EMISSIONS MONITORING SURVEY

(On Behalf Of Welsh Power Group Ltd)

Prepared for:

Cynon Power Ltd.

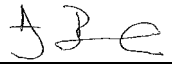
Aberaman Industrial Park,
Aberaman,
Aberdare,
Rhondda Cynon Taff
CF44 4AG

Permit Number	**: PAN-004125**
Variation Number	**: N/A**
Installation	**: Genset Engines 1 – 8**
Visit Details	**: Compliance 2019**
Job Number	**: P4099**
Report Number	**: R001**
Report Issue Date	**: 22nd October 2019**
Survey Dates	**: 4th October 2019**

Prepared by:

Environmental Compliance Limited
Unit G1
Main Avenue
Treforest Industrial Estate
Pontypridd
CF37 5BF.

Tel: 01443 841760
Fax: 01443 841761

Report Issue:		**FINAL**	
Report Prepared by:		**Report Reviewed & Approved by** **MCERTS Level Two** **Technical Endorsements TE1, TE2, TE3 & TE4**	
Name:	Scott Hackett	***Name:***	Andy Barnes
		MCERTS No:	MM 03 235
		Signature:	
Date:	22/10/2019	***Date:***	22/10/2019

This report is not to be used for contractual or engineering purposes unless this approval sheet is signed where indicated by the approver and the report is designated "FINAL".

mCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

UKAS TESTING 2499

This report has been prepared by Environmental Compliance Limited (ECL) in their professional capacity as Environmental Consultants. The contents of the report reflect the conditions that prevailed and the information available or supplied at the time of its preparation. The report, and the information contained therein, is provided by ECL solely for use and reliance by the Client in performance of ECLs duties and liabilities under its contract with the Client. Until ECL has received payment in full as detailed in the quotation or contract the contents of this report remain the legal property of ECL. The contents of the report do not, in any way, purport to include any manner of legal advice or opinion.

This report should not be reproduced, (except in full) without the written approval of the laboratory.

Should the Client wish to release this report to a Third Party for the party's reliance, Environmental Compliance Ltd may, at its discretion, agree to such release provided that:

- Environmental Compliance Ltd gives written agreement prior to such release and ECL has received payment in full for all works/services undertaken;

- By release of the report to the Third Party, that Third Party does not acquire any rights, contractual or otherwise, whatsoever against Environmental Compliance Ltd and, accordingly, Environmental Compliance Ltd assume no duties, liabilities or obligations to that Third Party;

- Environmental Compliance Ltd accepts no responsibility for any loss or damage incurred by the Client or for any conflict of Environmental Compliance Ltd interests arising out of the Clients' release of this report to the Third Party.

In the event that a report is revised and re-issued, the client shall ensure that any earlier versions of the report, and any copies thereof, are void and such copies should be marked with the words "superseded and revised".

Opinions and Interpretation expressed within this report are outside the scope of the UKAS accreditation.

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

TABLE OF CONTENTS

Section	Description	Page Number
	Document Control Sheet	
PART 1	EXECUTIVE SUMMARY	4
1	MONITORING OBJECTIVES	4
1.1	Monitoring Results	5
1.2	Operating Information	8
2	MONITORING DEVIATIONS	9
PART 2	SUPPORTING INFORMATION	10
3	SAMPLING STAFF DETAILS	10
4	SAMPLING PROTOCOLS / METHODOLOGIES	11
5	SAMPLE POINT DESCRIPTIONS	12
	EQUIPMENT IDs	13
	FIGURES	15
	FIELD CALIBRATION DATA	20
	UNCERTAINTY CALCULATIONS	23

PART 1 - EXECUTIVE SUMMARY

1 Monitoring Objectives

Environmental Compliance Ltd (ECL) was commissioned by **Welsh Power Group Ltd** to undertake an emission monitoring survey at **Cynon Power Ltd site in Aberdare**. This report presents the findings of the study.

The monitoring at this installation was carried out in accordance with our quotation reference **AM/P4056/Q001 & P4099**, 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
	Genset Engines 1 - 8
Oxides of Nitrogen (as NO_2)	● U
Carbon Monoxide	● U
Oxygen	● 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: *"During Normal 100% Operation"*

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
Genset 1	Oxides of Nitrogen (as NO_2)	190	179.56	mg/m^3	3	Dry & 15% O_2	04/10/2019	10:02 – 11:02	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	265.67	mg/m^3	3	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Paramagnetic)	...	10.02	%	2	Dry			BS EN 14789: 2017	UKAS / MCERTS		100%

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
Genset 2	Oxides of Nitrogen (as NO_2)	190	180.45	mg/m^3	3	Dry & 15% O_2	04/10/2019	11:28 – 12:28	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	285.09	mg/m^3	3	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Paramagnetic)	...	9.83	%	2	Dry			BS EN 14789: 2017	UKAS / MCERTS		100%

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
Genset 3	Oxides of Nitrogen (as NO_2)	190	179.07	mg/m^3	3	Dry & 15% O_2	04/10/2019	12:47 – 13:47	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	285.90	mg/m^3	3	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Paramagnetic)	...	10.07	%	2	Dry			BS EN 14789: 2017	UKAS / MCERTS		100%

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
Genset 4	Oxides of Nitrogen (as NO_2)	190	178.30	mg/m^3	3	Dry & 15% O_2	04/10/2019	14:13 – 15:13	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	283.75	mg/m^3	3	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Paramagnetic)	...	9.98	%	2	Dry			BS EN 14789: 2017	UKAS / MCERTS		100%

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
Genset 5	Oxides of Nitrogen (as NO_2)	190	156.61	mg/m^3	2	Dry & 15% O_2	04/10/2019	14:06 – 15:06	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	274.58	mg/m^3	2	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Paramagnetic)	...	9.69	%	2	Dry			BS EN 14789: 2017	UKAS / MCERTS		100%

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
Genset 6	Oxides of Nitrogen (as NO_2)	190	173.98	mg/m^3	2	Dry & 15% O_2	04/10/2019	12:45 – 13:45	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	290.55	mg/m^3	2	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Paramagnetic)	...	9.95	%	2	Dry			BS EN 14789: 2017	UKAS / MCERTS		100%

Cynon Power Ltd
Permit No : PAN-004125
Variation No : N/A
Report Ref : P4099 : R001

Installation Name : Genset Engines 1 – 8
Visit Details : Compliance 2019
Survey Dates : 4th October 2019
Report Issue Date : 22nd October 2019

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
Genset 7	Oxides of Nitrogen (as NO_2)	190	183.11	mg/m^3	2	Dry & 15% O_2	04/10/2019	11:27 – 12:27	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	265.53	mg/m^3	2	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Paramagnetic)	...	10.48	%	2	Dry			BS EN 14789: 2017	UKAS / MCERTS		100%

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
Genset 8	Oxides of Nitrogen (as NO_2)	190	185.10	mg/m^3	2	Dry & 15% O_2	04/10/2019	10:10 – 11:10	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	264.68	mg/m^3	2	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Paramagnetic)	...	10.60	%	2	Dry			BS EN 14789: 2017	UKAS / MCERTS		100%

Notes

The uncertainty figures presented in Table 1.1 for NO_x, CO & 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

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
Genset 1 - 8	Batch	On Demand	Gas	N/A	None	100 %	…	…	…	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: PAN-004125** 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 no substance deviations from the original and agreed emissions monitoring schedule.

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 any of the sampling locations. Such tests are not applicable to these locations (as the duct area is $< 1 m^2$) and were not requested by the client.

PART 2 – SUPPORTING INFORMATION

3 SAMPLING STAFF DETAILS

Site Sampling Team

Names of Site Team	Dates on Site	MCERTS No.	LEVEL	Technical Endorsements
Adam May	4th October 2019	MM 05 626	2	TE1, TE2, TE3, TE4
Andrew Barnes		MM 18 1507	Trainee	….

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

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

Combustion Gases (NO_x, CO & O_2)

Measurements of combustion gases were carried out using **two** MCERTS Certified **Horiba PG 350** stack gas analysers. Continuous monitoring of emissions was undertaken over each test period recording minute averaged data (one measurement every 60 seconds). The measurement techniques for each determinand are as follows:

Determinand	Technique	SRM
• NO_x	Chemiluminescence	BS EN 14792: 2017
• CO	Non-dispersive infrared	BS EN 15058: 2017
• O_2	Paramagnetic Sensor	BS EN 14789: 2017

The analyser was set up with reference to the manufacturers operator handbook and the in-house technical procedure **ECL/TPD/033d**. The analyser was calibrated on site using certified gases which are traceable to ISO 17025. (with uncertainty $< 2\%$). Zero measurements were performed using Nitrogen. The analyser was calibrated directly into the sample inlet and then checked through the entire sampling system (including sampling probe, heated & unheated gas transport lines and gas drying/ conditioning system).

Data is presented graphically in the Figures Section, and the minute averaged data is given in the Tables Section.

5 SAMPLE POINT DESCRIPTIONS

The homogeneity test is applicable to combustion processes. This includes but is not restricted to, those regulated under the Waste Incineration Directive (**WID**) and the Large Combustion Plant Directive (**LCPD**).

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:-

Genset Engines 1 – 8

Sampling on each Genset engine was undertaken from a pilot hole in a straight section of vertical ductwork located on the rear of the engine.

Each engine is accessed at ground level and located within an engine housing unit.

EQUIPMENT IDs
(Pre site checklist from SSP)

Cynon Power Ltd		Installation Name	: Genset Engines 1 – 8
Permit No	: PAN-004125	Visit Details	: Compliance 2019
Variation No	: N/A	Survey Dates	: 4th October 2019
Report Ref	: P4099 : R001	Report Issue Date	: 22nd October 2019

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								
MST Nozzle set									
MST "S" Type Pitot									
MST Probe									
MST Hot Box									
MST Impinger Arm									
Barometer		628							
Site Balance									
Site Check weights									
Horiba	E002	1065		969					
Heated Probe / Filter		1191		806					
Chiller		971		970					
MFC									
Heated Line		212	213	302	303				
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									
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	Zero	Bags (2kg bags)

FIGURES

Cynon Power Ltd
Permit No : PAN-004125
Variation No : N/A
Report Ref : P4099 : R001

Installation Name : Genset Engines 1 – 8
Visit Details : Compliance 2019
Survey Dates : 4th October 2019
Report Issue Date : 22nd October 2019

Figure 1

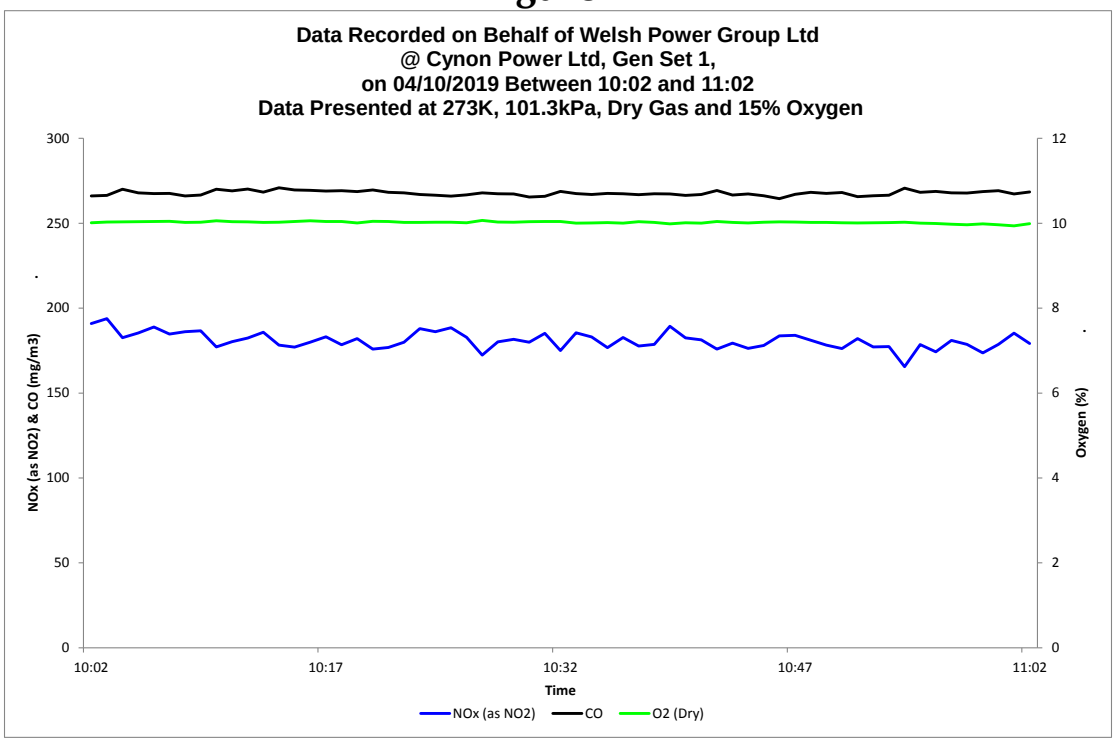


Figure 2

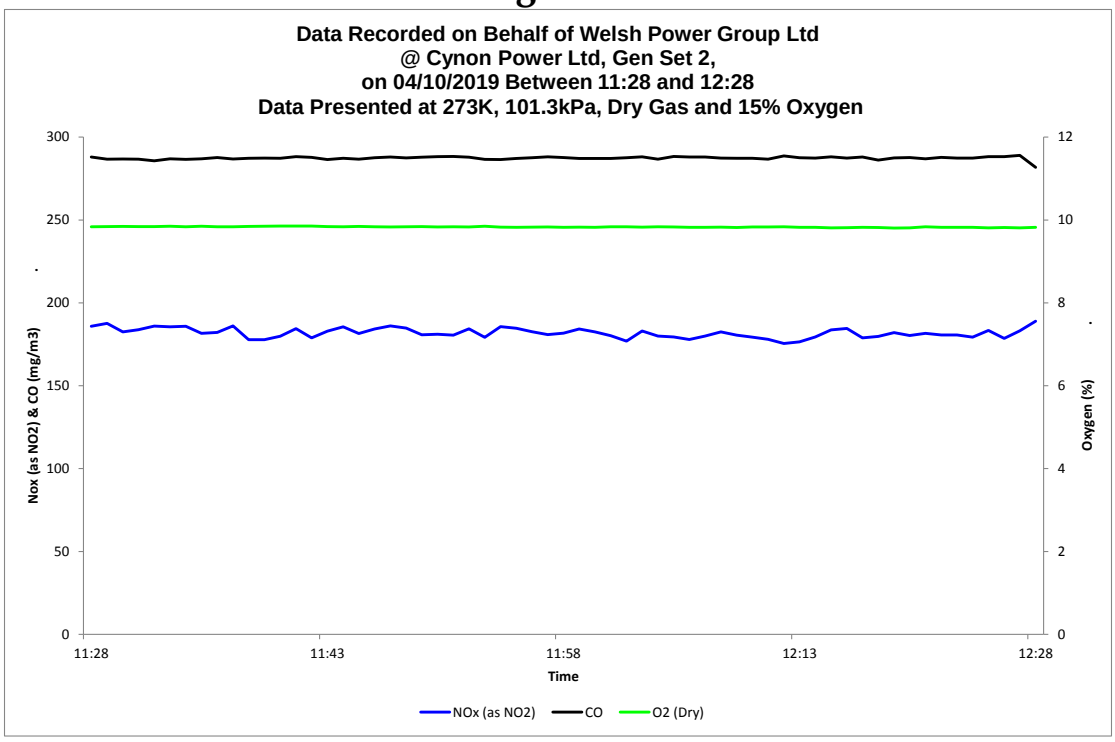


Figure 3

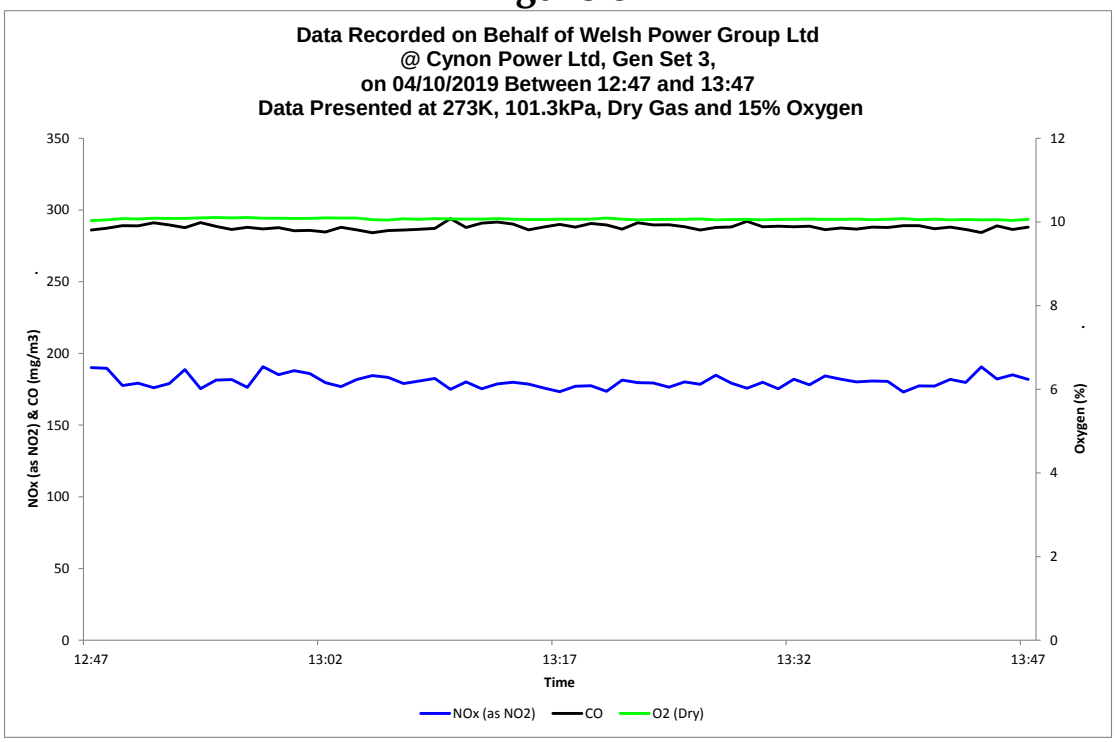


Figure 4

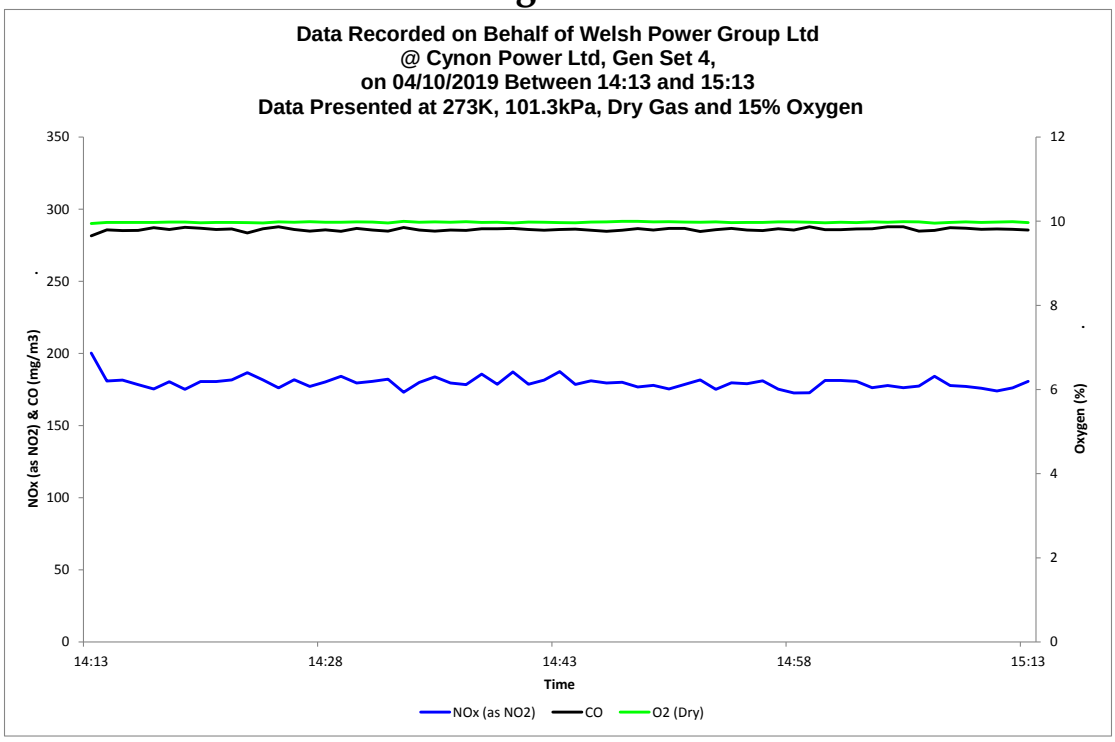


Figure 5

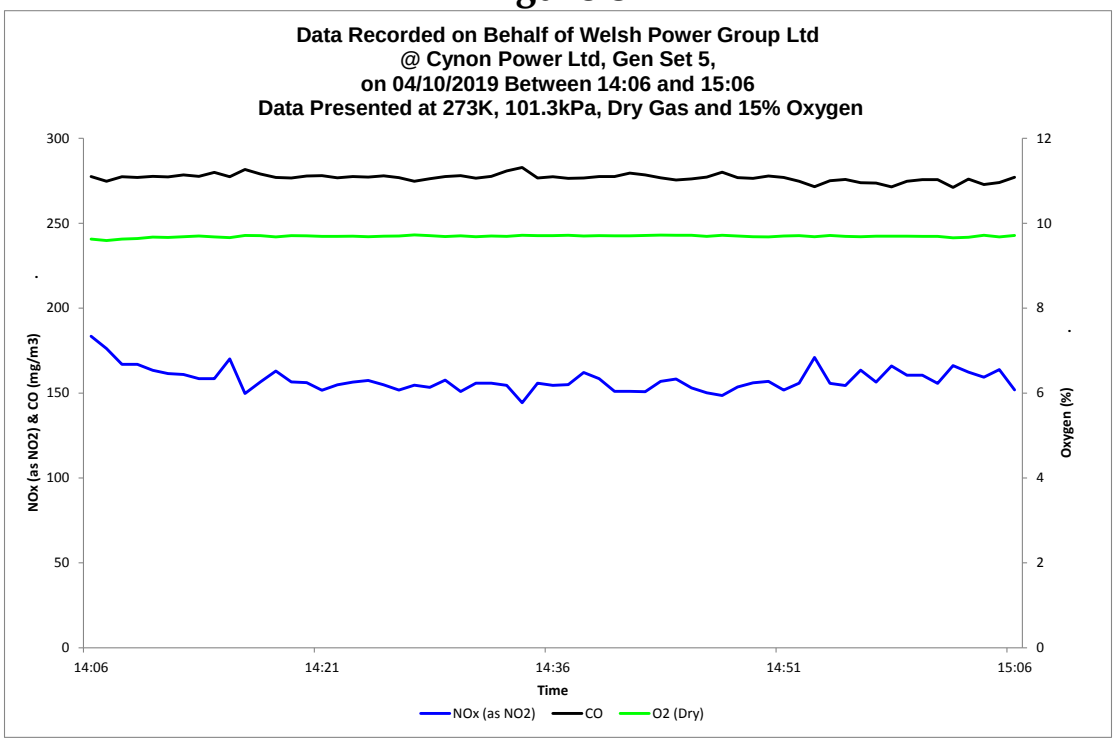


Figure 6

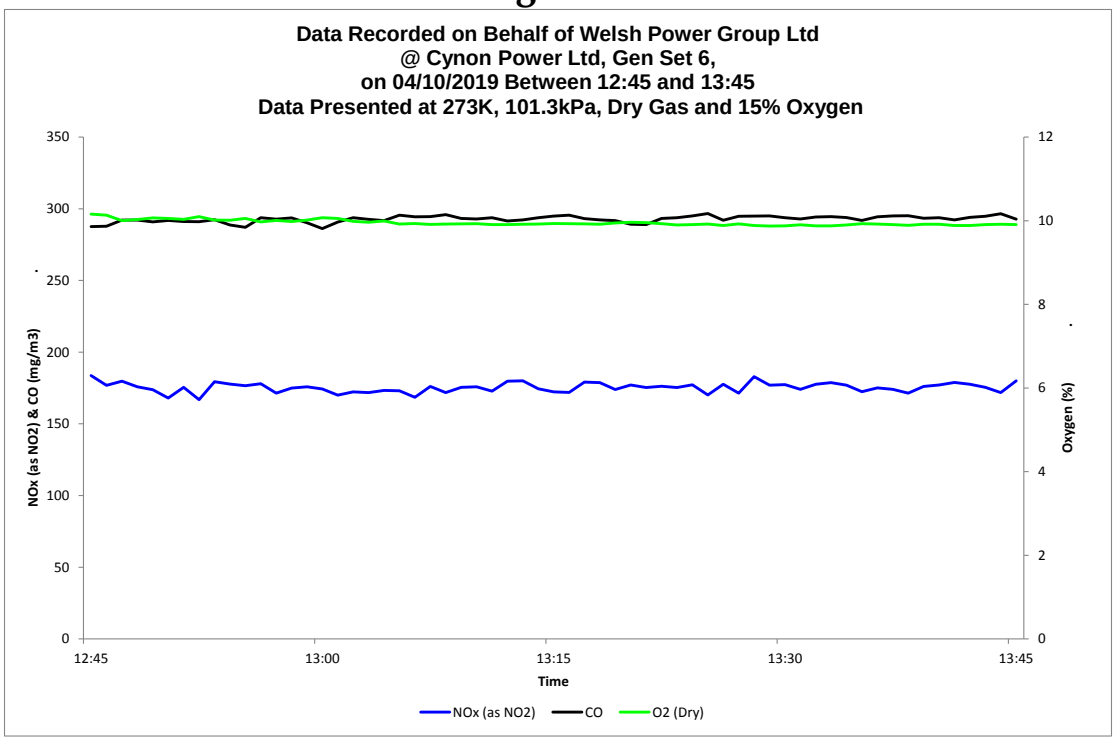


Figure 7

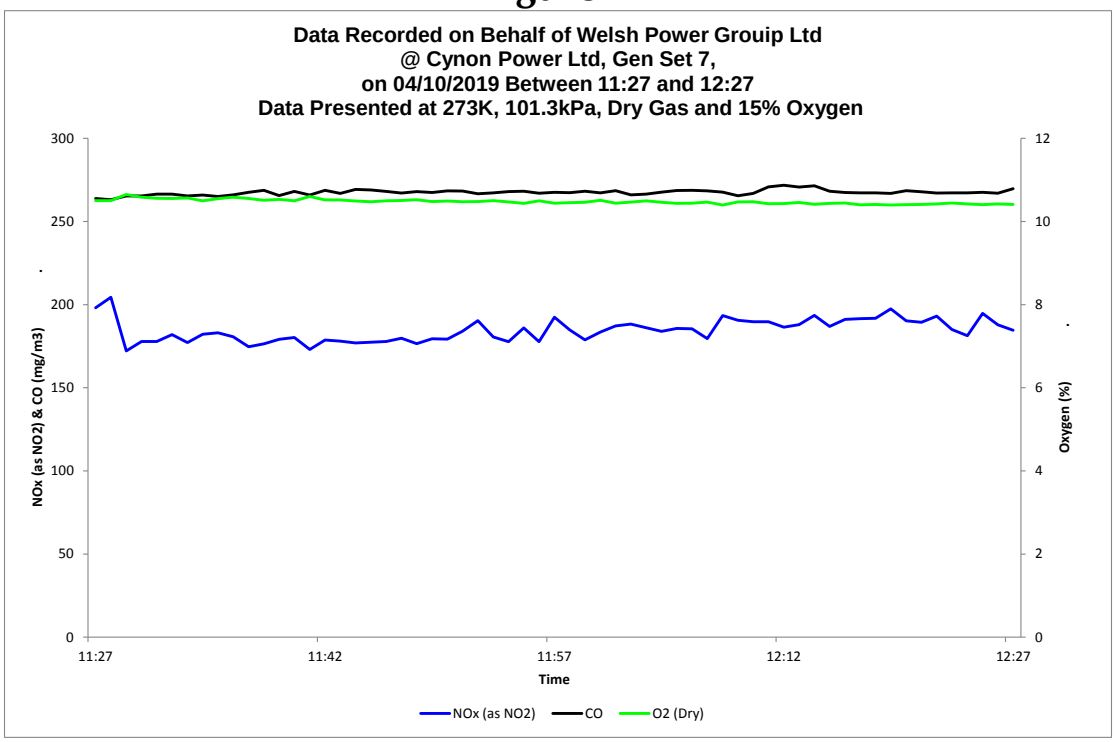
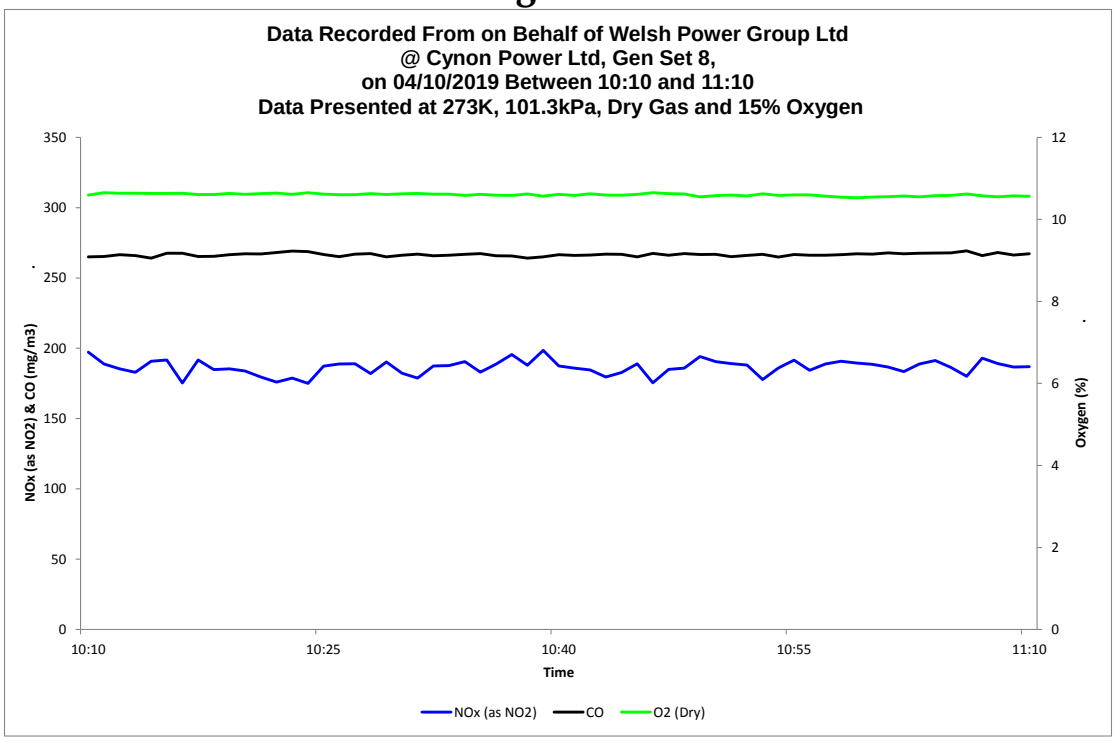


Figure 8



FIELD CALIBRATION DATA

Cynon Power Ltd			Installation Name	: Genset Engines 1 – 8
Permit No	: PAN-004125		Visit Details	: Compliance 2019
Variation No	: N/A		Survey Dates	: 4th October 2019
Report Ref	: P4099	: R001	Report Issue Date	: 22nd October 2019

Combustion Gases Calibration Summary (NOx, CO & O_2) - PG 350 Horiba – ID 969 (Units 1, 2, 3 & 4)

	Horiba PG 350 Measurement Ranges:		
	NO as NO_2	CO	O_2
Units	1025 mg/m^3	1250 mg/m^3	25 %Vol
	Zero Values (Direct)		
Mean Initial Direct Zero	0.00	0.02	-0.01
Mean Confirmation Direct Zero	0.00	-0.15	-0.04
Difference in Direct Zero	0.00	0.16	0.03
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	0.46	-0.64	-0.01
% of Measurement Range?	0.05%	-0.05%	-0.05%
Detection Limit (LOD)	0.40	0.56	0.20
	Applied Span:		
	NO	CO	O_2
Actual Applied Span Concentration	622.79	380.13	15.07
	Pre Test System Zero Values		
Mean Pre Test System Zero	0.46	-0.64	-0.01
Difference ≤ ± 2% of Span Value?	0.07%	0.17%	0.09%
	Post Test Direct Zero Values		
Mean Post Test Direct Zero	0.00	-0.06	-0.11
% of Certified Range?	0.00%	0.00%	-0.45%
Zero Drift ≤ ± 5% of Applied Span?	0.00%	0.02%	0.71%
	Pre Test System Span Values		
Mean Pre Test System Span	615.34	377.58	15.00
Difference ≤ ± 2% of Span Value ?	1.20%	0.67%	0.46%
	Post Test Direct Span Values		
Mean Post Test Direct Span	622.22	373.83	15.00
Span Drift ≤ ± 5% Span Value?	0.09%	1.66%	0.46%

Cynon Power Ltd			Installation Name	: Genset Engines 1 – 8
Permit No	: PAN-004125		Visit Details	: Compliance 2019
Variation No	: N/A		Survey Dates	: 4th October 2019
Report Ref	: P4099	: R001	Report Issue Date	: 22nd October 2019

Combustion Gases Calibration Summary (NOx, CO & O_2) - PG 350 Horiba – ID 1065 (Units 5, 6, 7 & 8)

	Horiba PG 350 Measurement Ranges:		
	NO as NO_2	CO	O_2
Units	1025 mg/m^3	1250 mg/m^3	25 %Vol
Zero Values (Direct)			
Mean Initial Direct Zero	0.00	0.14	-0.01
Mean Confirmation Direct Zero	0.00	0.32	-0.04
Difference in Direct Zero	0.00	0.18	0.03
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	1.03	0.02
% of Measurement Range?	0.00%	0.08%	0.10%
Detection Limit (LOD)	0.00	0.31	0.20
Applied Span:			
	NO	CO	O_2
Actual Applied Span Concentration	622.79	380.13	15.07
Pre Test System Zero Values			
Mean Pre Test System Zero	0.00	1.03	0.02
Difference ≤ ± 2% of Span Value?	0.00%	0.27%	0.16%
Post Test Direct Zero Values			
Mean Post Test Direct Zero	0.00	1.62	-0.07
% of Certified Range?	0.00%	0.13%	-0.28%
Zero Drift ≤ ± 5% of Applied Span?	0.00%	0.39%	0.36%
Pre Test System Span Values			
Mean Pre Test System Span	619.37	377.40	15.03
Difference ≤ ± 2% of Span Value ?	0.55%	0.72%	0.29%
Post Test Direct Span Values			
Mean Post Test Direct Span	621.42	378.85	15.02
Span Drift ≤ ± 5% Span Value?	0.22%	0.33%	0.35%

UNCERTAINTY CALCULATIONS

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Measurement Uncertainty (Genset 1- 4)

Measurement Uncertainty Calculations Part 1

Horiba PG 350 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)	2.81	3.10	0.057
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	5.56	3.39	0.28
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	1.80	2.00	0.15
Interferents[1]	u_i	Rectangular (Divisor = √3)	0.52	0.87	
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	10.79	6.58	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 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	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	2.81	3.10	0.057
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	4.30	1.47	0.040
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	1.39	0.87	0.022
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.40	0.38	
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	6.23	3.80	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		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2} + u2v + u2sg$	8.23	5.22	0.13
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	16.46	10.44	0.26
Applied Span Concentration			622.79	380.13	15.07
Measured Span Concentration, STP Dry Gas			619.27	375.70	15.00
Expanded measurement uncertainty as % of Applied Span			3%	3%	2%

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Uncertainty of Measurement Results – Genset 1

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 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}			5.56	3.39	0.28
Temperature dependant span drift[5]	u_t			1.80	2.00	0.15

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 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			1.39	0.87	0.02
Interferents	u_i			0.40	0.38	

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 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}	04/10/19 10:02 - 11:02	9.98	9.02	0.028
Standard Error of Measured Value	u_{SE}	04/10/19 10:02 - 11:02	1.15	0.32	0.00296

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.045

$$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = 0.5889 \qquad uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 = 7.62\ \%$$

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 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	04/10/19 10:02 - 11:02	179.56	265.67	10.02
Expanded Uncertainty as Percentage of Measured Concentration		14%	10%	8%

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%

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Uncertainty of Measurement Results – Genset 2

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 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}			5.56	3.39	0.28
Temperature dependant span drift[5]	u_t			1.80	2.00	0.15

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 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			1.39	0.87	0.022
Interferents	u_i			0.40	0.38	

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 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}	04/10/19 11:28 - 12:28	10.03	9.68	0.028
Standard Error of Measured Value	u_{SE}	04/10/19 11:28 - 12:28	0.70	0.23	0.0015

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement = 0.043$

$$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = 0.6001 \qquad uf_{o_2} = \frac{uCorr^n_{O_2}}{f_{o_2}} x100 = 7.22\ \%$$

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 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	04/10/19 11:28 - 12:28	180.45	285.09	9.83
Expanded Uncertainty as Percentage of Measured Concentration		13%	10%	7%

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%

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Uncertainty of Measurement Results – Genset 3

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 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}			5.56	3.39	0.28
Temperature dependant span drift[5]	u_t			1.80	2.00	0.15

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 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			1.39	0.87	0.022
Interferents	u_i			0.40	0.38	

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 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}	04/10/19 12:47 - 13:47	9.96	9.71	0.028
Standard Error of Measured Value	u_{SE}	04/10/19 12:47 - 13:47	1.00	0.46	0.0021

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})(20.9\% - O_{2,measured})} \times Uncertainty\ of\ O_2\ Measurement =$ 0.045

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.5859 $uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} \times 100 =$ 7.73 %

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 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	04/10/19 12:47 - 13:47	179.07	285.90	10.07
Expanded Uncertainty as Percentage of Measured Concentration		14%	10%	8%

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%

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Uncertainty of Measurement Results – Genset 4

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 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}			5.56	3.39	0.28
Temperature dependant span drift[5]	u_t			1.80	2.00	0.15

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 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			1.39	0.87	0.022
Interferents	u_i			0.40	0.38	

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 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}	04/10/19 14:13 - 15:13	9.91	9.63	0.028
Standard Error of Measured Value	u_{SE}	04/10/19 14:13 - 15:13	1.01	0.25	0.0014

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})(20.9\% - O_{2,measured})} x Uncertainty\ of\ O_2\ Measurement =$ 0.045

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.5914 $uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 =$ 7.52 %

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 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	04/10/19 14:13 - 15:13	178.30	283.75	9.98
Expanded Uncertainty as Percentage of Measured Concentration		14%	10%	8%

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%

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Measurement Uncertainty (Genset 5 - 8)

Measurement Uncertainty Calculations Part 1

Horiba PG 350 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)	0.90	1.92	0.047
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	2.55	3.63	0.17
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	1.80	2.00	0.15
Interferents[1]	u_i	Rectangular (Divisor = √3)	0.52	0.87	
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	10.79	6.58	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 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	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	0.90	1.92	0.047
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	1.97	1.57	0.025
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	1.39	0.87	0.022
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.40	0.38	
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	6.23	3.80	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		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2} + u2v + u2sg$	6.78	4.65	0.12
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	13.56	9.30	0.24
Applied Span Concentration			622.79	380.13	15.07
Measured Span Concentration, STP Dry Gas			620.39	378.13	15.02
Expanded measurement uncertainty as % of Applied Span			2%	2%	2%

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Uncertainty of Measurement Results – Genset 5

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 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}			2.55	3.63	0.17
Temperature dependant span drift[5]	u_t			1.80	2.00	0.15

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 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			1.39	0.87	0.022
Interferents	u_i			0.40	0.38	

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 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}	04/10/19 14:06 - 15:06	3.99	9.97	0.017
Standard Error of Measured Value	u_{SE}	04/10/19 14:06 - 15:06	1.63	0.53	0.0031

Effect on Uncertainty Caused by Oxygen $uCorr^{n}_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})(20.9\% - O_{2,measured})} \times Uncertainty\ of\ O_2\ Measurement =$ 0.042

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.6088 $uf_{O_2} = \frac{uCorr^{n}_{O_2}}{f_{O_2}} \times 100 =$ 6.94 %

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 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	04/10/19 14:06 - 15:06	156.61	274.58	9.69
Expanded Uncertainty as Percentage of Measured Concentration		9%	10%	7%

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%

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Uncertainty of Measurement Results – Genset 6

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 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		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}			2.55	3.63	0.17
Temperature dependant span drift[5]	u_t		$\sqrt{3}$	1.80	2.00	0.15

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 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		0.58	0.26	0.014
Span drift	$u_{d,s}$			0.073	0.024	0.00082
Temperature dependant span drift	u_t			1.39	0.87	0.022
Interferents	u_i		$\sqrt{3}$	0.40	0.38	

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 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}	04/10/19 12:45 - 13:45	4.44	10.55	0.017
Standard Error of Measured Value	u_{SE}	04/10/19 12:45 - 13:45	0.81	0.54	0.0087

Effect on Uncertainty Caused by Oxygen $uCorr^{n}_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.044

$$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = 0.5928 \qquad uf_{o_2} = \frac{uCorr^{n}_{o_2}}{f_{o_2}} x100 = 7.47\ \%$$

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 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	04/10/19 12:45 - 13:45	173.98	290.55	9.95
Expanded Uncertainty as Percentage of Measured Concentration		9%	10%	7%

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%

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Uncertainty of Measurement Results – Genset 7

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 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}			2.55	3.63	0.17
Temperature dependant span drift[5]	u_t			1.80	2.00	0.15

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 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			1.39	0.87	0.022
Interferents	u_i			0.40	0.38	

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 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}	04/10/19 11:27 - 12:27	4.67	9.64	0.018
Standard Error of Measured Value	u_{SE}	04/10/19 11:27 - 12:27	1.52	0.36	0.0072

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement = 0.049$

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.5631 $uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 =$ 8.68 %

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 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	04/10/19 11:27 - 12:27	183.11	265.53	10.48
Expanded Uncertainty as Percentage of Measured Concentration		10%	11%	9%

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%

Cynon Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-004125**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 4th October 2019**
Report Ref	**: P4099 : R001**	**Report Issue Date**	**: 22nd October 2019**

Uncertainty of Measurement Results – Genset 8

Uncertainty of Measurement Results - Calculations Part 1

Horiba PG 350 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		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}			2.55	3.63	0.17
Temperature dependant span drift[5]	u_t		$\sqrt{3}$	1.80	2.00	0.15

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 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			1.39	0.87	0.022
Interferents	u_i			0.40	0.38	

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 350 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}	04/10/19 10:10 - 11:10	4.72	9.61	0.018
Standard Error of Measured Value	u_{SE}	04/10/19 10:10 - 11:10	1.16	0.24	0.0039

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

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.5566 $uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 =$ 8.99 %

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 Uncertainty	Date & Time	NOx (as NO2) 0 - 134 mg/m³	CO 0 - 75 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	04/10/19 10:10 - 11:10	185.10	264.68	10.60
Expanded Uncertainty as Percentage of Measured Concentration		11%	12%	9%

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%