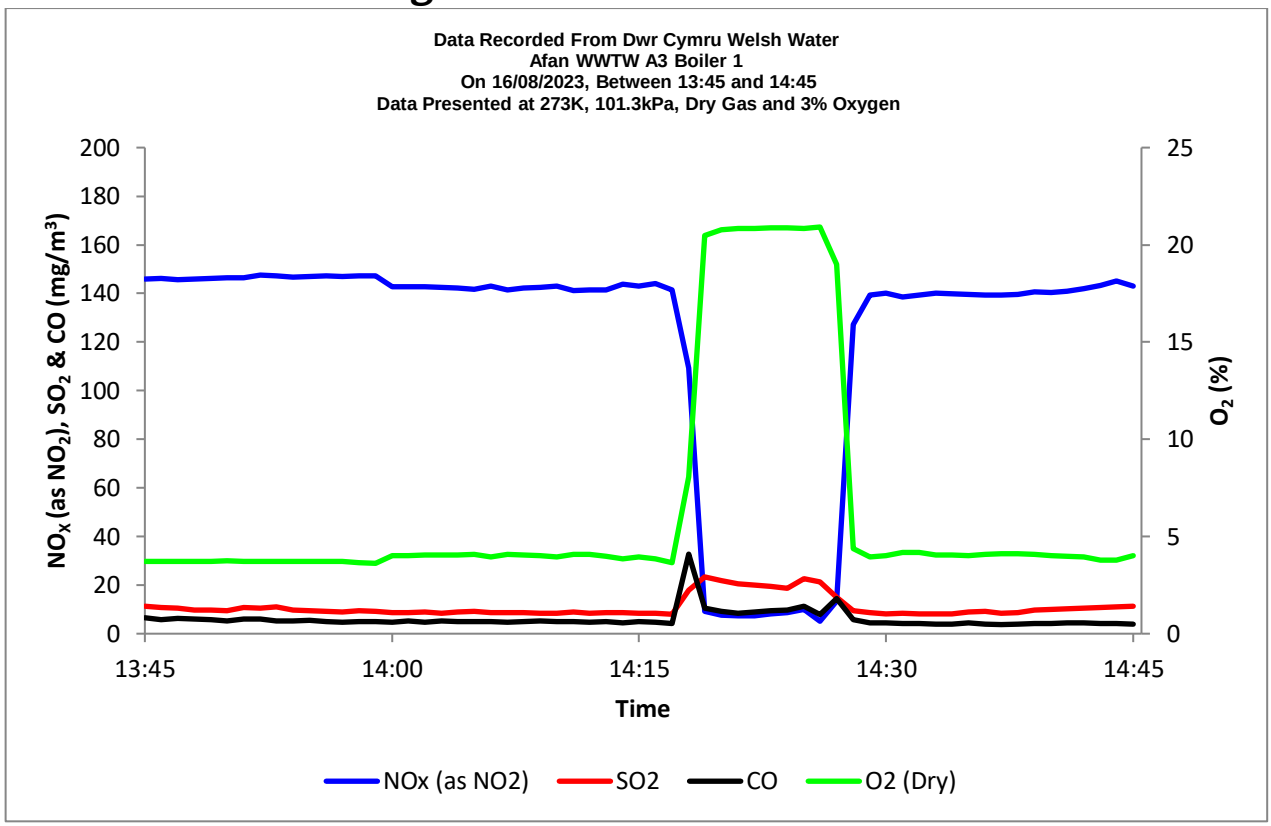


Figure 2 – Combustion Gases

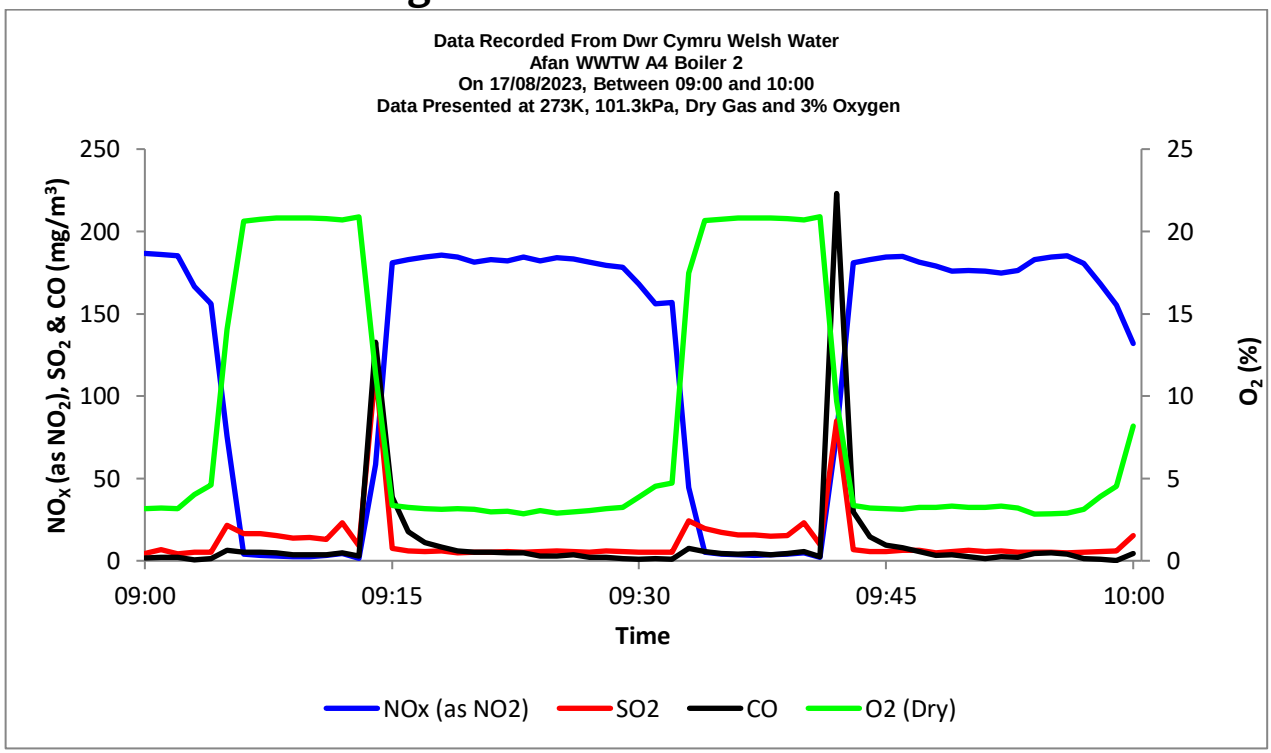
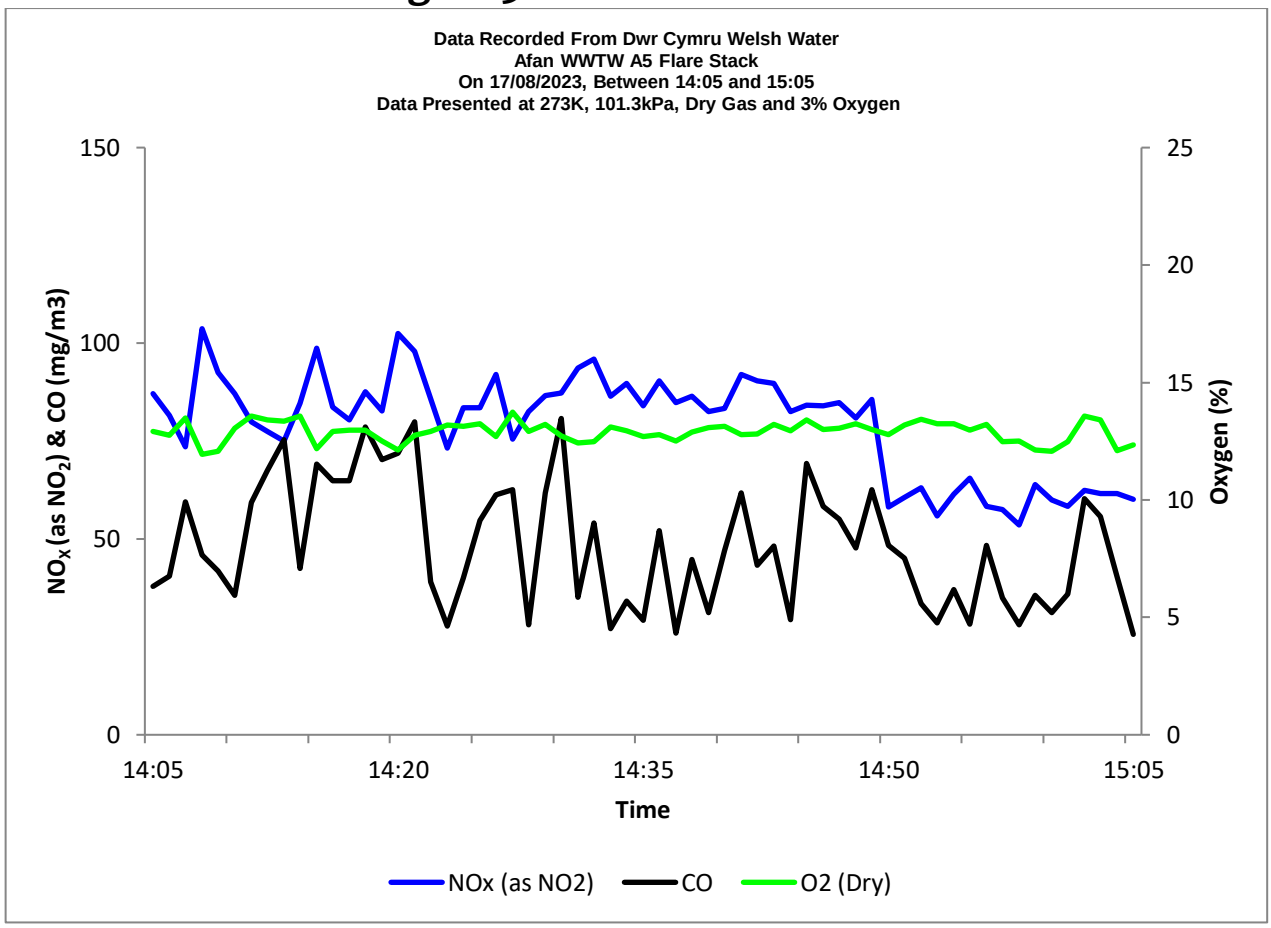


Figure 3 – Combustion Gases



TABLES

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
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Table 1 – Combustion Gases

Data Recorded from A3 – Boiler 1

Sample Period: 13:45 – 14:45 on the 16th August 2023

Volumetric Flowrate (Reference Conditions) = 0.77088 **m³/sec ***

	Average	Emission Rate
	mg/m³	Kg/hr
Sulphur Dioxide *	11.05	0.0307
Oxides of Nitrogen (as NO2) *	122.56	0.3401
Carbon Monoxide *	6.07	0.0168
Oxygen (%)	6.45	...

*** Reference Conditions (273K, 101.3 kPa, 3% Oxygen & Dry Gas)**

Table 2 – Combustion Gases

Data Recorded from A4 – Boiler 2

Sample Period: 09:00 – 10:00 on the 17th August 2023

Volumetric Flowrate (Reference Conditions) = 0.63800 **m³/sec ***

	Average	Emission Rate
	mg/m³	Kg/hr
Sulphur Dioxide *	12.11	0.0278
Oxides of Nitrogen (as NO2) *	124.44	0.2858
Carbon Monoxide *	11.01	0.0253
Oxygen (%)	8.63	...

*** Reference Conditions (273K, 101.3 kPa, 3% Oxygen & Dry Gas)**

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Table 3 – Sulphur Dioxide

Data Recorded from A5 Flare Stack - Boiler House

Emission Parameter	Units	SO2	Blank
Stack Diameter	metres	3.00	
Area of Sample Plane	m^2	7.069	
Moisture Content	%	5.95	
Oxygen Content	%	12.90	
Stack Temperature	^oC	1085	
Gas Velocity (as Measured)	m/sec	…	
Gas Velocity (Reference Conditions)	m/sec*	…	
Volumetric Flowrate (as Measured)	m^3/sec	…	
Volumetric Flowrate (Reference Conditions)	m^3/sec*	…	
Dry Gas Molecular Weight	g/gmole	29.47756835	
Sample Date	…	17/08/2023	
Sample Period	…	14:05 - 15:05	
Sample Volume (reference Conditions)	m^3*	0.230	0.230
Sample Reference	ECL/23/	4603 & 4604	4606
Mass of Sulphur Dioxide Collected	mg	0.51	0.14
Concentration of Sulphur Dioxide	mg/m^3*	**2.22**	0.59
Expanded Uncertainty (% Relative)	%	13	...
Emission Limit Value (ELV)	mg/m^3*	339	…
Impinger Collection Efficiency	%	69	...
Blank Concentration as Percentage of ELV	%	…	<1.00%

(Conc < 30% ELV)

***Reference Conditions (273K, 101.3kPa, 3% Oxygen, Dry Gas)**

VELOCITY TRAVERSE PROFILES

Environmental Compliance Limited

Dwr Cymru Welsh Water
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Environmental Compliance Limited	Traverse Data Profoma	Date of Measurement	16/08/2023

Company	Dwr Cymru Welsh Water	Stack Diameter Port A (mm)	550	Average Stack Diameter (mm)	550	Pitot tube coefficient	0.82
Site	Afan WWTW	Stack Diameter Port B (mm)	550	Port Length (mm)	100	Pitot Id	602
Location	Boiler 1	Duct Length Port A (mm)		Average Duct Length (mm) L		Stack Thermocouple ID	1194
Stack	A3	Duct Length Port B (mm)		Duct width (mm) B		Stack Temp Reader ID	013
Job No	P5579	Duct Length Port C (mm)		Barometric Pressure. (mb)	1018	Manometer ID	012
Operators	PB & LPH	Duct Length Port D (mm)		Ave Static Press. (mm $H_2$0)	-4.00	Barometer ID	1220

Pre - Traverse Checks Carried Out	Time	Pass/ Fail
Pre - Traverse PITOT Visual Inspection	13:16:00	Pass
Pre - Traverse PITOT Leak Check	13:18:00	Pass

Smooth Walls

Static Pressure Readings (mm H_2O)			
Port A	Port B	Port C	Port D
-4.00	-4.00		

Port/ Point	Distance to Point (mm)	Time	Temperature Readings (°C) 1	2	3	(ΔP) Pitot Readings (mm H_2O) 1	2	3	Average Temp. (°C)	Average (ΔP) (mm H_2O)	Swirl Test ° From Reference
A1	81	13:22:00	143.0	143.0	143.0	3.00	3.00	3.00	143.0	3.00	5
A2	469	13:25:00	143.0	143.0	143.0	3.00	3.00	3.00	143.0	3.00	6
B1	81	13:28:00	142.0	142.0	142.0	3.00	3.00	3.00	142.0	3.00	6
B2	469	13:30:00	142.0	143.0	143.0	3.00	3.00	3.00	142.7	3.00	6
Blockage Check @ A1 (L-Type Pitot Only)									570.7	12.0	Total
			Mean			Mean			143.0	3.0	Max
			Difference < 5% from Initial ?			Difference < 5% from Initial ?			142.0	3.0	Min
									142.7	3.0	Average

Stagnation Check (S-type Pitot Only)	Time	Reading
Static Pressure Via Positive Leg (mm H_2O)	13:33:00	-4.00
Static Pressure Via Negative Leg (mm H_2O)	13:35:00	-4.00
Difference (Pa) < 1 mm $H_2$0 ?		0.00

Post - Traverse Checks Carried Out	Time	Pass/ Fail
Post - Traverse PITOT Visual Inspection	13:38:00	Pass
Post - Traverse PITOT Leak Check	13:40:00	Pass

Average temp (K)	415.667

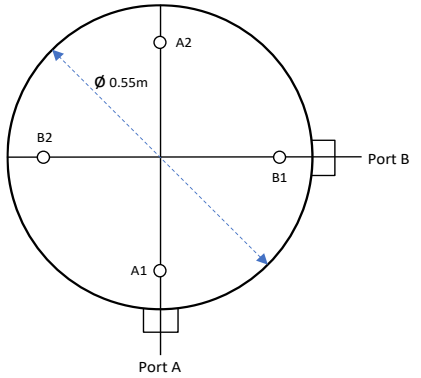
Suitability of Sampling Position	Actual Stack Conditions
Highest:lowest flow pressure ratio < 9:1?	1:1
Maximum deviation of flow from axis < 15° ?	6
X-sectional area for stacks= πr2	0.24 m^2
X-sectional area for ducts = L x B	m^2
Suitability of Position for Sampling	OK

Stack Moisture	10.43	%	Gas Velocity (as Measured) Adjusted for Smooth Walls	6.80149	m/sec
Measured Oxygen	6.45	%	Gas Velocity (Reference Conditions) Adjusted for Smooth Walls	3.24466	m/sec*
Measured Carbon Dioxide	10.853	%	Volumetric Flowrate (as Measured) Adjusted for Smooth Walls	1.61592	m^3/sec
Dry Gas Molecular Weight	29.99448	g/g mole	Volumetric Flowrate (Ref Cond) Adjusted for Smooth Walls	0.77088	m^3/sec*

* Reference Conditions: 273K, 101.3kPa, 3% Oxygen, Dry Gas

NOTE: Velocity / volume flowrate calculations exclude contributions from the measurement point(s) where swirl > 15°

Diagram/ Description of Cross Section of Stack/Duct



Notes
Including expected or actual deviations from procedures / non-conformities

Compliance With Positional Requirements?

Height of sample ports from Platform	1.5m
Number of sample ports	2
Width of platform (port back to handrail)	3m

Nearest downstream disturbance	Exit	> 10m
Nearest upstream disturbance	Bend	3m
Disturbances are classed as bends, fans or diameter variations		

Environmental Compliance Limited

Dwr Cymru Welsh Water		Installation Name	: Afan CHP Facility
Permit No	: EPR/ZP3032KQ	Visit Details	: Compliance – August 2023
Variation No	: EPR/ZP3032KQ/V004	Survey Dates	: 16th – 17th August 2023
Report Ref	: P5579 : R001	Report Issue Date	: 14th September 2023

Environmental Compliance Limited	Traverse Data Profoma	Date of Measurement	17/08/2023

Company	Dwr Cymru Welsh Water	Stack Diameter Port A (mm)	550	Average Stack Diameter (mm)	550	Pitot tube coefficient	0.82
Site	Afan WWTW	Stack Diameter Port B (mm)	550	Port Length (mm)	100	Pitot Id	602
Location	Boiler 2	Duct Length Port A (mm)		Average Duct Length (mm) L		Stack Thermocouple ID	1194
Stack	A4	Duct Length Port B (mm)		Duct width (mm) B		Stack Temp Reader ID	013
Job No	P5579	Duct Length Port C (mm)		Barometric Pressure. (mb)	1018	Manometer ID	012
Operators	PB & LPH	Duct Length Port D (mm)		Ave Static Press. (mm H_2O)	-3.50	Barometer ID	1220

Pre - Traverse Checks Carried Out	Time	Pass/ Fail
Pre - Traverse PITOT Visual Inspection	08:37:00	Pass
Pre - Traverse PITOT Leak Check	08:39:00	Pass

Smooth Walls

Static Pressure Readings (mm H_2O)			
Port A	Port B	Port C	Port D
-3.50	-3.50		

Port/ Point	Distance to Point (mm)	Time	Temperature Readings (^oC) 1	2	3	(ΔP) Pitot Readings (mm H_2O) 1	2	3	Average Temp. (^oC)	Average (ΔP) (mm H_2O)	Swirl Test ^{o} From Reference
A1	81	08:42:00	138.0	138.0	138.0	3.00	3.00	3.00	138.0	3.00	5
A2	469	08:44:00	138.0	138.0	139.0	3.00	3.00	3.00	138.3	3.00	5
B1	81	08:46:00	138.0	138.0	138.0	3.00	3.00	3.00	138.0	3.00	5
B2	469	08:49:00	138.0	138.0	138.0	3.00	3.00	3.00	138.0	3.00	5
Blockage Check @ A1 (L-Type Pitot Only)									552.3	12.0	Total
			Mean			Mean			138.3	3.0	Max
			Difference <5% from Initial ?			Difference <5% from Initial ?			138.0	3.0	Min
									138.1	3.0	Average

Stagnation Check (S-type Pitot Only)	Time	Reading
Static Pressure Via Positive Leg (mm H_2O)	08:52:00	-3.50
Static Pressure Via Negative Leg (mm H_2O)	08:54:00	-3.50
Difference (Pa) < 1 mm H_20 ?		0.00

Post - Traverse Checks Carried Out	Time	Pass/ Fail
Post - Traverse PITOT Visual Inspection	08:56:00	Pass
Post - Traverse PITOT Leak Check	08:58:00	Pass

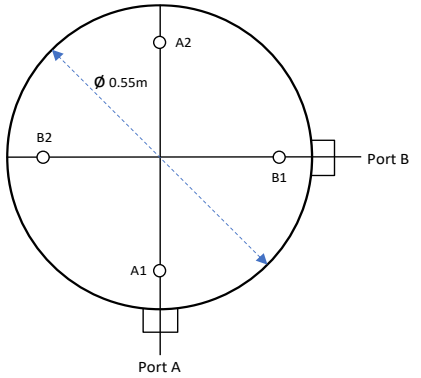
Average temp (K)	411.083

Suitability of Sampling Position	Actual Stack Conditions
Highest:lowest flow pressure ratio < 9:1?	1:1
Maximum deviation of flow from axis <15^o?	5
X-sectional area for stacks= πr2	0.24 m^2
X-sectional area for ducts = L x B	m^2
Suitability of Position for Sampling	OK

Stack Moisture	14.71	%	Gas Velocity (as Measured) Adjusted for Smooth Walls	6.88474	m/sec
Measured Oxygen	8.63	%	Gas Velocity (Reference Conditions) Adjusted for Smooth Walls	2.68536	m/sec*
Measured Carbon Dioxide	6.73	%	Volumetric Flowrate (as Measured) Adjusted for Smooth Walls	1.63570	m^3/sec
Dry Gas Molecular Weight	29.42200	g/g mole	Volumetric Flowrate (Ref Cond) Adjusted for Smooth Walls	0.63800	m^3/sec*

*Reference Conditions: 273K, 101.3kPa, 3% Oxygen, Dry Gas NOTE: Velocity / volume flowrate calculations exclude contributions from the measurement point(s) where swirl >15°

Diagram/ Description of Cross Section of Stack/Duct



Notes
Including expected or actual deviations from procedures / non-conformities

Compliance With Positional Requirements?

Height of sample ports from Platform	1.5m
Number of sample ports	2
Width of platform (port back to handrail)	3m

Nearest downstream disturbance	Exit	>10m
Nearest upstream disturbance	Bend	3m
Disturbances are classed as bends, fans or diameter variations		

FIELD CALIBRATION AND SAMPLING DATA

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
Visit Details : Compliance – August 2023
Survey Dates : 16th – 17th August 2023
Report Issue Date : 14th September 2023

Horiba Calibration Summary (NO_x, CO, SO_2 & O_2) A3 – Boiler 1

	Horiba PG 250 Measurement Ranges:			
	NO as NO_2	SO_2	CO	O_2
Units	1025 mg/m³	572 mg/m³	1250 mg/m³	25 %Vol
	Zero Values (Direct)			
Mean Initial Direct Zero	0.13	-1.67	-0.24	0.00
Mean Confirmation Direct Zero	0.15	0.23	0.07	0.00
Difference in Direct Zero	0.02	1.90	0.31	0.00
Repeatability at Zero	4.10	5.72	2.50	0.20
<2 x Repeatability at Zero?	YES	YES	YES	YES
	Pre Zero Values (System)			
Mean Pre Test Zero	0.45	0.53	-0.03	0.05
% of Measurement Range?	0.04%	0.09%	0.00%	0.20%
Detection Limit (LOD)	0.04	0.55	0.87	0.20
	Applied Span:			
	NO	SO_2	CO	O_2
Actual Applied Span Concentration	623.41	445.87	376.38	14.99
	Pre Test System Zero Values			
Mean Pre Test System Zero	0.45	0.53	-0.03	0.05
Difference ≤ ± 2% of Span Value ?	0.07%	0.12%	0.01%	0.33%
	Post Test Direct Zero Values			
Mean Post Test Direct Zero	0.34	-0.23	2.43	-0.08
% of Certified Range?	0.03%	-0.04%	0.19%	-0.32%
Zero Drift ≤ ± 5% of Applied Span?	0.03%	0.32%	0.71%	0.54%
	Pre Test System Span Values			
Mean Pre Test System Span	619.63	442.25	372.99	15.00
Difference ≤ ± 2% of Span Value ?	0.61%	0.81%	0.90%	0.06%
	Post Test Direct Span Values			
Mean Post Test Direct Span	615.72	446.68	371.98	15.00
Span Drift ≤ ± 5% Span Value?	1.23%	0.18%	1.17%	0.06%

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
Visit Details : Compliance – August 2023
Survey Dates : 16th – 17th August 2023
Report Issue Date : 14th September 2023

Horiba Calibration Summary (NO_x, CO, SO_2 & O_2) A4 – Boiler 2

	Horiba PG 250 Measurement Ranges:			
	NO as NO_2	SO_2	CO	O_2
Units	1025 mg/m³	572 mg/m³	1250 mg/m³	25 %Vol
	Zero Values (Direct)			
Mean Initial Direct Zero	0.13	-1.67	-0.24	0.00
Mean Confirmation Direct Zero	0.15	0.23	0.07	0.00
Difference in Direct Zero	0.02	1.90	0.31	0.00
Repeatability at Zero	4.10	5.72	2.50	0.20
<2 x Repeatability at Zero?	YES	YES	YES	YES
	Pre Zero Values (System)			
Mean Pre Test Zero	0.45	0.53	-0.03	0.05
% of Measurement Range?	0.04%	0.09%	0.00%	0.20%
Detection Limit (LOD)	0.04	0.55	0.87	0.20
	Applied Span:			
	NO	SO_2	CO	O_2
Actual Applied Span Concentration	623.41	445.87	376.38	14.99
	Pre Test System Zero Values			
Mean Pre Test System Zero	0.45	0.53	-0.03	0.05
Difference ≤ ± 2% of Span Value ?	0.07%	0.12%	0.01%	0.33%
	Post Test Direct Zero Values			
Mean Post Test Direct Zero	0.23	-4.41	0.56	-0.01
% of Certified Range?	0.02%	-0.77%	0.04%	-0.03%
Zero Drift ≤ ± 5% of Applied Span?	0.02%	0.61%	0.21%	0.05%
	Pre Test System Span Values			
Mean Pre Test System Span	619.63	442.25	372.99	15.00
Difference ≤ ± 2% of Span Value ?	0.61%	0.81%	0.90%	0.06%
	Post Test Direct Span Values			
Mean Post Test Direct Span	623.76	439.07	372.53	14.98
Span Drift ≤ ± 5% Span Value?	0.06%	1.53%	1.02%	0.07%

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
Visit Details : Compliance – August 2023
Survey Dates : 16th – 17th August 2023
Report Issue Date : 14th September 2023

Horiba Calibration Summary (NO_x, CO & O_2) A5 – Flare Stack

	Horiba PG 350 E Ranges:		
	NO as NO_2	CO	O_2
Units	1025 mg/m³	1250 mg/m³	25 %Vol
	Zero Values (Direct)		
Mean Initial Direct Zero	0.00	0.35	0.03
Mean Confirmation Direct Zero	0.00	-0.25	-0.03
Difference in Direct Zero	0.00	0.60	0.06
Repeatability at Zero	4.10	2.50	0.20
<2 x Repeatability at Zero?	YES	YES	YES
	Pre Zero Values (System)		
Mean Pre Test Zero	0.00	0.49	0.10
% of Measurement Range?	0.00%	0.04%	0.40%
Detection Limit (LOD)	0.00	0.35	0.20
	Applied Span:		
	NO	CO	O_2
Actual Applied Span Concentration	623.41	376.38	14.99
	Pre Test System Zero Values		
Mean Pre Test System Zero	0.00	0.49	0.10
Difference ≤ ± 2% of Span Value?	0.00%	0.13%	0.67%
	Post Test Direct Zero Values		
Mean Post Test Direct Zero	0.00	-0.31	0.04
% of Certified Range?	0.00%	-0.02%	0.17%
Zero Drift ≤ ± 5% of Applied Span?	0.00%	0.18%	0.11%
	Pre Test System Span Values		
Mean Pre Test System Span	624.40	373.12	14.98
Difference ≤ ± 2% of Span Value ?	0.16%	0.86%	0.05%
	Post Test Direct Span Values		
Mean Post Test Direct Span	626.39	377.08	15.00
Span Drift ≤ ± 5% Span Value?	0.48%	0.19%	0.06%

Environmental Compliance Limited

Dwr Cymru Welsh Water		**Installation Name**	**: Afan CHP Facility**
Permit No	**: EPR/ZP3032KQ**	**Visit Details**	**: Compliance – August 2023**
Variation No	**: EPR/ZP3032KQ/V004**	**Survey Dates**	**: 16th – 17th August 2023**
Report Ref	**: P5579 : R001**	**Report Issue Date**	**: 14th September 2023**

Sulphur Dioxide

Environmental Compliance Limited	NON ISOKINETIC SAMPLING PROFORMA	Date of Measurement	17/08/2023

If moisture was not measured see detailed notes below.

ECL/TPD/	039	Time taken to change Ports?	0	Start Time	14:05	End Time	15:05
				Test Duration	60 mins		

Client	Dwr Cymru Welsh Water	Stack Profile	Circular	Console id	U001	Barometer id	1220
Site	Afan WWTW	Stack Area (m^2)	7.07	Pump id	U001	Nozzle Id	n/a
Location	Boiler House	Barometric Pressure (mb)	1018	Probe id	1184/1185	Nozzle size	n/a
Stack ID	A5 Flare Stack	Static Pres. (mm $H_2$0)	0	DGM Yd	1.0320	Filter Id	1348
Test No.	SO2	Pitot coefficient	n/a	ΔH@	37.32	Pitot ID	n/a
Job No	P5579	Probe Heater Setting (^{O}C)	180	Impinger Id	979	Hot Box ID	n/a
ECL Site Staff	PB & LPH	Hot Box Setting (^{O}C)	180	Balance Id	1225		

For all parameters a leak check is OPTIONAL at the end of the test.
(and when moving between sample ports if any disconnections are required).

	Sample	Leak 1	Leak 2	Leak 3	Leak 4	Leak 5	Total
Start Volume	762690.0						
Final Volume	763238.5						
Total Volume	548.5	0.0	0.0	0.0	0.0	0.0	548.5

Required Sample Flowrate l/min	Suggested ΔH Entered Below
3	1
6	3
10	10
15	25
25	50
Initial ΔH	10
Reference Oxygen Percentage	3

Leak Check	First	Second	Third	Fourth	Fifth
Leak rate l/min	0				
Vaccum "Hg	16				
Time of Check	14:00				
Set Rate l/min	10				
Leak < 2%?	YES				

Dry O_2 (Atmospheric)	12.90
Dry Carbon Dioxide %	6.01
Dry Carbon Monoxide ppm	17.33

Traverse Point	A1	A1	A1	A1	A1	A1			Total
Time/Point (mins)	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60			
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)	10.00	10.00	10.00	10.00	10.00	10.00			10.00
Meter (Tm in)	32.00	33.00	33.00	34.00	34.00	34.00			33.33
Meter (Tm out)	29.00	28.00	28.00	28.00	29.00	29.00			28.50
Stack Temp (Ts)	1112.00	1086.00	1084.00	1023.00	1045.00	1161.00			1085.17
Impinger T Outlet	6.00	10.00	13.00	15.00	17.00	19.00			13.33
Vaccum (" Hg)	12.00	12.00	12.00	12.00	12.00	12.00			12.00

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

Traverse Point									Total
Time/Point(mins)									
ΔP (mm H20)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
K factor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ΔH (Orifice)									
Meter (Tm in)									
Meter (Tm out)									
Stack Temp (Ts)									
Impinger T Outlet									
Vaccum (" Hg)									

	Impinger 1	Impinger 2	Impinger3	Impinger 4	Impinger 5	Impinger 6	Impinger 7	Impinger 8
Contents	3% H2O2	3% H2O2	3% H2O2	Empty	Silica			
SOL/	4961	4961	4961	...	...			
Start Weight (g)	654.1	642.2	631.8	595.5	836.9			
End Weight (g)	657.4	657.5	633.7	595.8	842.1			
Total weight (g)	3.3	15.3	1.9	0.3	5.2	0	0	0

Total (g)	26.00
Silica < 50% used at End of Test? Y/N	YES

Rinse Solutions used	
Solution	SOL NO
DI Water	4960
Acetone	4978

Additional Moisture Weighings

	1	2	3	4	5	6	7	8	9	10
Item Name										
Start Weight (g)										
End Weight (g)										
Total weight (g)	0	0	0	0	0	0	0	0	0	0

If moisture was not measured and gas was dried before entering the gas meter, impinger weights must be included to produce the moisture concentration used in the isokinetic calculations. If the gas was not dried before it entered the gas meter then impinger weights may be included to produce a nominal 0.1% moisture value.

LABORATORY ANALYSIS RESULTS

Laboratory analysis for Sulphur Dioxide was subcontracted to RPS laboratories, a UKAS Accredited Testing Laboratory, Number 0605.

RPS DO hold UKAS & MCERTS accreditation for this analysis.

As required by the MCERTS Performance Standard for Organisations, the analysis results are shown below.

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
Visit Details : Compliance – August 2023
Survey Dates : 16th – 17th August 2023
Report Issue Date : 14th September 2023

Results Summary

Report No.: 23-09273-1

Customer Reference: 2023 Stack Preferential Rates

Customer Order No: E0863 P5579

Customer Sample No						ECL/23/4603	ECL/23/4604	ECL/23/4605	ECL/23/4606
RPS Sample No						199474	199475	199476	199477
Sample Matrix						SOLUTION	SOLUTION	SOLUTION	SOLUTION
Sampling Date						17/08/2023	17/08/2023	17/08/2023	17/08/2023
Determinand	**CAS No**	**Codes**	**SOP**	**RL**	**Units**				
volume of sample supplied		U	N/A	n/a	ml	357	235	377	212
sulphur dioxide	7446-09-5	UM	C27	0.05	ug/mL	0.99	0.67	0.66	0.64

UNCERTAINTY CALCULATIONS

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
Visit Details : Compliance – August 2023
Survey Dates : 16th – 17th August 2023
Report Issue Date : 14th September 2023

A3 – Boiler 1 Combustion Gases (NO_x, CO, SO_2 & O_2) Measurement Uncertainty

Measurement Uncertainty Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distributiuon	Minimum Certified Range (R_i) NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular (Divisor = √3)	0.40	0.80	0.40	0.13
Span drift[2]	$u_{d,s}$	Rectangular (Divisor = √3)	0.27	0.27	0.29	0.029
Repeatability Standard Deviation (span)[3]	u_r	Normal (Divisor = 1)	1.73	0.67	0.65	0.037
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	3.02	0.79	3.57	0.039
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	0.18	0.15	0.050	0.070
Interferents[1]	u_i	Rectangular (Divisor = √3)	1.20	1.50	2.90	0.56
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	10.80	7.72	6.52	0.15
Effect of Voltage Fluctuation[7]	u_v	Rectangular (Divisor = √3)	...	...	...	...
Effect of Sample Gas Flow/ Pressure[7]	u_{sg}	Rectangular (Divisor = √3)	...	...	...	...

Note:

$$when\ \left|(x_{i,\max} - x_{i,adj})\right| = \left|(x_{i,\min} - x_{i,adj})\right|, then\ u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Expressed as standard uncertainty in units of measurement i.e. mg/m³ / %Vol inc additional uncertainty of 2% for gas blending
7 Data not available so not included

Measurement Uncertainty Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty	Value of Standard Uncertainty	NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	$u(x_i) = \frac{u_{lof} \times R_i}{\sqrt{3}} =$	0.29	2.12	0.22	0.019
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.20	0.72	0.16	0.0041
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	1.73	0.67	0.65	0.037
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	2.18	2.09	1.96	0.0056
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	0.19	0.60	0.041	0.015
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.87	3.98	1.59	0.081
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	6.23	4.46	3.76	0.087
Effect of Voltage Fluctuation[7]	u_v	$u(x_i) = \frac{u_v \times R_i}{\sqrt{3}} =$	...	...	...	...
Effect of Sample Gas Flow/ Pressure[7]	u_{sg}	$u(x_i) = \frac{u_{syn} \times R_i}{\sqrt{3}} =$	...	...	...	...
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	6.89	6.78	4.58	0.13
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	13.79	13.56	9.17	0.25
Applied Span Concentration			623.41	445.87	376.38	14.99
Measured Span Concentration, STP Dry Gas			617.68	444.47	372.48	15.00
Expanded measurement uncertainty as % of Applied Span			2%	3%	2%	2%

Dwr Cymru Welsh Water		Installation Name	: Afan CHP Facility
Permit No	: EPR/ZP3032KQ	Visit Details	: Compliance – August 2023
Variation No	: EPR/ZP3032KQ/V004	Survey Dates	: 16th – 17th August 2023
Report Ref	: P5579 : R001	Report Issue Date	: 14th September 2023

A3 – Boiler 1 Combustion Gases (NO_x, CO, SO_2 & O_2) Uncertainty of Measurement Results

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Minimum Certified Range (R_i) NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.80	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			3.02	0.79	3.57	0.039
Temperature dependant span drift[5]	u_t			0.18	0.15	0.050	0.070
Effect of Voltage Fluctuation (not available)	u_v						
Effect of Sample Gas Flow/ Pressure (not available)	u_{sg}						

Notes:

For rectangular distributions, $u(x_i) = \frac{u \times R_i}{\sqrt{3}}$

For $u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,max} - x_{i,adj})^2 + (x_{i,min} - x_{i,adj})(x_{i,max} - x_{i,adj}) + (x_{i,min} - x_{i,adj})^2}{3}}$, when $|(x_{i,max} - x_{i,adj})| = |(x_{i,min} - x_{i,adj})|$, then $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

Where $u(x_i) = \frac{\sigma}{\sqrt{n}}$ (See note 6 below), $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	2.12	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.72	0.16	0.0041
Temperature dependant span drift	u_t			0.34	1.04	0.071	0.026
Interferents	u_i			0.87	3.98	1.59	0.081
Effect of Voltage Fluctuation (not available)	u_v						
Effect of Sample Gas Flow/ Pressure (not available)	u_{sg}						

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	16/08/23 13:45 - 14:45	3.70	0.087	0.22	0.0025
Standard Error of Measured Value	u_{SE}	16/08/23 13:45 - 14:45	4.97	0.44	0.42	0.76

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.015

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 2.7750 $uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 =$ 0.56 %

The effect of oxygen on the overall uncertainties (below) is incorporated using the following equation:-

$u_{combined} = \sqrt{\sum (uf_{O_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$

Where oxygen or moisture correction is required, uncertainty based on the standard error of the measured peripheral value is converted to units of final measurement using a sensitivity coefficient C,

$\therefore u(x_i) = C_i u_i$ where $C_i = \frac{\partial f}{\partial x_i}$

Uncertainty of Measurement Results - Calculations Part 3

Horiba PG 250 Uncertainty	Date & Time	NOx (as NO2) 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	16/08/23 13:45 - 14:45	122.56	11.05	6.07	6.45
Expanded Uncertainty as Percentage of Measured Concentration		10%	85%	55%	24%

Combined Standard Uncertainty $u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2 + u_v^2 + u_{sm}^2}$

Expanded uncertainty (at 95% confidence) $U_{Exp} = 2 \times u_c$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Where the uncertainty of Moisture is taken as the standard error of the time averaged value used to correct to Dry Conditions
7 If no value for uncertainty is presented above, the uncertainty is considered to be > 100%

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
Visit Details : Compliance – August 2023
Survey Dates : 16th – 17th August 2023
Report Issue Date : 14th September 2023

A4 – Boiler 2 Combustion Gases (NO_x, CO, SO_2 & O_2) Measurement Uncertainty

Measurement Uncertainty Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distributiuon	Minimum Certified Range (R_i) NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular (Divisor = √3)	0.40	0.80	0.40	0.13
Span drift[2]	$u_{d,s}$	Rectangular (Divisor = √3)	0.27	0.27	0.29	0.029
Repeatability Standard Deviation (span)[3]	u_r	Normal (Divisor = 1)	1.84	0.41	0.45	0.055
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	3.02	0.79	3.57	0.039
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	0.18	0.15	0.050	0.070
Interferents[1]	u_i	Rectangular (Divisor = √3)	1.20	1.50	2.90	0.56
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	10.80	7.72	6.52	0.15
Effect of Voltage Fluctuation[7]	u_v	Rectangular (Divisor = √3)	...	...	...	...
Effect of Sample Gas Flow/ Pressure[7]	u_{sg}	Rectangular (Divisor = √3)	...	...	...	...

Note:

$$when\ \left|(x_{i,\max} - x_{i,adj})\right| = \left|(x_{i,\min} - x_{i,adj})\right|, then\ u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Expressed as standard uncertainty in units of measurement i.e. mg/m³ / %Vol inc additional uncertainty of 2% for gas blending
7 Data not available so not included

Measurement Uncertainty Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty	Value of Standard Uncertainty	NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	$u(x_i) = \frac{u_{lof} \times R_i}{\sqrt{3}} =$	0.29	2.12	0.22	0.019
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.20	0.72	0.16	0.0041
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	1.84	0.41	0.45	0.055
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	2.18	2.09	1.96	0.0056
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	0.13	0.40	0.027	0.010
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.87	3.98	1.59	0.081
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	6.23	4.46	3.76	0.087
Effect of Voltage Fluctuation[7]	u_v	$u(x_i) = \frac{u_v \times R_i}{\sqrt{3}} =$	...	...	...	...
Effect of Sample Gas Flow/ Pressure[7]	u_{sg}	$u(x_i) = \frac{u_{syn} \times R_i}{\sqrt{3}} =$	...	...	...	...
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	6.92	6.74	4.56	0.13
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	13.84	13.49	9.12	0.26
Applied Span Concentration			623.41	445.87	376.38	14.99
Measured Span Concentration, STP Dry Gas			621.70	440.66	372.76	14.99
Expanded measurement uncertainty as % of Applied Span			2%	3%	2%	2%

Dwr Cymru Welsh Water		Installation Name	: Afan CHP Facility
Permit No	: EPR/ZP3032KQ	Visit Details	: Compliance – August 2023
Variation No	: EPR/ZP3032KQ/V004	Survey Dates	: 16th – 17th August 2023
Report Ref	: P5579 : R001	Report Issue Date	: 14th September 2023

A4 – Boiler 2 Combustion Gases (NO_x, CO, SO_2 & O_2) Uncertainty of Measurement Results

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 250 Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Minimum Certified Range (R_i) NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.80	0.40	0.13
Span drift[2]	$u_{d,S}$			0.27	0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			3.02	0.79	3.57	0.039
Temperature dependant span drift[5]	u_t			0.18	0.15	0.050	0.070
Effect of Voltage Fluctuation (not available)	u_v						
Effect of Sample Gas Flow/ Pressure (not available)	u_{sg}						

Notes:

For rectangular distributions, $u(x_i) = \frac{u \times R_i}{\sqrt{3}}$

For $u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,\max} - x_{i,adj})^2 + (x_{i,\min} - x_{i,adj})(x_{i,\max} - x_{i,adj}) + (x_{i,\min} - x_{i,adj})^2}{3}}$, when $\left|(x_{i,\max} - x_{i,adj})\right| = \left|(x_{i,\min} - x_{i,adj})\right|$, then $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

Where $u(x_i) = \frac{\sigma}{\sqrt{n}}$ (See note 6 below), $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	2.12	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.72	0.16	0.0041
Temperature dependant span drift	u_t			0.13	0.40	0.027	0.010
Interferents	u_i			0.87	3.98	1.59	0.081
Effect of Voltage Fluctuation (not available)	u_v						
Effect of Sample Gas Flow/ Pressure (not available)	u_{sg}						

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	17/08/23 09:00 - 10:00	3.76	0.095	0.39	0.0034
Standard Error of Measured Value	u_{SE}	17/08/23 09:00 - 10:00	6.89	1.54	2.87	0.99

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.021

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 2.0738 $uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 =$ 1.03 %

The effect of oxygen on the overall uncertainties (below) is incorporated using the following equation:-

$u_{combined} = \sqrt{\sum (uf_{O_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$

Where oxygen or moisture correction is required, uncertainty based on the standard error of the measured peripheral value is converted to units of final measurement using a sensitivity coefficient C,

$\therefore u(x_i) = C_i u_i$ where $C_i = \frac{\partial f}{\partial x_i}$

Uncertainty of Measurement Results - Calculations Part 3

Horiba PG 250 Uncertainty	Date & Time	NOx (as NO2) 0 - 125 mg/m³	SO_2 0 - 460 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	17/08/23 09:00 - 10:00	124.44	12.11	11.01	8.63
Expanded Uncertainty as Percentage of Measured Concentration		13%	80%	60%	23%

Combined Standard Uncertainty $u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2 + u_v^2 + u_{syn}^2}$

Expanded uncertainty (at 95% confidence) $U_{Exp} = 2 \times u_c$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Where the uncertainty of Moisture is taken as the standard error of the time averaged value used to correct to Dry Conditions
7 If no value for uncertainty is presented above, the uncertainty is considered to be > 100%

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
Visit Details : Compliance – August 2023
Survey Dates : 16th – 17th August 2023
Report Issue Date : 14th September 2023

A5 – Flare Stack Combustion Gases (NO_x, CO & O_2) Measurement Uncertainty

Measurement Uncertainty Calculations Part 1

Horiba PG 350 E Performance Characteristics	Standard Uncertainty (% of Range)	Distributiuon	Minimum Certified Range (R_i) NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular (Divisor = √3)	0.75	0.61	0.10
Span drift[2]	$u_{d,s}$	Rectangular (Divisor = √3)	0.094	0.056	0.0057
Repeatability Standard Deviation (span)[3]	u_r	Normal (Divisor = 1)	0.84	2.91	0.042
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	0.74	4.34	0.031
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	0.051	0.057	0.014
Interferents[1]	u_i	Rectangular (Divisor = √3)	0.52	0.87	0.010
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	10.80	6.52	0.15
Effect of Voltage Fluctuation[7]	u_v	Rectangular (Divisor = √3)	0.40	0.50	0.020
Effect of Sample Gas Flow/ Pressure[7]	u_{sg}	Rectangular (Divisor = √3)	0.10	0.10	0.10

Note:

$$when\ \left|(x_{i,\max} - x_{i,adj})\right| = \left|(x_{i,\min} - x_{i,adj})\right|, then\ u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Expressed as standard uncertainty in units of measurement i.e. mg/m³ / %Vol inc additional uncertainty of 2% for gas blending
7 Expressed as a percentage of the certified range

Measurement Uncertainty Calculations Part 2

Horiba PG 350 E Performance Characteristics	Uncertainty	Value of Standard Uncertainty	NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	$u(x_i) = \frac{u_{lof} \times R_i}{\sqrt{3}} =$	0.58	0.26	0.014
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.073	0.024	0.00082
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	0.84	2.91	0.042
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	0.58	1.88	0.0045
Temperature dependant span drift	u_t	$u(x_i)=\frac{u_t}{100}\times R_i \times \sqrt{\frac{(x_{i,max}-x_{adj})^2+(x_{i,min}-x_{adj})(x_{i,max}-x_{adj})+(x_{i,min}-x_{adj})^2}{3}}$	0.020	0.012	0.0010
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.40	0.38	0.0014
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	6.23	3.76	0.087
Effect of Voltage Fluctuation [7]	u_v	$u(x_i) = \frac{u_v \times R_i}{\sqrt{3}} =$	0.23	0.29	0.012
Effect of Sample Gas Flow / Pressure [7]	u_{sg}	$u(x_i) = \frac{usg \times R_i}{\sqrt{3}} =$	0.058	0.058	0.058
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2} + u2v + u2sg$	6.36	5.14	0.11
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	12.72	10.29	0.23
Applied Span Concentration			623.41	376.38	14.99
Measured Span Concentration, STP Dry Gas			625.40	375.10	14.99
Expanded measurement uncertainty as % of Applied Span			2%	3%	2%

Dwr Cymru Welsh Water		Installation Name	: Afan CHP Facility
Permit No	: EPR/ZP3032KQ	Visit Details	: Compliance – August 2023
Variation No	: EPR/ZP3032KQ/V004	Survey Dates	: 16th – 17th August 2023
Report Ref	: P5579 : R001	Report Issue Date	: 14th September 2023

A5 – Flare Stack Combustion Gases (NO_x, CO & O_2) Uncertainty of Measurement Result

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 E Performance Characteristics	Standard Uncertainty (% of Range)	Distribution	Divisor	Minimum Certified Range (R_i) NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.75	0.61	0.10
Span drift[2]	$u_{d,s}$			0.094	0.056	0.0057
Losses / leakage in the sample system[4]	u_{loss}			0.74	4.34	0.031
Temperature dependant span drift[5]	u_t			0.051	0.057	0.014
Interferents[1]	u_i			0.52	0.87	0.010
Effect of Voltage Fluctuation[7]	u_v			0.40	0.50	0.020
Sample Gas Pressure/ Flow[7]	u_{sg}			0.10	0.10	0.10

Notes:

For rectangular distributions, $u(x_i) = \frac{u \times R_i}{\sqrt{3}}$

For $u(x_i) = \Delta x_i \sqrt{\frac{(x_{i,\max} - x_{i,adj})^2 + (x_{i,\min} - x_{i,adj})(x_{i,\max} - x_{i,adj}) + (x_{i,\min} - x_{i,adj})^2}{3}}$, when $|(x_{i,\max} - x_{i,adj})| = |(x_{i,\min} - x_{i,adj})|$, then $u(x_i) = \frac{\Delta x_i}{\sqrt{3}}$

Where $u(x_i) = \frac{\sigma}{\sqrt{n}}$ (See note 6 below), $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Horiba PG 350 E Performance Characteristics	Uncertainty (Units of final measurement)	Distribution	Divisor	NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.58	0.26	0.014
Span drift	$u_{d,s}$			0.073	0.024	0.00082
Temperature dependant span drift	u_t			0.020	0.012	0.0010
Interferents	u_i			0.40	0.38	0.0014
Effect of Voltage Fluctuation[7]	u_v			0.31	0.22	0.0029
Sample Gas Pressure/ Flow[7]	u_{sg}			0.077	0.043	0.014

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 E Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	17/08/23 14:05 - 15:05	0.60	2.10	0.0040
Standard Error of Measured Value	u_{SE}	17/08/23 14:05 - 15:05	0.75	0.91	0.056

Effect on Uncertainty Caused by Oxygen $uCorr^{n}_{o_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.050

$$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = \quad 1.3877 \qquad uf_{o_2} = \frac{uCorr^{n}_{o_2}}{f_{o_2}} x100 = \quad 3.63\ \%$$

The effect of oxygen on the overall uncertainties (below) is incorporated using the following equation:-

$$u_{combined} = \sqrt{\sum (uf_{o_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$$

Where oxygen or moisture correction is required, uncertainty based on the standard error of the measured peripheral value is converted to units of final measurement using a sensitivity coefficient C,

$\therefore u(x_i) = C_i u_i$ where $C_i = \frac{\partial f}{\partial x_i}$

Uncertainty of Measurement Results - Calculations Part 3

Horiba PG 350 E Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	17/08/23 14:05 - 15:05	79.92	48.47	12.90
Expanded Uncertainty as Percentage of Measured Concentration		5%	10%	4%

Combined Standard Uncertainty $u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2 + u_v^2 + u_{sg}^2}$

Expanded uncertainty (at 95% confidence) $U_{Exp} = 2 \times u_c$

1 Expressed as a percentage of the certified range
2 Expressed as a percentage of the certified range as maximum drift per 24hr period
3 Expressed as a percentage of the certified range
4 Expressed as a percentage of the certified range
5 Expressed as a percentage of the certified range per one degree centigrade
6 Where the uncertainty of Moisture is taken as the standard error of the time averaged value used to correct to Dry Conditions
7 If no value for uncertainty is presented above, the uncertainty is considered to be > 100%

Dwr Cymru Welsh Water		Installation Name	: Afan CHP Facility
Permit No	: EPR/ZP3032KQ	Visit Details	: Compliance – August 2023
Variation No	: EPR/ZP3032KQ/V004	Survey Dates	: 16th – 17th August 2023
Report Ref	: P5579 : R001	Report Issue Date	: 14th September 2023

A5 - Sulphur Dioxide Uncertainty

Site: Afan WWTW
Location: A5 Flare Stack

$$u_{mass} = \sqrt{\sum (u_{filter})^2 + (u_{solution})^2}$$

Determinand	Filter mg	Solution mg	Recovered Mass mg	LAB Method Uncert (%) K= 2 Filter mg	LAB Method Uncert (%) K= 2 Solution mg	Standard Uncertainty Filter mg	Standard Uncertainty Solution mg	Combined Uncertainty mg
				SO2				
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
Sulphur Dioxide	...	0.51	0.51	...	0.0664	...	0.0332	0.0332
...	...	...	...	...	...	...	...	...
				...				
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...

	SO2			Standard Uncertainty @ 95%		
Sampled Volume (V_m)	0.55	m^3	uV_m	0.001	m^3	
Meter Correction Factor (Yd)	1.03	...		...	...	
Meter Temperature (T_m)	303.92	k	uT_m	1.5	k	
Average Differential Pressure (ΔH)	10.00	mmH_2O	$u\Delta H$	0.25	mmH_2O	
Barometric Pressure (ρ_b)	763.56	mmHg	up_b	3.8	mmHg	
$\Delta H + \rho s$ (ρ_{mj})	101.90	kPa		...	...	
Oxygen content ($O_{2,m}$)	12.90	% by volume	$uO_{2,m} = \sigma/\sqrt{n}$	0.0555		% by volume
Moisture Content (H_2O)	5.95	% by volume	uH_2O	0.32		% by volume

Note: In the following calculations, the sensitivity coefficient (C) is estimated using: $C_i = \frac{\partial f}{\partial x_i}$

For each factor, uncertainty is then calculated by $C_i u_i$ where C is the sensitivity coefficient, u is the standard uncertainty and i is the index identifying the contributing factor e.g. i = uV_m, uT_m etc.

Where results are required at wet conditions, the following correction factor is used to convert the data from the dry gas meter:

SO2:

$$f_{s,wet} = \frac{100}{(100 - H_2O)} = \quad 1.00$$

Uncertainty in correction factor to STP due to measured ΔH uncertainty component ($u\Delta H$), measured stack pressure uncertainty component (up_b) & measured temperature of dry gas uncertainty component ($uT_{m\,Dry}$)

SO2:

$$f_s = \frac{273}{760} \times \frac{P_b + \frac{\Delta H}{13.6}}{T_m} \times Y_d = \quad 0.932$$

	Maximum	Minimum	Sensitivity	ufstp
$u\Delta H$	0.93	0.93	0.0000897	0.0000224
up_b	0.94	0.93	0.00122	0.00457
uT_m	0.94	0.93	0.00307	0.00460
H_2O	...	...	...	...

$$\frac{uf_s}{f_s} = \sqrt{\left(\frac{\sqrt{(u\Delta H)^2 + (uP_s)^2}}{(P_m/101.3)}\right)^2 + \left(\frac{uT_m}{(T_m/273.15)}\right)^2 + \left(\frac{uH_2O}{100/(100 - H_2O)}\right)^2} = \quad 0.00573$$

Uncertainty in volume @ STP due to volume correction factor uncertainty component (uV_{std}) & volume uncertainty component (uV_m)

SO2:

$$V_{std} = V_{measured} \times f_s = \quad 0.511$$

	Maximum m^3	Minimum m^3	Sensitivity	Standard Uncertainty (m^3)
Effect of uV_{std}	0.51	0.51	0.55	0.00314
Effect of uV_m	0.51	0.51	0.93	0.000932

Combined Standard Uncertainty

$$\frac{uV_{std}}{V_{std}} = \sqrt{\left(\frac{uV_{std}}{f_s}\right)^2 + \left(\frac{uV_m}{V_m}\right)^2} = \quad 0.00193$$

Uncertainty of Oxygen Correction Factor (%):-

SO2:

$$f_{o_2} = \frac{20.9\% - O_{2,\,ref}}{20.9\% - O_{2,\,measured}} = \quad 2.24$$

$$uCorr^n{}_{o_2} = \frac{20.9\% - O_{2,\,ref}}{(20.9\% - O_{2,\,measured}) x (20.9\% - O_{2,\,measured})} x\, Uncertainty\ of\ O_2\ Measurement = \quad 0.0503$$

$$uf_{o_2} = \frac{uCorr^n{}_{o_2}}{f_{o_2}} x100 = \quad 2.25\ \%$$

Dwr Cymru Welsh Water
Permit No : EPR/ZP3032KQ
Variation No : EPR/ZP3032KQ/V004
Report Ref : P5579 : R001

Installation Name : Afan CHP Facility
Visit Details : Compliance – August 2023
Survey Dates : 16th – 17th August 2023
Report Issue Date : 14th September 2023

Uncertainty in final measurement @ reference conditions due to mass uncertainty component (uM)

Determinand	SO2: Maximum mg/Nm³	Minimum mg/Nm³	Sensitivity	uM mg/Nm³
...	...	...	...	...
...	...	...	...	...
Sulphur Dioxide	2.38	2.09	4.38	0.15
...	...	...	...	...

Uncertainty in final measurement @ reference conditions due to uncertainty component arrising from leak and/or loss (assumed 2% max) in the sample system (uL)

Determinand	SO2: uL mg/Nm³
...	...
...	...
Sulphur Dioxide	0.0258
...	...

Uncertainty in final measurement @ Reference Conditions due to uVstp

Determinand	SO2: Maximum mg/Nm³	Minimum mg/Nm³	Sensitivity	uVstp mg/Nm³
...	...	...	...	...
...	...	...	...	...
Sulphur Dioxide	2.24	2.23	4.37	0.00844
...	...	...	...	...

Combined Uncertainty excluding oxygen contribution

$$u_{combined} = \sqrt{\sum (u_M)^2 + (u_L)^2 + (uV_{stp})^2}$$

Determinand	SO2: Combined Uncertainty mg/Nm³	Expanded Uncertainty mg/Nm³	Measured Concentration mg/Nm³	Percent of Measured Concentration
...	...	...	...	...
...	...	...	...	...
Sulphur Dioxide	0.15	0.30	2.24	13.23
...	...	...	...	...

Combined Uncertainty including oxygen contribution

$$u_{combined} = \sqrt{\sum (uf_{o_2})^2 + (Uncertainty\ of\ Measurement\ of\ Determinand)^2}$$

Determinand	Measurement Uncertainty of Determinand	Measurement Uncertainty of Oxygen Corrn Factor	Overall Measurement Uncertainty inc O_2 Corr^n factor (Ucombined)
...	...	...	...
...	...	...	...
Sulphur Dioxide	13.23	2.25	13.42
...	...	...	...

Dwr Cymru Welsh Water		Installation Name	: Afan CHP Facility
Permit No	: EPR/ZP3032KQ	Visit Details	: Compliance – August 2023
Variation No	: EPR/ZP3032KQ/V004	Survey Dates	: 16th – 17th August 2023
Report Ref	: P5579 : R001	Report Issue Date	: 14th September 2023

Stack Reference A3

Measurement Uncertainty Calculations - Velocity at Stack Conditions

Contribution From	Standard u/c (mm H_2O)	
Pitot Calibration Uncertainty Contribution	0.015	A
Manometer Calibration Uncertainty Contribution	0.015	B
Variation in Actual Pitot reading at sample points	0.00	C
Combined u/c (mm H_2O) =	**Combined u/c (mm H_2O)**	
SQRT $(A/\sqrt{3})^2 + (B/\sqrt{3})^2 + (C/\sqrt{3})^2$	0.01	
Expanded Uncertainty of Flow Measurements (mm H_2O)	**0.02**	
	Standard u/c (K)	
Temperature Calibration (K)	2.08	D
Variation in Actual Temp reading at sample points	0.13	E
Combined u/c of Temp (K)	**Combined u/c (K)**	
SQRT $((D/\sqrt{3^2}) + (E/\sqrt{3})^2)$	1.20	
Expanded Uncertainty of Temp Measurements (K)	**2.40**	
Measured Average Velocity (m/s) at Stack Conds	6.84	
Maximum Average Velocity (m/s) at Stack Conds	6.88	
Standard Uncertainty Velocity at Stack Conditions (%)	0.70	
Expanded Uncertainty Velocity (at Stack Conditions)	**1.39 (%)**	

Measurement Uncertainty Calculations - Flowrate at Stack Conditions

Contribution From	Standard u/c (m^2)
Area (m2)	0.00238
Measured Average Flowrate (m^3/s) at Stack Conds	1.62
Maximum Average Flowrate (m^3/s) at Stack Conds	1.65
Standard Uncertainty Flowrate (m^3/s) at Stack Conditions (%)	1.70
Expanded Uncertainty Flowrate (m^3/s) at Stack Conditions	**3.41 (%)**

Measurement Uncertainty Calculations - Flowrate at STP & Wet Gas

Contribution From	Standard u/c (%)
Temperature Calibration (K)	0.5
Barometer Calibration	0.5
Measured Average Flowrate (m^3/s) at STP Wet	1.07
Maximum Average Flowrate (m^3/s) at STP Wet	1.09
Standard Uncertainty Flowrate (m^3/s) at STP Wet	2.04
Expanded Uncertainty Flowrate (m^3/s) at STP Wet	**4.08 (%)**

Measurement Uncertainty Calculations - Flowrate at STP & Dry Gas

Contribution From	Standard u/c (%)
Moisture Uncertainty (% v/v)	0.21
Measured Average Flowrate (m^3/s) at STP Dry	0.96
Maximum Average Flowrate (m^3/s) at STP Dry	0.98
Standard Uncertainty Flowrate (m^3/s) at STP Dry	2.28
Expanded Uncertainty Flowrate (m^3/s) at STP Dry	**4.55 (%)**

Measurement Uncertainty Calculations - Flowrate at STP, Dry Gas & Ref Oxygen

Contribution From	Standard u/c (%)
Oxygen Uncertainty (% v/v)	0.065
Measured Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.78
Maximum Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.80
Standard Uncertainty Flowrate (m^3/s) at STP Dry & Ref Oxygen	2.73
Expanded Uncertainty Flowrate (m^3/s) at STP Dry & Ref O_2	**5.46 (%)**

Dwr Cymru Welsh Water		Installation Name	: Afan CHP Facility
Permit No	: EPR/ZP3032KQ	Visit Details	: Compliance – August 2023
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Report Ref	: P5579 : R001	Report Issue Date	: 14th September 2023

Stack Reference A4

Measurement Uncertainty Calculations - Velocity at Stack Conditions

Contribution From	Standard u/c (mm H_2O)	
Pitot Calibration Uncertainty Contribution	0.015	A
Manometer Calibration Uncertainty Contribution	0.015	B
Variation in Actual Pitot reading at sample points	0.00	C
Combined u/c (mm H_2O) =	**Combined u/c (mm H_2O)**	
SQRT $(A/\sqrt{3})^2 + (B/\sqrt{3})^2 + (C/\sqrt{3})^2$	0.01	
Expanded Uncertainty of Flow Measurements (mm H_2O)	**0.02**	
	Standard u/c (K)	
Temperature Calibration (K)	2.06	D
Variation in Actual Temp reading at sample points	0.13	E
Combined u/c of Temp (K)	**Combined u/c (K)**	
SQRT $((D/\sqrt{3^2}) + (E/\sqrt{3})^2)$	1.19	
Expanded Uncertainty of Temp Measurements (K)	**2.38**	
Measured Average Velocity (m/s) at Stack Conds	6.92	
Maximum Average Velocity (m/s) at Stack Conds	6.97	
Standard Uncertainty Velocity at Stack Conditions (%)	0.70	
Expanded Uncertainty Velocity (at Stack Conditions)	**1.39 (%)**	

Measurement Uncertainty Calculations - Flowrate at Stack Conditions

Contribution From	Standard u/c (m^2)
Area (m2)	0.00238
Measured Average Flowrate (m^3/s) at Stack Conds	1.64
Maximum Average Flowrate (m^3/s) at Stack Conds	1.67
Standard Uncertainty Flowrate (m^3/s) at Stack Conditions (%)	1.70
Expanded Uncertainty Flowrate (m^3/s) at Stack Conditions	**3.41 (%)**

Measurement Uncertainty Calculations - Flowrate at STP & Wet Gas

Contribution From	Standard u/c (%)
Temperature Calibration (K)	0.5
Barometer Calibration	0.5
Measured Average Flowrate (m^3/s) at STP Wet	1.10
Maximum Average Flowrate (m^3/s) at STP Wet	1.12
Standard Uncertainty Flowrate (m^3/s) at STP Wet	2.04
Expanded Uncertainty Flowrate (m^3/s) at STP Wet	**4.08 (%)**

Measurement Uncertainty Calculations - Flowrate at STP & Dry Gas

Contribution From	Standard u/c (%)
Moisture Uncertainty (% v/v)	0.16
Measured Average Flowrate (m^3/s) at STP Dry	0.94
Maximum Average Flowrate (m^3/s) at STP Dry	0.96
Standard Uncertainty Flowrate (m^3/s) at STP Dry	2.23
Expanded Uncertainty Flowrate (m^3/s) at STP Dry	**4.47 (%)**

Measurement Uncertainty Calculations - Flowrate at STP, Dry Gas & Ref Oxygen

Contribution From	Standard u/c (%)
Oxygen Uncertainty (% v/v)	0.086
Measured Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.64
Maximum Average Flowrate (m^3/s) at STP Dry & Ref Oxygen	0.66
Standard Uncertainty Flowrate (m^3/s) at STP Dry & Ref Oxygen	2.95
Expanded Uncertainty Flowrate (m^3/s) at STP Dry & Ref O_2	**5.89 (%)**