EMISSIONS MONITORING SURVEY

(On Behalf Of Welsh Power Group Ltd)

Prepared for:

Larigan Power Ltd.

Units B1-B2
Coedcae Lane Industrial Estate,
Pontyclun
CF72 9HG

Permit Number	**: PAN-003972**
Variation Number	**: N/A**
Installation	**: Genset Engines 1 – 8**
Visit Details	**: Compliance 2019**
Job Number	**: P4101**
Report Number	**: R001**
Report Issue Date	**: 25th October 2019**
Survey Dates	**: 10th October 2019**

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Report Issue:		**FINAL**	
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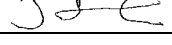
		Signature:	
Date:	23/10/2019	***Date:***	25/10/2019

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mCERTS THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

UKAS TESTING
2499

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

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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 **Larigan Power Ltd site in Pontyclun**. 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 & P4101**, 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	140.02	mg/m^3	2	Dry & 15% O_2	10/10/2019	11:00 – 12:00	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	273.54	mg/m^3	3	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Zirconia Cell)	...	9.50	%	4	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	138.19	mg/m^3	2	Dry & 15% O_2	10/10/2019	11:25 – 12:25	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	283.17	mg/m^3	2	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Zirconia Cell)	...	9.55	%	3	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	143.41	mg/m^3	2	Dry & 15% O_2	10/10/2019	12:20 – 13:20	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	277.32	mg/m^3	3	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Zirconia Cell)	...	9.63	%	4	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	122.26	mg/m^3	2	Dry & 15% O_2	10/10/2019	12:50 – 13:50	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	…	291.27	mg/m^3	2	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Zirconia Cell)	…	9.59	%	3	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	150.23	mg/m^3	2	Dry & 15% O_2	10/10/2019	13:40 – 14:40	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	…	286.21	mg/m^3	3	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Zirconia Cell)	…	9.58	%	4	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	141.80	mg/m^3	2	Dry & 15% O_2	10/10/2019	14:15 – 15:15	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	…	284.49	mg/m^3	2	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Zirconia Cell)	…	9.57	%	3	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 7	Oxides of Nitrogen (as NO_2)	190	127.03	mg/m^3	2	Dry & 15% O_2	10/10/2019	15:20 – 16:20	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	274.05	mg/m^3	3	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Zirconia Cell)	...	9.55	%	4	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	116.42	mg/m^3	2	Dry & 15% O_2	10/10/2019	15:40 – 16:40	BS EN 14792: 2017	UKAS / MCERTS		100%
	Carbon Monoxide	...	277.49	mg/m^3	2	Dry & 15% O_2			BS EN 15058: 2017	UKAS / MCERTS		100%
	Oxygen (Zirconia Cell)	...	9.57	%	3	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-003972** 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
Paul Jones	10th October 2019	MM 02 021	2	TE1, TE2, TE3, TE4
Pete Brockway		MM 17 1459	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

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 250** 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	Zirconia Cell	BS EN 14789: 2017

The analyser was set up with reference to the manufacturers operator handbook and the in-house technical procedure **ECL/TPD/033c**. 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)

Larigan Power Ltd		Installation Name	: Genset Engines 1 – 8
Permit No	: PAN-003972	Visit Details	: Compliance 2019
Variation No	: N/A	Survey Dates	: 10th October 2019
Report Ref	: P4101 : R001	Report Issue Date	: 25th 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		351							
Site Balance									
Site Check weights									
Horiba	E002	271		096					
Heated Probe / Filter		572		631					
Chiller		270		972					
MFC									
Heated Line		1009	1010	567	569				
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

Larigan Power Ltd
Permit No : PAN-003972
Variation No : N/A
Report Ref : P4101 : R001

Installation Name : Genset Engines 1 – 8
Visit Details : Compliance 2019
Survey Dates : 10th October 2019
Report Issue Date : 25th October 2019

Figure 1

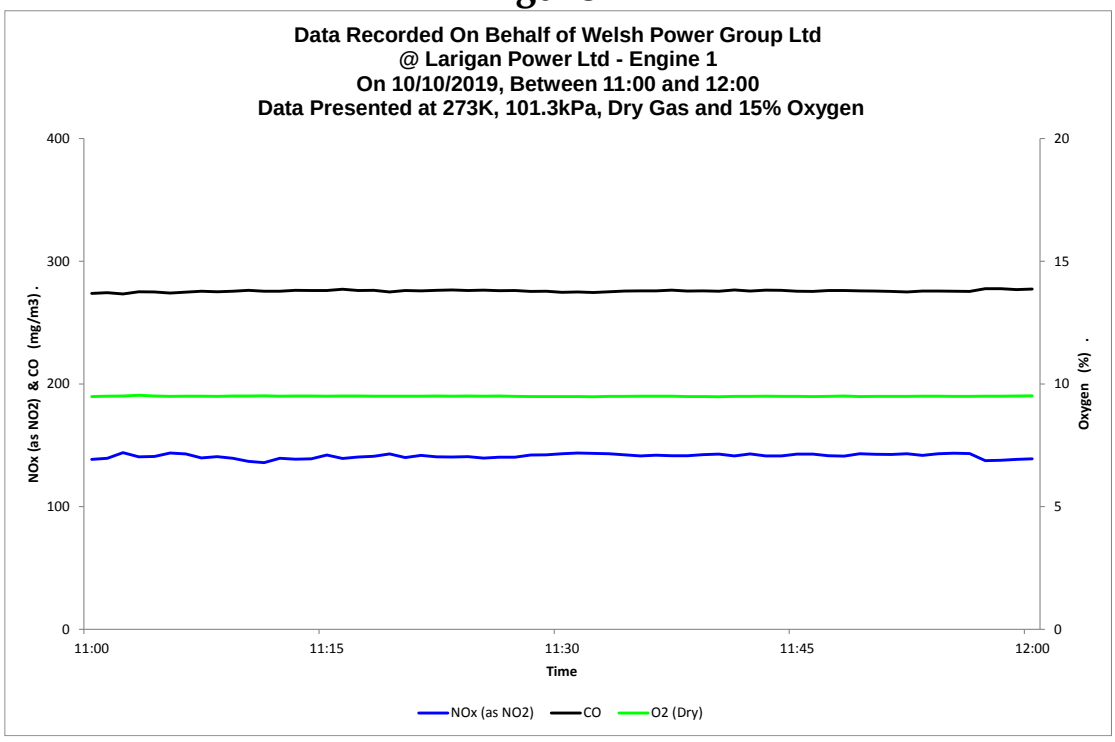


Figure 2

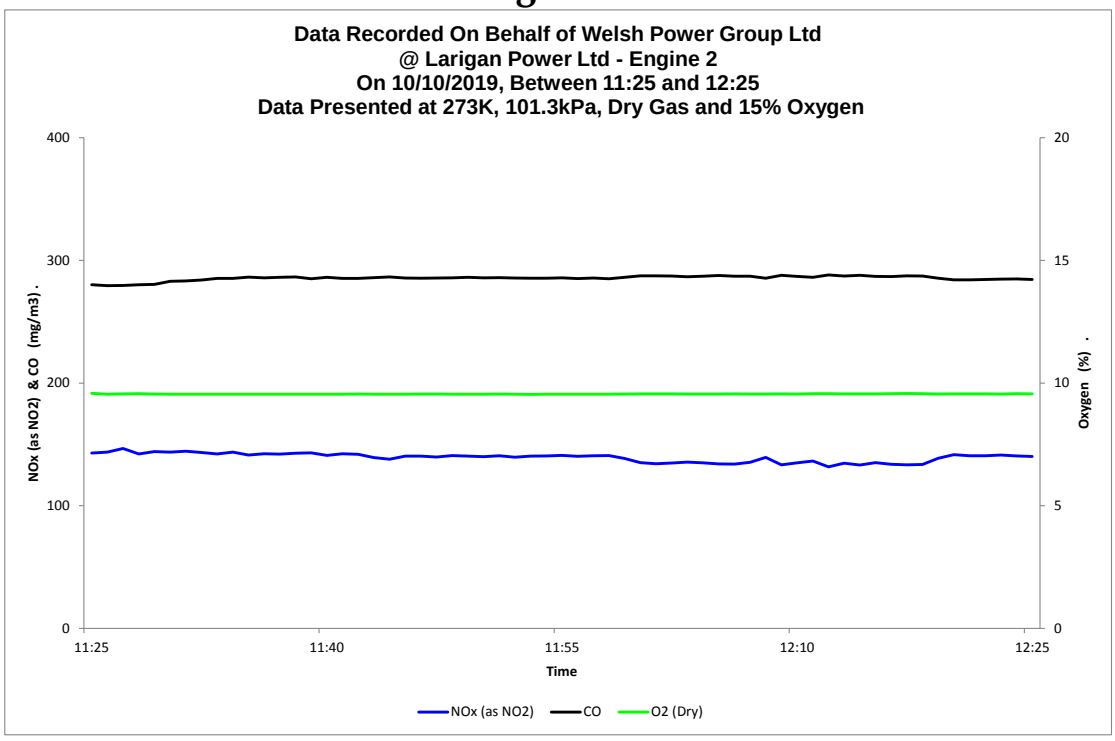


Figure 3

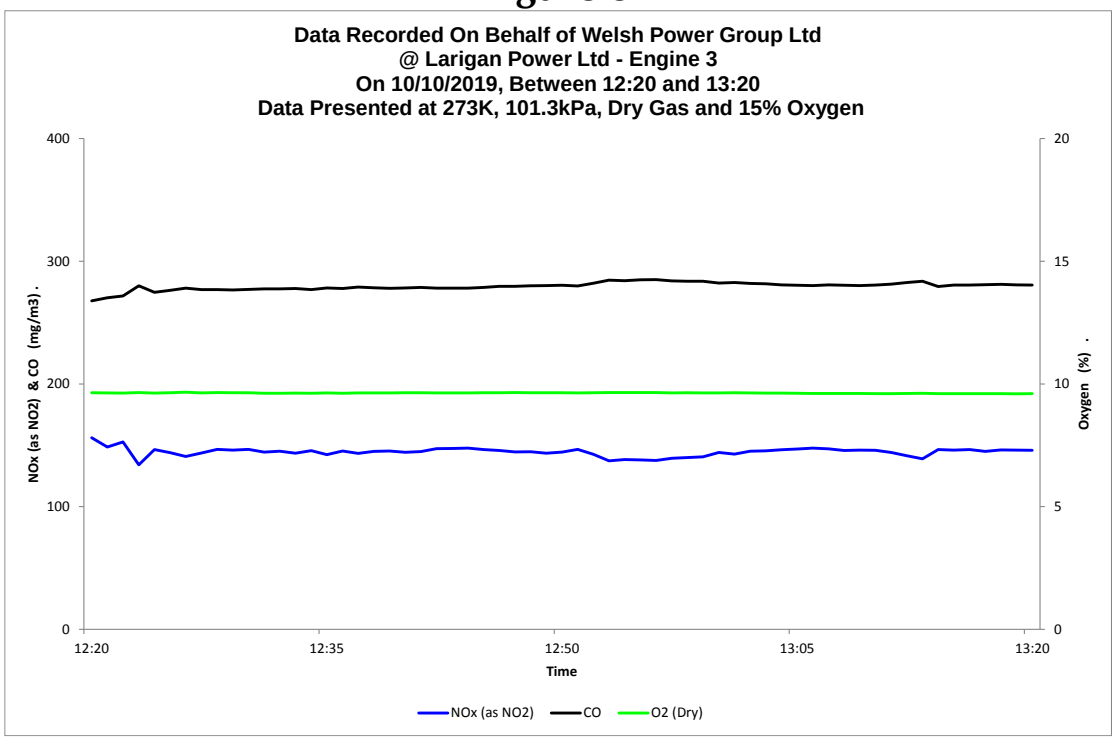


Figure 4

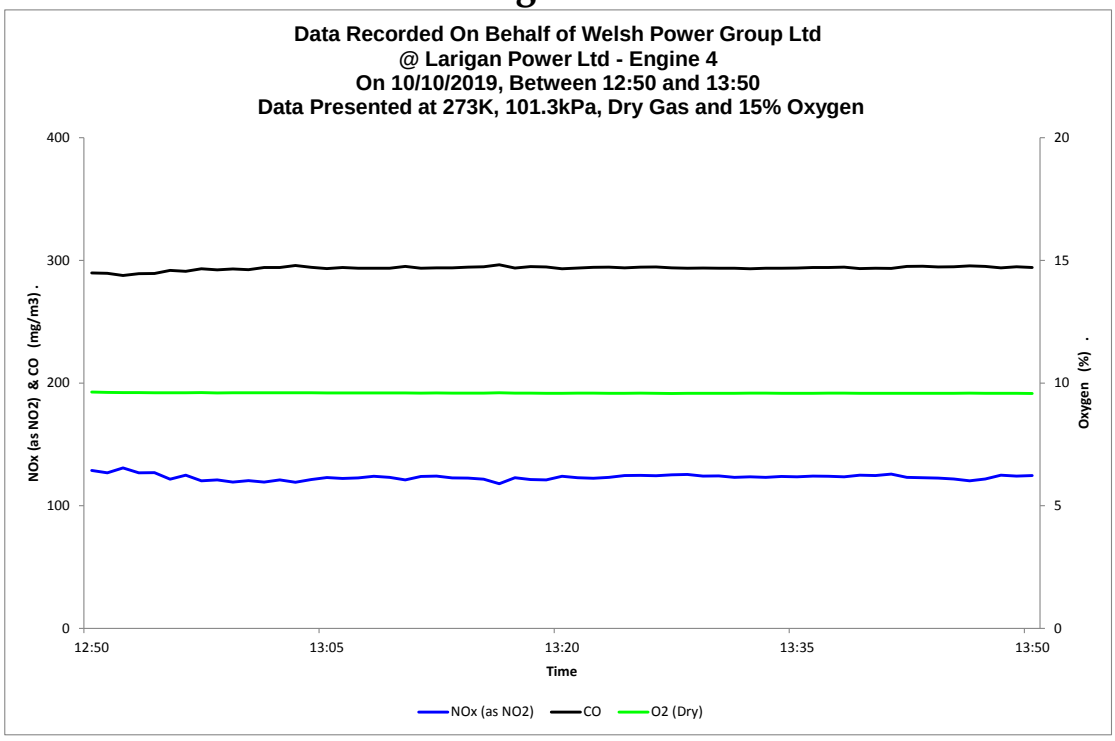


Figure 5

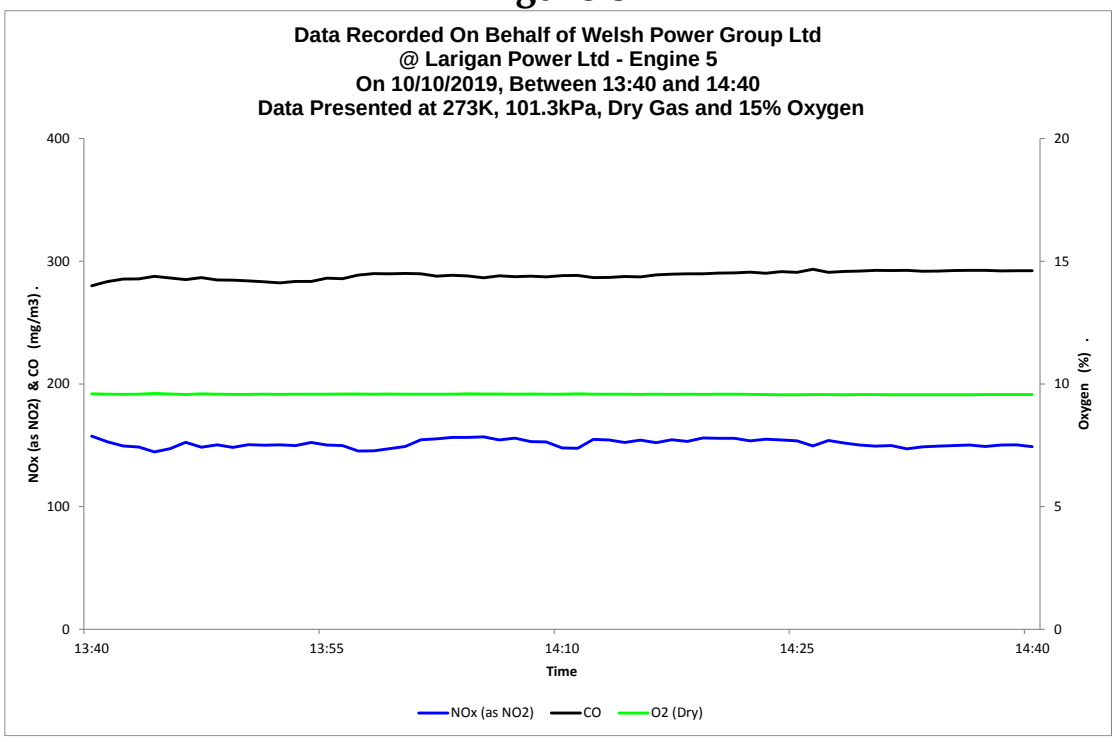


Figure 6

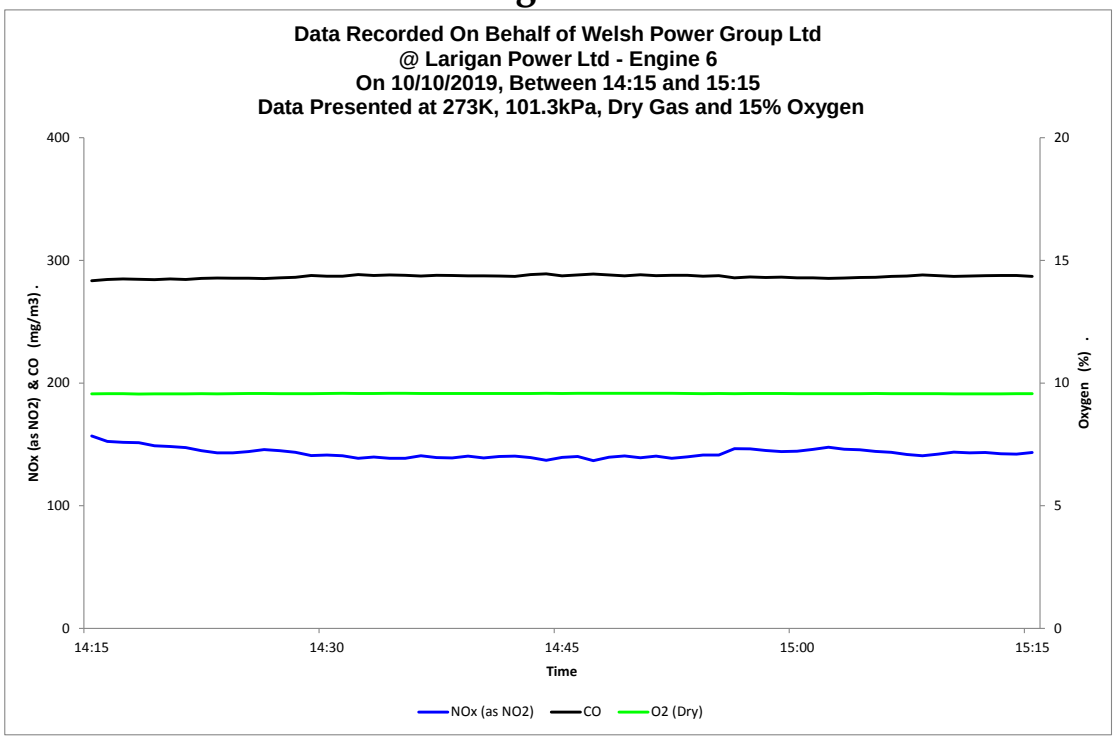


Figure 7

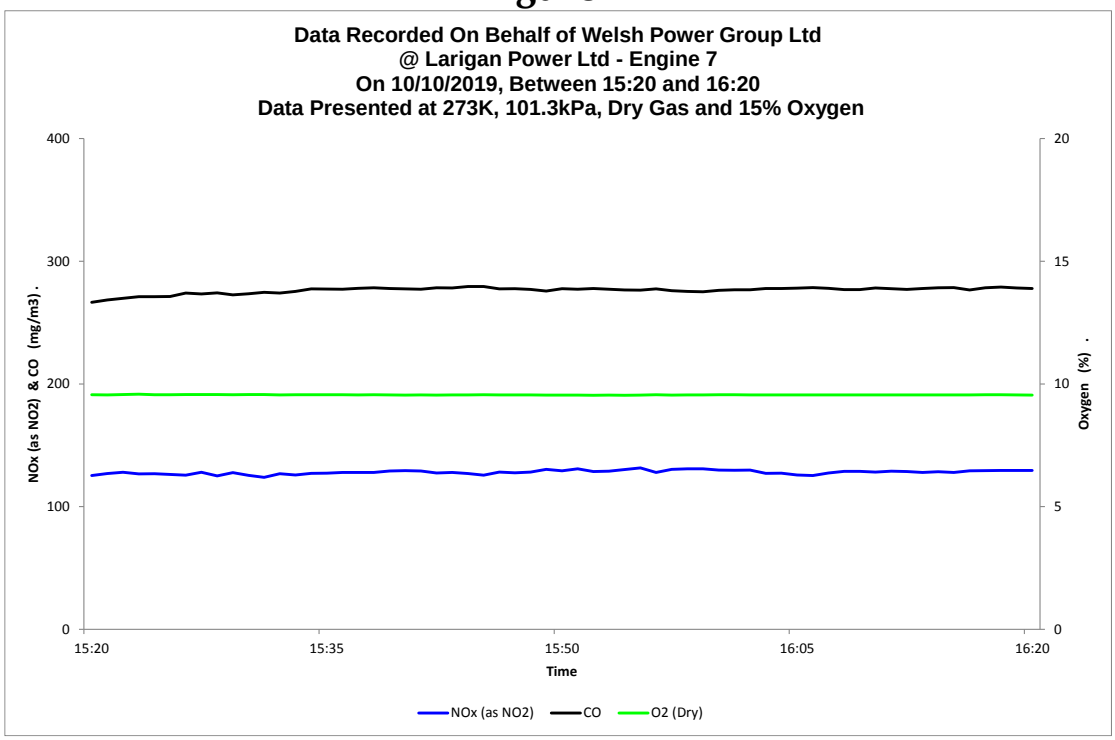
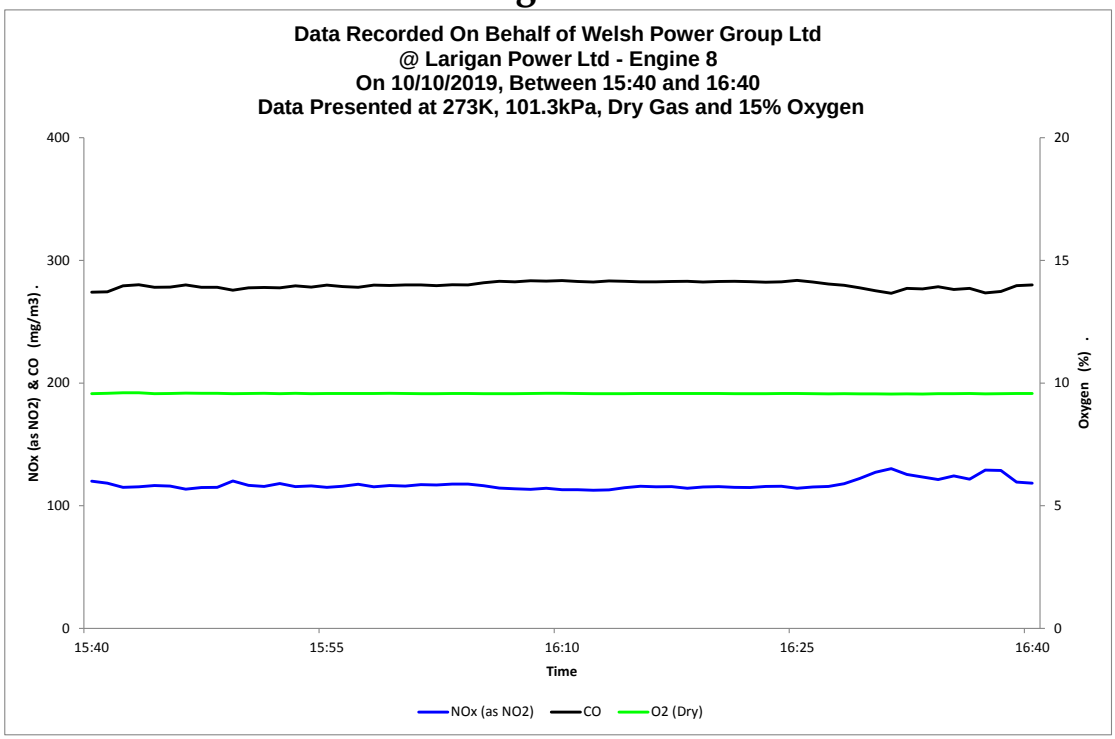


Figure 8



FIELD CALIBRATION DATA

Larigan Power Ltd
Permit No : PAN-003972
Variation No : N/A
Report Ref : P4101 : R001

Installation Name : Genset Engines 1 – 8
Visit Details : Compliance 2019
Survey Dates : 10th October 2019
Report Issue Date : 25th October 2019

Combustion Gases Calibration Summary (NOx, CO & O_2) - PG 250 Horiba – ID 096 (Units 1, 3, 5 & 7)

	Horiba PG 250 Measurement Ranges:		
	NO as NO_2	CO	O_2
Units	1025 mg/m^3	625 mg/m^3	25 %Vol
	Zero Values (Direct)		
Mean Initial Direct Zero	0.24	-0.17	0.03
Mean Confirmation Direct Zero	0.43	-0.11	0.06
Difference in Direct Zero	0.19	0.06	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	0.41	0.07	0.10
% of Measurement Range?	0.04%	0.01%	0.40%
Detection Limit (LOD)	0.09	0.53	0.20
	Applied Span:		
	NO	CO	O_2
Actual Applied Span Concentration	620.54	255.00	15.02
	Pre Test System Zero Values		
Mean Pre Test System Zero	0.41	0.07	0.10
Difference ≤ ± 2% of Span Value ?	0.07%	0.03%	0.66%
	Post Test Direct Zero Values		
Mean Post Test Direct Zero	0.39	0.86	0.06
% of Certified Range?	0.04%	0.14%	0.24%
Zero Drift ≤ ± 5% of Applied Span?	0.02%	0.40%	0.20%
	Pre Test System Span Values		
Mean Pre Test System Span	615.08	253.10	14.97
Difference ≤ ± 2% of Span Value ?	0.88%	0.74%	0.32%
	Post Test Direct Span Values		
Mean Post Test Direct Span	608.41	250.92	14.86
Span Drift ≤ ± 5% Span Value?	1.95%	1.60%	1.06%

Larigan Power Ltd			Installation Name	: Genset Engines 1 – 8
Permit No	: PAN-003972		Visit Details	: Compliance 2019
Variation No	: N/A		Survey Dates	: 10th October 2019
Report Ref	: P4101	: R001	Report Issue Date	: 25th October 2019

Combustion Gases Calibration Summary (NOx, CO & O_2) - PG 250 Horiba – ID 271 (Units 2, 4, 6 & 8)

	Horiba PG 250 Measurement Ranges:		
	NO as NO_2	CO	O_2
Units	1025 mg/m^3	625 mg/m^3	25 %Vol
	Zero Values (Direct)		
Mean Initial Direct Zero	0.23	0.30	0.01
Mean Confirmation Direct Zero	0.26	0.55	0.04
Difference in Direct Zero	0.03	0.25	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	0.29	0.56	0.07
% of Measurement Range?	0.03%	0.09%	0.30%
Detection Limit (LOD)	0.03	0.15	0.20
	Applied Span:		
	NO	CO	O_2
Actual Applied Span Concentration	620.54	255.00	15.02
	Pre Test System Zero Values		
Mean Pre Test System Zero	0.29	0.56	0.07
Difference ≤ ± 2% of Span Value ?	0.05%	0.22%	0.49%
	Post Test Direct Zero Values		
Mean Post Test Direct Zero	1.70	1.77	0.00
% of Certified Range?	0.17%	0.28%	0.02%
Zero Drift ≤ ± 5% of Applied Span?	0.24%	0.58%	0.06%
	Pre Test System Span Values		
Mean Pre Test System Span	617.63	255.58	15.03
Difference ≤ ± 2% of Span Value ?	0.47%	0.23%	0.08%
	Post Test Direct Span Values		
Mean Post Test Direct Span	609.51	254.69	14.96
Span Drift ≤ ± 5% Span Value?	1.78%	0.12%	0.38%

UNCERTAINTY CALCULATIONS

Larigan Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-003972**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 10th October 2019**
Report Ref	**: P4101 : R001**	**Report Issue Date**	**: 25th October 2019**

Measurement Uncertainty (Genset 1,3,5,7)

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular (Divisor = √3)	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$	Rectangular (Divisor = √3)	0.27	0.29	0.029
Repeatability Standard Deviation (span)[3]	u_r	Normal (Divisor = 1)	2.88	1.30	0.28
Losses / leakage in the sample system[4]	u_{loss}	Rectangular (Divisor = √3)	4.36	2.00	0.19
Temperature dependant span drift[5]	u_t	Rectangular (Divisor = √3)	0.18	0.050	0.070
Interferents[1]	u_i	Rectangular (Divisor = √3)	1.20	2.90	0.56
Uncertainty of Reference Gas[6]	u_{ref}	Rectangular (Divisor = √3)	10.75	4.42	0.15

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	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	0.22	0.019
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.20	0.16	0.0041
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	2.88	1.30	0.28
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	3.15	1.09	0.028
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	0.15	0.032	0.012
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.87	1.59	0.081
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	6.21	2.55	0.087
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	7.59	3.46	0.31
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	15.18	6.93	0.62
Applied Span Concentration			620.54	255.00	15.02
Measured Span Concentration, STP Dry Gas			612.12	252.01	14.92
Expanded measurement uncertainty as % of Applied Span			2%	3%	4%

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Report Ref	**: P4101 : R001**	**Report Issue Date**	**: 25th October 2019**

Uncertainty of Measurement Results – Genset 1

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			4.36	2.00	0.19
Temperature dependant span drift[5]	u_t			0.18	0.050	0.070

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.15	0.032	0.012
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	10/10/19 11:00 - 12:00	6.11	5.46	0.018
Standard Error of Measured Value	u_{SE}	10/10/19 11:00 - 12:00	0.46	0.21	0.0012

Effect on Uncertainty Caused by Oxygen $uCorr^n_{o_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.041

$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.6211 $\quad uf_{o_2} = \frac{uCorr^n_{o_2}}{f_{o_2}} x100 =$ 6.58 %

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_i

$\therefore u(x_i) = C_i u_i$ 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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	10/10/19 11:00 - 12:00	140.02	273.54	9.50
Expanded Uncertainty as Percentage of Measured Concentration		11%	8%	7%

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

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%

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Uncertainty of Measurement Results – Genset 3

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			4.36	2.00	0.19
Temperature dependant span drift[5]	u_t			0.18	0.050	0.070

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.15	0.032	0.012
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	10/10/19 12:20 - 13:20	6.26	5.53	0.018
Standard Error of Measured Value	u_{SE}	10/10/19 12:20 - 13:20	0.85	0.79	0.0019

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

$$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = 0.6127 \qquad uf_{O_2} = \frac{uCorr^{n}_{O_2}}{f_{O_2}} x100 = 6.82\ \%$$

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	10/10/19 12:20 - 13:20	143.41	277.32	9.63
Expanded Uncertainty as Percentage of Measured Concentration		11%	8%	7%

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

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%

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Uncertainty of Measurement Results – Genset 5

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			4.36	2.00	0.19
Temperature dependant span drift[5]	u_t			0.18	0.050	0.070

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.15	0.032	0.012
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	10/10/19 13:40 - 14:40	6.55	5.71	0.018
Standard Error of Measured Value	u_{SE}	10/10/19 13:40 - 14:40	0.77	0.76	0.0014

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 = 0.041

$$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = 0.6160 \quad uf_{o_2} = \frac{uCorr^n_{o_2}}{f_{o_2}} x100 = 6.73\ \%$$

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_i

$\therefore u(x_i) = C_i u_i$ 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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	10/10/19 13:40 - 14:40	150.23	286.21	9.58
Expanded Uncertainty as Percentage of Measured Concentration		11%	8%	7%

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

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%

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Uncertainty of Measurement Results – Genset 7

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			4.36	2.00	0.19
Temperature dependant span drift[5]	u_t			0.18	0.050	0.070

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.15	0.032	0.012
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	10/10/19 15:20 - 16:20	5.54	5.47	0.018
Standard Error of Measured Value	u_{SE}	10/10/19 15:20 - 16:20	0.40	0.66	0.0010

Effect on Uncertainty Caused by Oxygen $uCorr^n_{x_i} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.041

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.6175 $\quad uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 =$ 6.68 %

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_i

$\therefore u(x_i) = C_i u_i$ 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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	10/10/19 15:20 - 16:20	127.03	274.05	9.55
Expanded Uncertainty as Percentage of Measured Concentration		11%	8%	7%

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

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%

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Measurement Uncertainty (Genset 2,4,6,8)

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit(1)	u_{lof}	Rectangular (Divisor = √3)	0.40	0.40	0.13
Span drift(2)	$u_{d,s}$	Rectangular (Divisor = √3)	0.27	0.29	0.029
Repeatability Standard Deviation (span)(3)	u_r	Normal (Divisor = 1)	3.46	0.68	0.15
Losses / leakage in the sample system(4)	u_{loss}	Rectangular (Divisor = √3)	2.33	0.61	0.05
Temperature dependant span drift(5)	u_t	Rectangular (Divisor = √3)	0.18	0.050	0.070
Interferents(1)	u_i	Rectangular (Divisor = √3)	1.20	2.90	0.56
Uncertainty of Reference Gas(6)	u_{ref}	Rectangular (Divisor = √3)	10.75	4.42	0.15

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	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	0.22	0.019
Span drift	$u_{d,s}$	$u(x_i) = \frac{u_{d,s} \times R_i}{\sqrt{3}} =$	0.20	0.16	0.0041
Repeatability Standard Deviation (span)	u_r	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} =$	3.46	0.68	0.15
Losses / leakage in the sample system	u_{loss}	$u(x_i) = \frac{u_{loss} \times R_i}{\sqrt{3}} =$	1.68	0.33	0.007
Temperature dependant span drift	u_t	$u(x_i) = \frac{u_t}{100} \times R_i \times \sqrt{\frac{(x_{i,max} - x_{adj})^2 + (x_{i,min} - x_{adj})(x_{i,max} - x_{adj}) + (x_{i,min} - x_{adj})^2}{3}}$	0.15	0.032	0.012
Interferents	u_i	$u(x_i) = \frac{u_i \times R_i}{\sqrt{3}} =$	0.87	1.59	0.081
Uncertainty of Reference Gas	u_{ref}	$u(x_i) = \frac{u_{ref}}{\sqrt{3}} =$	6.21	2.55	0.087
Combined Standard Uncertainty		$u_c = \sqrt{u_{lof}^2 + u_{d,s}^2 + u_r^2 + u_{loss}^2 + u_t^2 + u_i^2 + u_{ref}^2}$	7.36	3.11	0.19
Expanded measurement uncertainty (at 95% confidence)		$U_{EXP} = 2 \times u_c$	14.72	6.22	0.39
Applied Span Concentration			620.54	255.00	15.02
Measured Span Concentration, STP Dry Gas			613.57	255.18	15.00
Expanded measurement uncertainty as % of Applied Span			2%	2%	3%

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Uncertainty of Measurement Results – Genset 2

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			2.33	0.61	0.05
Temperature dependant span drift[5]	u_t			0.18	0.050	0.070

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.15	0.032	0.012
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	10/10/19 11:25 - 12:25	3.21	1.71	0.004
Standard Error of Measured Value	u_{SE}	10/10/19 11:25 - 12:25	0.88	0.49	0.0011

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.041

$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.6176 $uf_{o_2} = \frac{uCorr^n_{o_2}}{f_{o_2}} x100 =$ 6.68 %

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 250 Uncertainty	Date & Time	NOx (as NO2) 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	10/10/19 11:25 - 12:25	138.19	283.17	9.55
Expanded Uncertainty as Percentage of Measured Concentration		8%	7%	7%

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

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%

Larigan Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-003972**	**Visit Details**	**: Compliance 2019**
Variation No	**: N/A**	**Survey Dates**	**: 10th October 2019**
Report Ref	**: P4101 : R001**	**Report Issue Date**	**: 25th October 2019**

Uncertainty of Measurement Results – Genset 4

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular		0.40	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			2.33	0.61	0.05
Temperature dependant span drift[5]	u_t		$\sqrt{3}$	0.18	0.050	0.070

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular		0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.15	0.032	0.012
Interferents	u_i		$\sqrt{3}$	0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	10/10/19 12:50 - 13:50	2.84	1.76	0.004
Standard Error of Measured Value	u_{SE}	10/10/19 12:50 - 13:50	0.55	0.40	0.0015

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

$$f_{o_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} = 0.6151 \qquad uf_{o_2} = \frac{uCorr^n_{O_2}}{f_{o_2}} x100 = 6.75\ \%$$

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	10/10/19 12:50 - 13:50	122.26	291.27	9.59
Expanded Uncertainty as Percentage of Measured Concentration		8%	7%	7%

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

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%

Larigan Power Ltd		**Installation Name**	**: Genset Engines 1 – 8**
Permit No	**: PAN-003972**	**Visit Details**	**: Compliance 2019**
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Report Ref	**: P4101 : R001**	**Report Issue Date**	**: 25th October 2019**

Uncertainty of Measurement Results – Genset 6

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			2.33	0.61	0.05
Temperature dependant span drift[5]	u_t			0.18	0.050	0.070

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.15	0.032	0.012
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m³	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	10/10/19 14:15 - 15:15	3.30	1.72	0.004
Standard Error of Measured Value	u_{SE}	10/10/19 14:15 - 15:15	0.97	0.31	0.0009

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.041

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.6164 $uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 =$ 6.71 %

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	CO 0 - 95 mg/m³	O_2 0 - 25 %Vol
Measured Concentration	10/10/19 14:15 - 15:15	141.80	284.49	9.57
Expanded Uncertainty as Percentage of Measured Concentration		8%	7%	7%

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

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%

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Uncertainty of Measurement Results – Genset 8

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/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Lack of fit[1]	u_{lof}	Rectangular	$\sqrt{3}$	0.40	0.40	0.13
Span drift[2]	$u_{d,s}$			0.27	0.29	0.029
Losses / leakage in the sample system[4]	u_{loss}			2.33	0.61	0.05
Temperature dependant span drift[5]	u_t			0.18	0.050	0.070

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/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Lack of fit	u_{lof}	Rectangular	$\sqrt{3}$	0.29	0.22	0.019
Span drift	$u_{d,s}$			0.20	0.16	0.0041
Temperature dependant span drift	u_t			0.15	0.032	0.012
Interferents	u_i			0.87	1.59	0.081

Uncertainty of Measurement Results - Calculations Part 2

Horiba PG 250 Performance Characteristics	Uncertainty (Units of final measurement)	Date & Time	NO 0 - 125 mg/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Losses / leakage in the sample system	u_{loss}	10/10/19 15:40 - 16:40	2.71	1.68	0.004
Standard Error of Measured Value	u_{SE}	10/10/19 15:40 - 16:40	1.00	0.69	0.0011

Effect on Uncertainty Caused by Oxygen $uCorr^n_{O_2} = \frac{20.9\% - O_{2,ref}}{(20.9\% - O_{2,measured})x(20.9\% - O_{2,measured})} x\, Uncertainty\ of\ O_2\ Measurement =$ 0.041

$f_{O_2} = \frac{20.9\% - O_{2,ref}}{20.9\% - O_{2,measured}} =$ 0.6163 $uf_{O_2} = \frac{uCorr^n_{O_2}}{f_{O_2}} x100 =$ 6.71 %

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/m^3	CO 0 - 95 mg/m^3	O_2 0 - 25 %Vol
Measured Concentration	10/10/19 15:40 - 16:40	116.42	277.49	9.57
Expanded Uncertainty as Percentage of Measured Concentration		9%	7%	7%

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

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%