NATIONAL PHYSICAL LABORATORY
Teddington Middlesex UK TW11 0LW Telephone +44 20 8977 3222

Test Report

UKAS TESTING
0002

This test report is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceability of measurement to the SI system of units and/or to units of measurement realised at the National Physical Laboratory or other recognised national metrology institutes. This test report may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

OXIDES OF NITROGEN (AS NO_2) AND CARBON MONOXIDE COMPLIANCE TESTING AT SOUTH HOOK LNG TERMINAL ON BEHALF OF INTERTEK LIMITED

Permit Number:	**XP3538LD**
Operator Name:	**South Hook LNG (on behalf of Intertek Limited)**
Installation Name:	**South Hook LNG Terminal**
Dates of Monitoring Visit:	**13th - 14th August 2018**
Contract Reference:	**E08040221**
Client Contact:	**Adrian Walsh**
Client Organisation:	**Intertek Limited**
Address:	**Unit 14 - Waterston Trading Estate** **Main Road, Waterston** **Milford Haven** **SA73 3SL**
Monitoring Organisation:	**National Physical Laboratory**
Address:	**Hampton Road** **Teddington** **Middlesex** **TW11 0LW**
Date of Report:	**16th August 2018**
Report Author	**Matthew Ellison**

Reference: XP3538LD/INTERTEK/SHLNG/AUG2018/SCV/PPC/Q3/V1

Report Approver:	Kevin Blakley	NPL Authorised Signatory
MCERTS Registration:	MM-03-317	Name: Mr R Robinson (for NPLML)
Level & TEs Held:	Level 2, TE1, TE2, TE3 & TE4	Signature:
Signature:		

CONTENTS PAGE

1.1 Monitoring Objectives

NPL were awarded a contract by Intertek Limited to carry out emissions compliance testing at South Hook LNG plant near Milford Haven, Pembrokeshire. The scope of work includes carrying out emissions monitoring on the SCV flue stacks phases one and two.

There are a total of fifteen SCV units on the South Hook site that require monitoring, eight on phase one and seven on phase two. Three units were measured for oxides of nitrogen and carbon monoxide.

In addition, oxygen measurements were taken to allow a correction to reference conditions. Water vapour and flow measurements were also taken to determine the moisture content and velocity of the flue gas.

NPL carried out the monitoring visit between the 13th and 14th August 2018. The report documents the results obtained.

1.2.1 SCV A (Phase One) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV A (Phase One)

Field	Units	Oxides of Nitrogen (as NO_2)	Carbon Monoxide	Oxygen	Moisture
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	105.8	272	12.3	1.6
Uncertainty (95% Confidence Level)	**Reference Conditions**	21.9	39	0.6	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	4.1			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	13/08/2018			
Sample Period	**From hh:mm**	13:55			
	To hh:mm	14:55			
Monitoring Method		BS EN 14792	BS EN 15058	BS EN 14789	BS EN 14790
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	80			
Burner Demand	**Burner Demand (%)**	19			

1.2.2 SCV A (Phase Two) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV A (Phase Two)

Field	Units	Oxides of Nitrogen (as NO_2)	Carbon Monoxide	Oxygen	Moisture
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	36.6	718	12.3	1.8
Uncertainty (95% Confidence Level)	**Reference Conditions**	15.2	72	0.4	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	3.3			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	14/08/2018			
Sample Period	**From hh:mm**	12:00			
	To hh:mm	13:00			
Monitoring Method		BS EN 14792	BS EN 15058	BS EN 14789	BS EN 14790
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	80			
Process Status	**Burner Demand (%)**	20			

1.2.3 SCV F (Phase Two) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV F (Phase Two)

Field	Units	Oxides of Nitrogen (as NO_2)	Carbon Monoxide	Oxygen	Moisture
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	42.4	515	12.9	1.8
Uncertainty (95% Confidence Level)	**Reference Conditions**	16.4	52	0.4	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	3.3			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	13/08/2018			
Sample Period	**From hh:mm**	16:45			
	To hh:mm	17:45			
Monitoring Method		BS EN 14792	BS EN 15058	BS EN 14789	BS EN 14790
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	80			
Process Status	**Burner Demand (%)**	20			

1.3 Operating Information

South Hook LNG Terminal, situated in Pembrokeshire South West Wales, is a regasification plant for natural gas. The LNG is transported in specially designed vessels to Milford Haven where it is then transferred into storage tanks, where it awaits reheating and distribution into the UK National Grid.

A total of fifteen SCVs have been built across two phases. Each one has at least two five inch ports installed, as set out in BS EN 13284-1. The ports are located approximately thirteen metres from the base of the stack and can be accessed by ladders that lead to a permanent platform. The sampling platform has lighting, toe boards and handrails. There is sufficient parking on the roadway at the base of the stacks for the mobile laboratory and provision of 240v 16A power supply outlets.

<table>
<tr><td>Continuous or Batch Process?</td><td colspan="5">Each SCV operates on a batch process. The number of SCVs operating and the load at which they are set depend upon the required site output.</td></tr>
<tr><td>What part of the batch process was sampled? (If applicable)</td><td colspan="5">The periodic monitoring is carried out once an SCV has been brought online to the operators required load and has stabilised. This loading remains constant through the one hour test.</td></tr>
<tr><td>What fuel was used during monitoring? (If applicable)</td><td colspan="5">A small amount of LNG is used as fuel to heat a volume of water. This heat exchange warms up the LNG allowing it to be passed out into the National Grid system.</td></tr>
<tr><td>What feedstock was used during monitoring? (If applicable)</td><td colspan="5">N/A</td></tr>
<tr><td rowspan="4">What was the load during monitoring?</td><td colspan="2">Emission Point</td><td colspan="2">Load (Ton/hr)</td><td>Burner Demand (%)</td></tr>
<tr><td colspan="2">SCV 1A</td><td colspan="2">80</td><td>19</td></tr>
<tr><td colspan="2">SCV 2A</td><td colspan="2">80</td><td>20</td></tr>
<tr><td colspan="2">SCV 2F</td><td colspan="2">80</td><td>20</td></tr>
<tr><td>What abatement systems are present? Were they in operation?</td><td colspan="5">Each SCV uses water injection to abate NOx emissions. The system was in operation during the periodic monitoring of each SCV.</td></tr>
<tr><td rowspan="3">Periodic monitoring results and corresponding CEM values</td><td>Emission Point</td><td>Substance Monitored</td><td>CEM Result</td><td>Periodic Monitoring Result</td><td>Units</td></tr>
<tr><td>SCV 2A</td><td>Oxides of Nitrogen</td><td>45.5</td><td>36.6</td><td>mg/Nm^3</td></tr>
<tr><td>SCV 2A</td><td>Oxygen</td><td>12.1</td><td>12.3</td><td>% Vol</td></tr>
</table>

1.4 Monitoring Deviations

Were all substances in the monitoring objectives monitored? If not why?	All substances set out in the objective were monitored.
Were all substances monitored in accordance to the relevant method? If not why?	All substances set out in the monitoring objectives were measured in accordance to the relevant standards.
Were there any other issues relevant to the monitoring results?	No.

1.5 Conclusions

NPL carried out the emissions monitoring at South Hook LNG over a period of one week. Three SCVs were monitored for the required determinands.

The client is aware of BS EN 15259 and the requirement to carry out homogeneity testing. These tests were carried out on SCVs 1H and 2A, both units passed.

Reference - XP3538LD/INTERTEK/SHLNG/JULY2011/SCV/HOMOGENEITY.

1.6 References

1. STA – Risk Assessment Guide: Industrial-emission monitoring.

2. Environmental Agency - Manual Stack emission monitoring performance standard for Organisations.

3. Environmental Agency – M1 Technical Guidance Note – Sampling requirements for stack emission monitoring.

4. Environmental Agency – M2 Technical Guidance Note – Monitoring of stack emissions to air.

5. Environment Agency - MID 14792 - Stationary source emissions - Determination of mass concentration of nitrogen oxides (NOx) - Reference Method: Chemiluminescence.

6. Environment Agency - MID 15259 - Stationary source emissions - Requirements for the measurement sections and sites and for the measurement objective, plan and report.

7. Guidance on Assessing Measurement Uncertainty in Stack Emissions Monitoring, by Pullen J and Robinson R, Source Testing Association, Quality Guidance Note QGN1.

APPENDIX ONE

2.1.1 Emissions Testing Personnel Details

Name	Role	MCERTS Number	Certification Level & Expiry Dates					
			Level 1	Level 2	TE1	TE2	TE3	TE4
Matthew Ellison	Team Leader	MM-05-682	N/A	Sep-2023	Sep-2023	Sep-2023	Dec-2023	Sep-2023
Bob Lipscombe	Site Assistant	MM-07-879	Apr-2023	N/A	N/A	N/A	N/A	N/A

2.1.2 Emissions Testing Procedures

	Instrumental Methods			Manual Methods		
Determinand	**NOx**	**CO**	**O_2**	**H_2O**	**Stack Flow**	**Temperature**
SRM Standard	BS EN 14792	BS EN 15058	BS EN 14789	BS EN 14790	BS ISO 16911	BS ISO 16911
Instrument	Horiba PG-250	Horiba PG-250	Horiba PG-250	N/A	Pitot	Type K Thermocouple
Instrument Serial No.	AS0450	AS0450	AS0450	N/A	AS0638	AS0638
Principle	Chemiluminescence	NDIR	Zirconia	Water vapour table	Flow	Temperature
Operational Range	0 - 250 ppm	0 - 500 ppm	0 - 25%	N/A	N/A	N/A
Certified Range	0 - 125 mg/m^3	0 - 95 mg/m^3	0 - 25%	N/A	N/A	N/A
Uncertainty	10%	6%	6%	20%	N/A	N/A
NPL Procedure	QPAS B 538	QPAS B 538	QPAS B 538	QPAS B 540	QPAS B 567	QPAS B 567
UKAS Accreditation	YES	YES	YES	YES	YES	YES

The sample gas was extracted from the stack via a chemically inert heated line and drawn through a conditioning unit. All moisture in the gas sample was removed and cooled down to 4°C before it was pumped down another line to the NPL Mobile Source Emissions Laboratory and analysed using a Horiba PG-250. The entire sampling system had been leak tested before testing was carried out to ensure no dilution of the sample gas.

The conventional analyser zero and span settings were checked before and after each test run using zero grade nitrogen (ex BOC), a suitable gas mixture (BOC beta gas standard), traceable to national reference standards and a gas dilution system. The certified accuracies of the gas standards are listed below: -

Component	Sample Location	Cylinder ID	Certified Amount	Certified Uncertainty
Carbon Monoxide	Phase 1 & 2 SCVs	146117	153.2 ppm	1%
Nitrogen Oxide		146117	152.8 ppm	1%
Oxygen		172344	14.86%	1%

These measurement uncertainties are expressed at a 95% level of confidence.

The ranges of the Horiba PG-250 SRM analyser used for the testing and the values used to calibrate the instrument before and after the testing are listed below: -

Gaseous Components	Horiba Ranges	Calibrated Values
Carbon Monoxide	0 - 200 ppm	153.2 ppm
Oxides of Nitrogen (as NO_2)	0 - 250 ppm	152.8 ppm
Oxygen	0 - 20%	14.86%

A leak test was conducted before testing to confirm hydraulic integrity of the gaseous sampling system. This was conducted by sending nitrogen down the entire sample line and ensuring a zero reading was obtained.

The electrical volt/millivolt outputs from the PG-250 gas analyser was collected by data logger software on a PC and downloaded to digital media at the end of each day. Under the program used during the tests, the software records and stores individual readings either every 1 or 10 seconds. From this data, the logger can perform a series of calculations to output 1 minute averaged measurement on a volume/volume or mass/volume basis. After each 1 minute average has been established the data buffer is reset and the process repeats.

2.1.3 Equipment Checklist Reference

See workfile INTK41AUG18/Equipment Checklist.

2.1.4 Data Capture Location Reference

All data collected using the NPL computer system on site is backed up at the end of each day onto a memory stick. When the team returns to site this information is then uploaded onto the NPL servers and stored in the relevant location for that job. The link below is where the South Hook emissions data is stored:

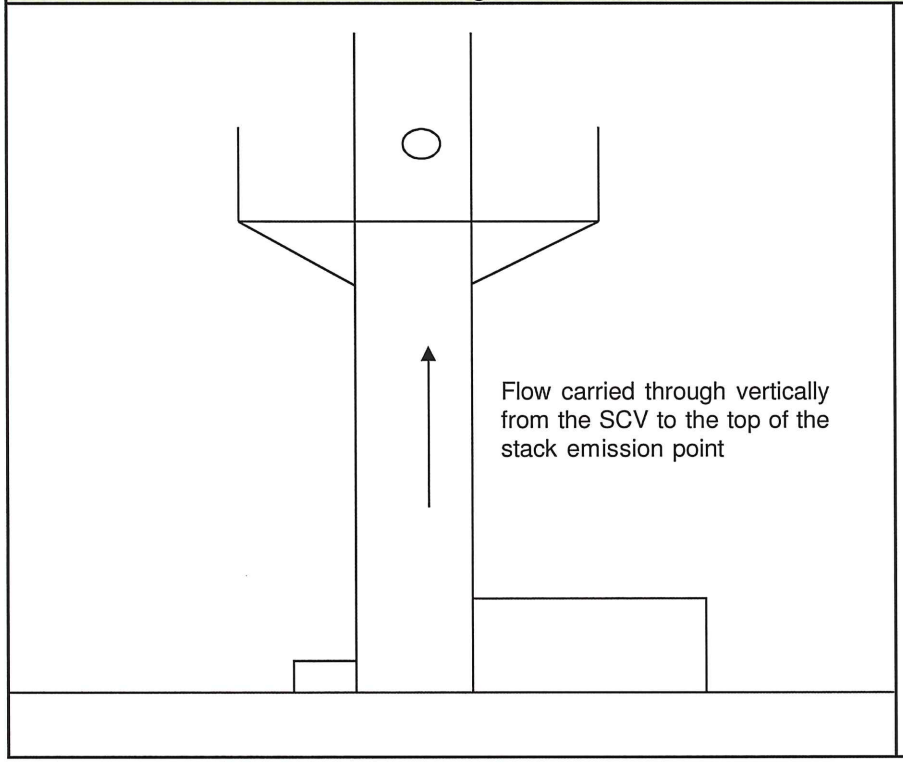
P:\Stack Emissions Team\South Hook LNG - Intertek\INTK41AUG18\7. Monitoring Record Sheets

APPENDIX TWO

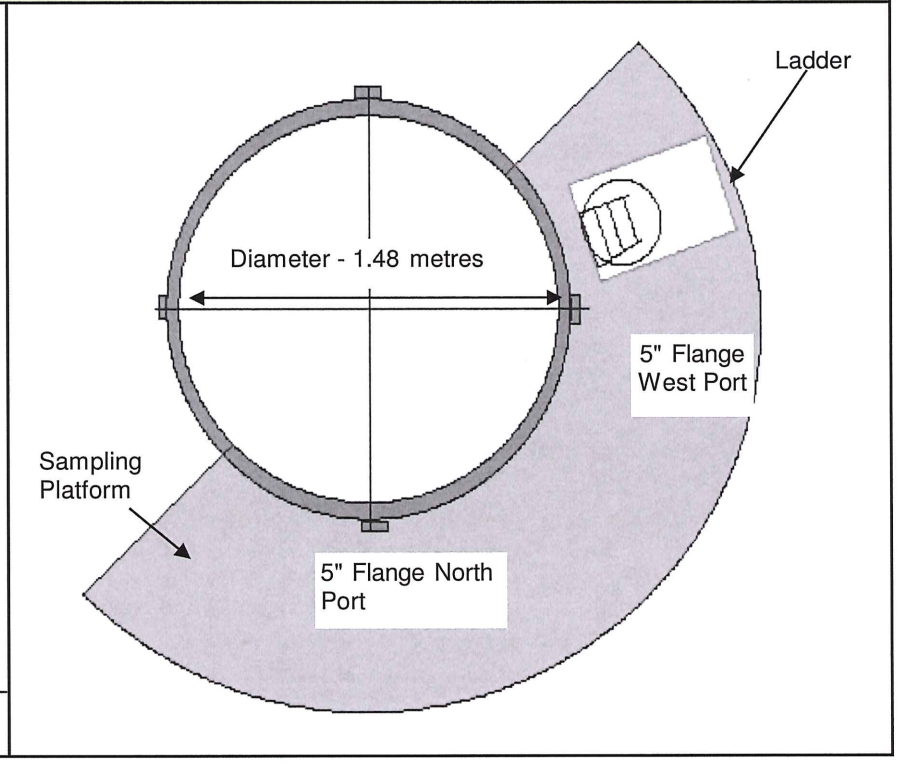
2.2.1 - Stack Diagram

Company	Installation	Stack	Substances Monitored	Permit
Intertek	South Hook LNG	SCVs Phases One & Two	CO, NOx, O_2 and H_2O	XP3538LD

Stack Diagram



Stack Cross-Section



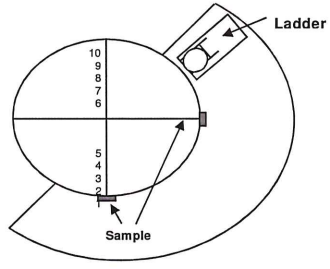
Position	1	2	3	4	5	6	7	8	9	10
% of Diameter	3.2	8.2	14.6	22.6	34.2	65.8	77.4	85.4	91.8	96.8
Insertion, m	0.05	0.12	0.22	0.33	0.51	0.97	1.15	1.26	1.36	1.43
Insertion plus offset, m	0.15	0.22	0.32	0.43	0.61	1.07	1.25	1.36	1.46	1.53

Notes - The circular stack diameter was measured as 1.48 metres, whilst the port offset (distance between the edge of the stack to the end of the port) was measured as 23 centimetres. Access to the top of the stack was by a series of three ladders. Each one had a resting platform in-between with a self closing gate installed. The main platform itself is a permanent structure with toe boards, railings and self closing gate.

2.2.2 - Flow Criteria Measurements

Monitoring Objective	Traverse	Site:	South Hook LNG	Stack ID:	SCV 1A
Date	13/08/2018	Site Team:	MRE/RPL	Time of Survey:	13:50
Tape Measure ID	AS0589				
Laser Measurement Device ID	N/A				
Traverse Pitot Type	S-Type				
Traverse Pitot Tube ID	AS0466				
Pitot Assembly Visual Inspection (Pre)	Pass				
Pre Test Leak Check <2.5 mm H2O	Pass				
Traverse Manometer Type	Digital				
Traverse Manometer ID	AS0638				
Traverse Manometer Range	240				
Traverse Temp. Readout ID	AS0638				
Traverse Thermocouple ID	AS0451a				
Static Pressure	Δp (mmH20)				
	7.15				
	Pass				
Swirl Test Conducted	Yes				
Protractor ID	AS0626				
Post-Test Blockage Test (L-Type only)					
Post Test Leak Check <2.5 mm H2O	Pass				
Pitot Assembly Visual Inspection (Post)	Pass				

Diagram of Sample Location:



Comments/Deviations:

Conditions	Value	Units
Stack pressure	767.13	mmHg
Ref O_2 Value	3	%
Moisture Content	1.6	%
CO	183	ppm
CO_2	5	%
N_2	83.28	%
O_2	11.70	%
Dry Molecular wt	29.27	
Stack Molecular wt	29.09	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1021.8	mbar
Pbar	767	mmHg
Pitot tube coeft	0.83	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature	18	°C

Duct Dimensions

Port ID	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Port Depth
A					
B					
C					
D					

Circular Duct

Line ID	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Diameter
A					
B					

Rectangular Duct

Line ID	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Depth
A					
B					
C					
D					

	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Width
Outside Side Division					

			Static Measurement	Δp (mmH20)	
			Measurement Line	Reading 1	Reading 2(180°)
Enter manually from previous visit	Circular Duct	Rectangular Duct	A	7.20	7.20
Duct Diameter (m)	1.48		B	7.00	7.20
Duct Depth (m)			C		
Duct Width (m)			D		

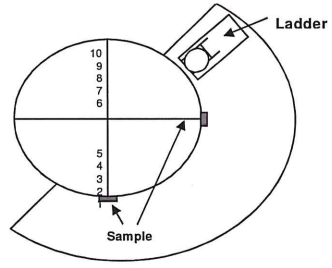
Post-Test Blockage Test (L	Traverse Point	Δp Reading (mm H_2O)	Δp Reading (mm H_2O)	Δp Reading (mm H_2O)	Δp Average (mm H_2O)
Reading 1					
Reading 2					

SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	2.40	2.40	2.40	2.40	23.53	14.2	5.10	8	1.55
2	1.26	2.60	2.60	2.60	2.60	25.49	14.1	5.31	6	1.61
3	1.04	2.40	2.40	2.40	2.40	23.53	13.9	5.10	5	1.55
4	0.44	1.90	1.90	1.90	1.90	18.63	13.8	4.54	4	1.38
5	0.22	1.90	1.90	1.90	1.90	18.63	14.0	4.54	6	1.38
6	0.06	1.90	1.90	1.90	1.90	18.63	14.3	4.54	6	1.38
SAMPLING LINE: West										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	1.40	1.40	1.40	1.40	13.72	14.4	3.90	6	1.18
2	1.26	2.00	2.00	2.00	2.00	19.61	14.2	4.66	6	1.41
3	1.04	2.10	2.10	2.10	2.10	20.59	14.0	4.77	6	1.45
4	0.44	2.60	2.60	2.60	2.60	25.49	14.0	5.31	7	1.61
5	0.22	2.80	2.80	2.80	2.80	27.45	14.2	5.51	6	1.67
6	0.06	2.60	2.60	2.60	2.60	25.49	14.8	5.32	7	1.61
Average values		**2.2**	**2.2**	**2.2**	**2.2**	**21.7**	**14.2**	**4.9**	**6.1**	**1.5**

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	4.88	ms^{-1}	Is the Flow Ratio 3:1 or less?	1.4 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	4.07	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	8.39	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	8.26	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	8.05	m^3s^{-1}	Minimum Δp detected > 0.5 mmH2O	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	4.14	m^3s^{-1}		

Monitoring Objective	Traverse	Site:	South Hook LNG	Stack ID:	SCV 2A
Date	14/08/2018	Site Team:	MRE/RPL	Time of Survey:	14:00
Tape Measure ID	AS0589				
Laser Measurement Device ID	N/A				
Traverse Pitot Type	S-Type				
Traverse Pitot Tube ID	AS0466				
Pitot Assembly Visual Inspection (Pre)	Pass				
Pre Test Leak Check <2.5 mm H2O	Pass				
Traverse Manometer Type	Digital				
Traverse Manometer ID	AS0638				
Traverse Manometer Range	240				
Traverse Temp. Readout ID	AS0638				
Traverse Thermocouple ID	AS0451a				
Static Pressure	Δp (mmH20)				
	7.50				
	Pass				
Swirl Test Conducted	Yes				
Protractor ID	AS0626				
Post-Test Blockage Test (L-Type only)					
Post Test Leak Check <2.5 mm H2O	Pass				
Pitot Assembly Visual Inspection (Post)	Pass				

Diagram of Sample Location:



Comments/Deviations:

Conditions	Value	Units
Stack pressure	766.78	mmHg
Ref O_2 Value	3	%
Molsture Content	1.78	%
CO	260	ppm
CO_2	4.7	%
N_2	83.07	%
O_2	12.20	%
Dry Molecular wt	29.24	
Stack Molecular wt	29.04	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1021.3	mbar
Pbar	766	mmHg
Pitot tube coeft	0.83	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature	18	°C

Duct Dimensions

Port ID	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Port Depth
A					
B					
C					
D					

Circular Duct

Line ID	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Diameter
A					
B					

Rectangular Duct

Line ID	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Depth
A					
B					
C					
D					

	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Width
Outside Side Division					

			Static Measurement	Δp (mmH20)	
			Measurement Line	Reading 1	Reading 2(180°)
Enter manually from previous visit	Circular Duct	Rectangular Duct	A	7.50	7.50
Duct Diameter (m)	1.48		B	7.40	7.60
Duct Depth (m)			C		
Duct Width (m)			D		

Post-Test Blockage Test (L	Traverse Point	Δp Reading (mm H_2O)	Δp Reading (mm H_2O)	Δp Reading (mm H_2O)	Δp Average (mm H_2O)
Reading 1					
Reading 2					

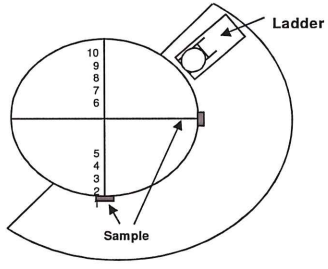
SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	1.70	1.70	1.70	1.70	16.67	15.8	4.31	4	1.30
2	1.26	1.50	1.50	1.50	1.50	14.70	15.8	4.05	4	1.22
3	1.04	1.80	1.80	1.80	1.80	17.65	15.7	4.43	3	1.34
4	0.44	1.60	1.60	1.60	1.60	15.68	15.6	4.18	3	1.26
5	0.22	1.90	1.90	1.90	1.90	18.63	15.7	4.56	3	1.38
6	0.06	1.80	1.80	1.80	1.80	17.65	15.8	4.43	4	1.34
SAMPLING LINE: West										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	1.40	1.40	1.40	1.40	13.72	15.8	3.91	5	1.18
2	1.26	1.30	1.30	1.30	1.30	12.74	15.7	3.77	4	1.14
3	1.04	1.20	1.20	1.20	1.20	11.76	15.6	3.62	5	1.10
4	0.44	1.80	1.80	1.80	1.80	17.65	15.8	4.43	5	1.34
5	0.22	1.90	1.90	1.90	1.90	18.63	15.8	4.56	4	1.38
6	0.06	2.30	2.30	2.30	2.30	22.55	15.9	5.01	4	1.52
Average values		**1.7**	**1.7**	**1.7**	**1.7**	**16.5**	**15.8**	**4.3**	**4.0**	**1.3**

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	4.27	ms^{-1}	Is the Flow Ratio 3:1 or less?	1.4 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	3.35	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	7.35	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	7.22	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	7.01	m^3s^{-1}	Minimum Δp detected > 0.5 mmH2O	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	3.41	m^3s^{-1}		

Monitoring Objective	Traverse	Site:	South Hook LNG
Date	14/08/2018	Site Team:	MRE/RPL
Tape Measure ID	AS0589		
Laser Measurement Device ID	N/A		
Traverse Pitot Type	S-Type		
Traverse Pitot Tube ID	AS0466		
Pitot Assembly Visual Inspection (Pre)	Pass		
Pre Test Leak Check <2.5 mm H2O	Pass		
Traverse Manometer Type	Digital		
Traverse Manometer ID	AS0638		
Traverse Manometer Range	240		
Traverse Temp. Readout ID	AS0638		
Traverse Thermocouple ID	AS0451a		
Static Pressure	Δp (mmH20)		
	8.50		
	Pass		
Swirl Test Conducted	Yes		
Protractor ID	AS0626		
Post-Test Blockage Test (L-Type only)			
Post Test Leak Check <2.5 mm H2O	Pass		
Pitot Assembly Visual Inspection (Post)	Pass		

Stack ID:	SCV 2F
Time of Survey:	16:15

Diagram of Sample Location:



Comments/Deviations:

Conditions	Value	Units
Stack pressure	767.23	mmHg
Ref O_2 Value	3	%
Moisture Content	1.79	%
CO	175	ppm
CO_2	4.3	%
N_2	82.68	%
O_2	13.00	%
Dry Molecular wt	29.21	
Stack Molecular wt	29.01	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1021.8	mbar
Pbar	767	mmHg
Pitot tube coeft	0.83	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature	19	°C

Duct Dimensions

Port ID	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Port Depth
A					
B					
C					
D					

Circular Duct

Line ID	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Diameter
A					
B					

Rectangular Duct

Line ID	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Depth
A					
B					
C					
D					

	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Width
Outside Side Division					

Enter manually from previous visit	Circular Duct	Rectangular Duct
Duct Diameter (m)	1.48	
Duct Depth (m)		
Duct Width (m)		

Post-Test Blockage Test (L	Traverse Point	Δp Reading (mm H_2O)	Δp Reading (mm H_2O)	Δp Reading (mm H_2O)	Δp Average (mm H_2O)
Reading 1					
Reading 2					

Static Measurement	Δp (mmH20)	
Measurement Line	Reading 1	Reading 2(180°)
A	8.50	8.70
B	8.30	8.50
C		
D		

SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	1.70	1.70	1.70	1.70	16.67	15.8	4.31	6	1.30
2	1.26	2.00	2.00	2.00	2.00	19.61	15.6	4.67	5	1.41
3	1.04	1.90	1.90	1.90	1.90	18.63	15.5	4.56	5	1.38
4	0.44	2.10	2.10	2.10	2.10	20.59	15.4	4.79	6	1.45
5	0.22	1.60	1.60	1.60	1.60	15.68	15.9	4.18	7	1.26
6	0.06	1.60	1.60	1.60	1.60	15.68	16.0	4.18	8	1.26
SAMPLING LINE: West										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	1.40	1.40	1.40	1.40	13.72	16.0	3.91	7	1.18
2	1.26	1.50	1.50	1.50	1.50	14.70	16.0	4.05	8	1.22
3	1.04	1.90	1.90	1.90	1.90	18.63	15.8	4.56	5	1.38
4	0.44	2.30	2.30	2.30	2.30	22.55	15.9	5.02	7	1.52
5	0.22	2.60	2.60	2.60	2.60	25.49	16.4	5.34	4	1.61
6	0.06	2.60	2.60	2.60	2.60	25.49	16.5	5.34	8	1.61
Average values		**1.9**	**1.9**	**1.9**	**1.9**	**19.0**	**15.9**	**4.6**	**6.3**	**1.4**

Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	4.58	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	3.25	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	7.87	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	7.73	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	7.51	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	3.31	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	1.4 :1
Any local negative flow?	NO
Flow <15° of duct axis?	YES
Minimum Δp detected > 0.5 mmH2O	YES

2.2.3 - One Minute Averaged Gaseous Emissions Data

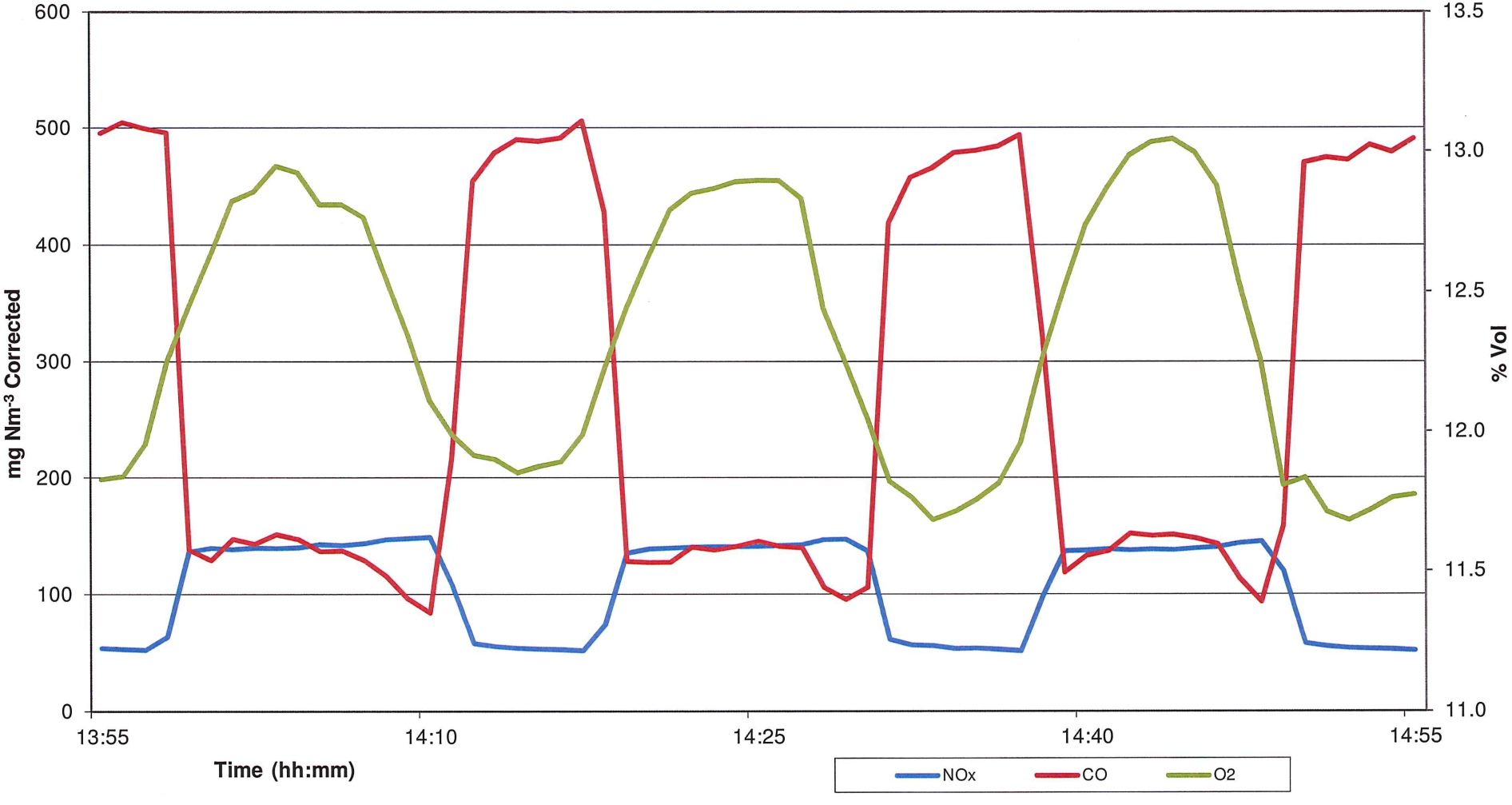
Minute Averaged Gaseous Data from South Hook LNG 13th August 2018 SCV A - Phase One Referenced to 273K, 101.3kPa and 3% Oxygen on a Dry Basis			
Time (hh:mm)	**Carbon Monoxide (mg/Nm^3)**	**Oxides of Nitrogen (mg/Nm^3)**	**Oxygen (%)**
13:55	495	54.1	11.8
13:56	504	53.2	11.8
13:57	499	52.6	12.0
13:58	496	63.9	12.2
13:59	138	136.1	12.4
14:00	129	139.4	12.6
14:01	147	138.3	12.8
14:02	143	139.6	12.9
14:03	151	139.2	12.9
14:04	147	139.9	12.9
14:05	136	142.5	12.8
14:06	137	141.8	12.8
14:07	129	143.7	12.8
14:08	115	146.8	12.6
14:09	96	147.6	12.3
14:10	84	148.8	12.1
14:11	216	108.0	12.0
14:12	454	58.3	11.9
14:13	478	55.6	11.9
14:14	490	54.2	11.9
14:15	488	53.6	11.9
14:16	491	52.8	11.9
14:17	506	52.1	12.0
14:18	428	74.4	12.2
14:19	128	135.2	12.4
14:20	127	138.7	12.6
14:21	127	139.3	12.8
14:22	140	140.3	12.8
14:23	138	140.8	12.9
14:24	141	140.7	12.9
14:25	145	141.0	12.9
14:26	141	141.6	12.9
14:27	140	142.4	12.8
14:28	106	146.7	12.4
14:29	95	147.1	12.2
14:30	106	136.8	12.0
14:31	419	61.5	11.8
14:32	457	56.8	11.8
14:33	465	56.2	11.7
14:34	479	53.7	11.7
14:35	480	54.0	11.8
14:36	484	53.0	11.8
14:37	494	51.7	12.0
14:38	324	98.3	12.3
14:39	118	136.9	12.5
14:40	133	137.5	12.7
14:41	137	138.6	12.9
14:42	152	137.7	13.0
14:43	150	138.4	13.0
14:44	151	138.0	13.0
14:45	148	139.1	13.0
14:46	143	140.5	12.9
14:47	113	143.7	12.5
14:48	93	145.4	12.3
14:49	159	119.9	11.8
14:50	470	58.3	11.8
14:51	474	55.4	11.7
14:52	472	54.0	11.7
14:53	485	53.4	11.7
14:54	479	52.8	11.8
14:55	491	52.0	11.8
Min Value	**84**	**51.7**	**11.7**
Max Value	**506**	**148.8**	**13.0**
Average	**272**	**105.8**	**12.3**

Minute Averaged Gaseous Data from South Hook LNG 14th August 2018 SCV A - Phase Two Referenced to 273K, 101.3kPa and 3% Oxygen on a Dry Basis			
Time (hh:mm)	**Carbon Monoxide (mg/Nm^3)**	**Oxides of Nitrogen (mg/Nm^3)**	**Oxygen (%)**
12:00	775	36.6	12.3
12:01	788	36.3	12.3
12:02	795	36.6	12.3
12:03	767	36.6	12.3
12:04	755	36.7	12.2
12:05	737	36.3	12.3
12:06	736	36.7	12.3
12:07	714	36.5	12.3
12:08	709	36.9	12.3
12:09	695	36.7	12.3
12:10	671	37.1	12.2
12:11	674	37.0	12.2
12:12	681	36.7	12.2
12:13	658	37.1	12.2
12:14	662	37.0	12.2
12:15	677	36.8	12.3
12:16	664	37.1	12.3
12:17	698	36.8	12.3
12:18	708	36.5	12.3
12:19	717	36.6	12.3
12:20	717	36.7	12.4
12:21	724	36.9	12.3
12:22	723	36.5	12.3
12:23	730	36.7	12.3
12:24	737	36.8	12.2
12:25	719	36.6	12.2
12:26	719	36.9	12.2
12:27	705	36.7	12.2
12:28	705	36.6	12.3
12:29	734	36.4	12.3
12:30	723	36.4	12.3
12:31	738	36.0	12.3
12:32	735	36.2	12.3
12:33	738	36.4	12.3
12:34	738	36.0	12.3
12:35	722	36.5	12.3
12:36	725	36.4	12.3
12:37	710	36.8	12.3
12:38	698	36.9	12.3
12:39	706	36.8	12.3
12:40	715	36.4	12.3
12:41	718	36.4	12.3
12:42	723	36.3	12.3
12:43	717	36.3	12.4
12:44	731	36.1	12.4
12:45	729	36.4	12.3
12:46	710	36.6	12.3
12:47	714	36.6	12.3
12:48	727	36.4	12.3
12:49	712	36.6	12.3
12:50	716	36.7	12.3
12:51	731	36.4	12.3
12:52	731	36.4	12.4
12:53	733	36.4	12.4
12:54	729	36.7	12.3
12:55	717	36.6	12.3
12:56	707	36.6	12.3
12:57	710	37.0	12.3
12:58	713	36.6	12.3
12:59	708	36.8	12.3
13:00	698	37.0	12.3
Min Value	**658**	**36.0**	**12.2**
Max Value	**795**	**37.1**	**12.4**
Average	**718**	**36.6**	**12.3**

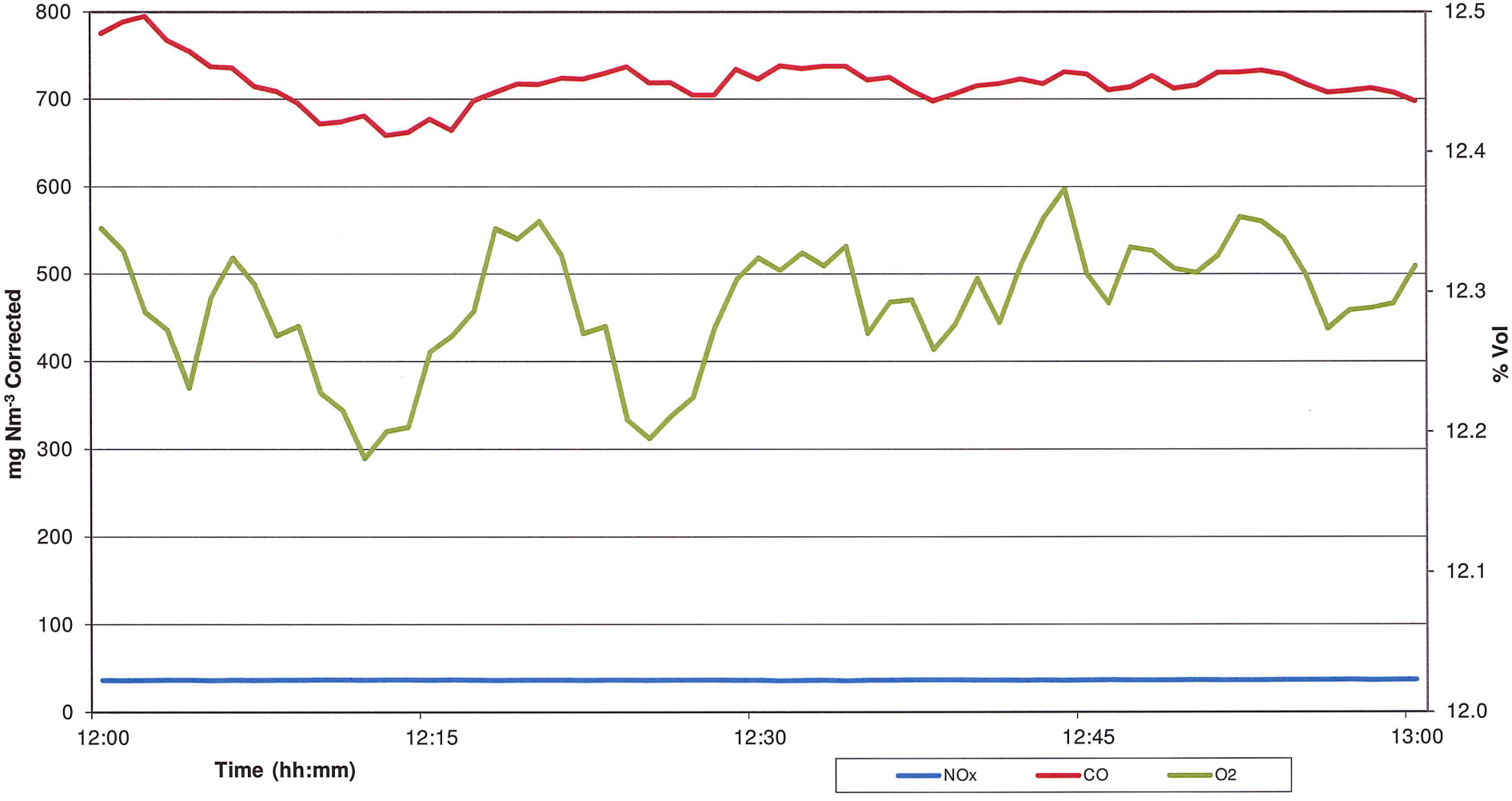
Minute Averaged Gaseous Data from South Hook LNG 13th August 2018 SCV F - Phase Two Referenced to 273K, 101.3kPa and 3% Oxygen on a Dry Basis			
Time (hh:mm)	Carbon Monoxide (mg/Nm^3)	Oxides of Nitrogen (mg/Nm^3)	Oxygen (%)
16:45	517	42.9	12.9
16:46	509	43.3	12.8
16:47	513	43.3	12.8
16:48	504	43.2	12.7
16:49	502	43.1	12.8
16:50	505	43.2	12.8
16:51	494	43.6	12.8
16:52	501	43.2	12.8
16:53	495	43.4	12.8
16:54	488	43.3	12.8
16:55	482	43.4	12.8
16:56	488	43.1	12.8
16:57	495	43.2	12.9
16:58	512	42.8	12.9
16:59	513	42.6	13.0
17:00	512	42.7	13.0
17:01	507	43.0	13.0
17:02	514	42.7	13.0
17:03	515	42.8	12.9
17:04	534	41.8	12.9
17:05	533	41.7	13.0
17:06	522	42.2	12.9
17:07	535	41.6	12.9
17:08	546	41.1	12.9
17:09	542	41.4	12.9
17:10	539	41.5	12.9
17:11	548	41.4	13.0
17:12	528	42.1	12.9
17:13	515	42.4	12.9
17:14	516	42.5	12.8
17:15	524	42.3	12.8
17:16	504	42.5	12.8
17:17	512	42.6	12.8
17:18	502	43.0	12.8
17:19	509	42.7	12.8
17:20	490	43.1	12.7
17:21	498	42.7	12.7
17:22	491	42.9	12.8
17:23	483	43.0	12.8
17:24	504	42.1	12.8
17:25	516	41.3	12.8
17:26	522	41.5	12.8
17:27	514	41.5	12.8
17:28	513	41.6	12.8
17:29	524	41.5	12.9
17:30	516	41.8	12.9
17:31	517	41.9	12.9
17:32	505	42.3	12.9
17:33	514	42.5	12.9
17:34	515	42.2	12.9
17:35	509	42.7	12.9
17:36	517	42.4	12.9
17:37	536	42.1	13.0
17:38	551	42.1	13.0
17:39	532	42.3	12.9
17:40	529	42.6	12.8
17:41	518	42.9	12.8
17:42	516	42.6	12.8
17:43	518	42.7	12.8
17:44	545	41.4	12.8
17:45	543	41.1	12.8
Min Value	**482**	**41.1**	**12.7**
Max Value	**551**	**43.6**	**13.0**
Average	**515**	**42.4**	**12.9**

2.2.4 - Gaseous Emissions Graphical Data

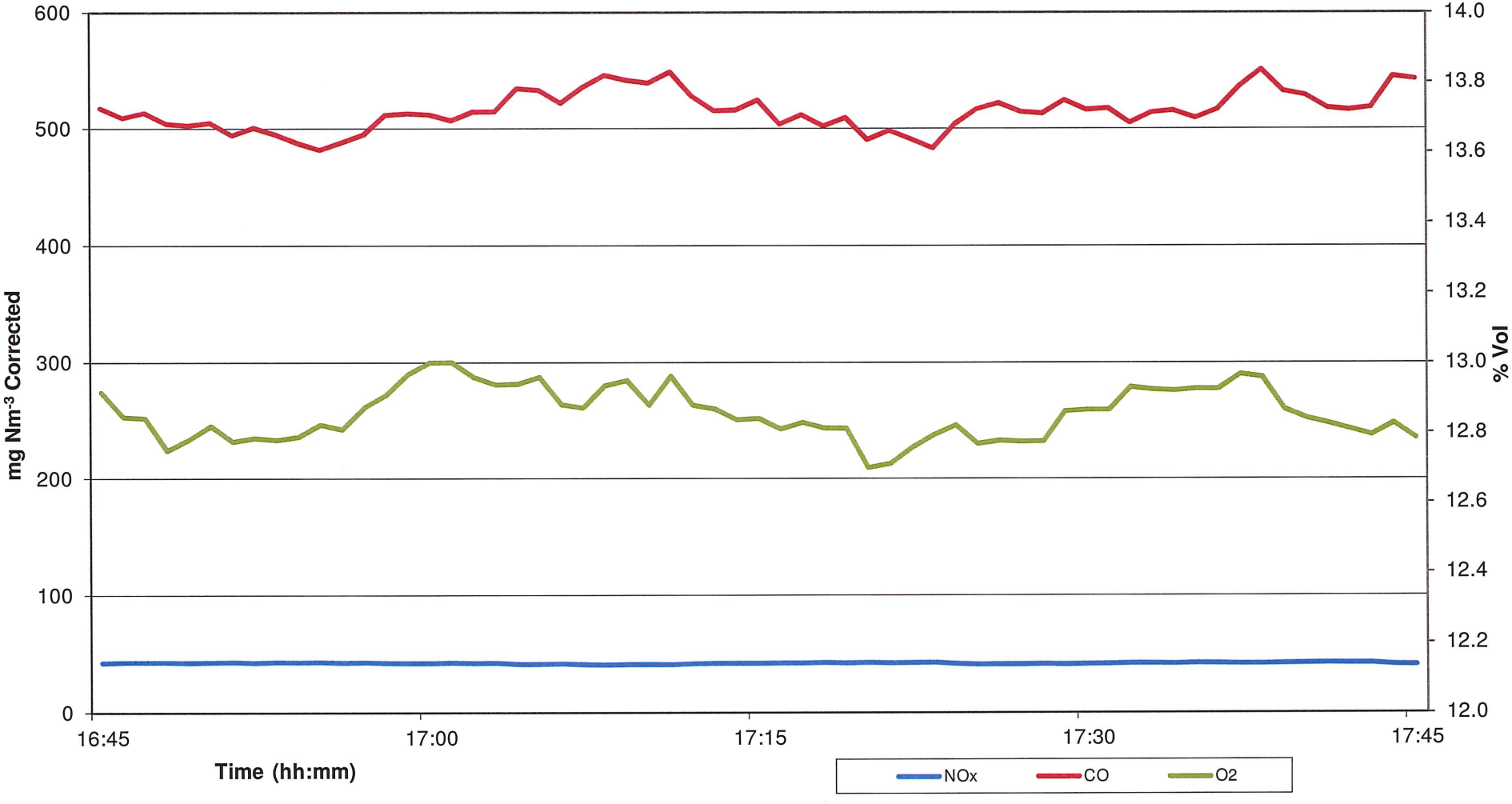
SCV 1A One Minute Averaged Gaseous Emissions Data - 13th August 2018
(273.15K, 101.325kPa, 3% O_2, on a Dry Gas basis) using the NPL Conventional Analysis Package



SCV 2A One Minute Averaged Gaseous Emissions Data - 14th August 2018
(273.15K, 101.325kPa, 3% O_2, on a Dry Gas basis) using the NPL Conventional Analysis Package



SCV 2F One Minute Averaged Gaseous Emissions Data - 13th August 2018
(273.15K, 101.325kPa, 3% O_2, on a Dry Gas basis) using the NPL Conventional Analysis Package



2.2.5 - Gas Calibration Log

GAS CALIBRATION MEASUREMENTS

					SO_2 (ppm)		CO (ppm)		NO\NOx (ppm)		N_2O (ppm)	
Client:	Intertek Ltd	Date:	13/08/2018									
Site:	South Hook LNG	Job Number:	INTK41AUG18	CBISS auto ranges	0-26	0-200	0-60	0-200	0-100	0-250 (only NOx)	0-15	
Stack ID:	SCV 1A	Initial N_2 pressure bar:	180		0-700		0-400			0-400 (only NO)		
Reference oxygen %	3	Leak check method	Cylinder method	Testo ranges	0-5000		0-10000			0-3000 (only NO)		

GAS CALIBRATION LOG - ANALYSER ADJUSTMENT

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Gas Cylinder ID:			146117	146117		172344	172344		
Initial Reg. Pressure bar			150	150		140	140		
Analyser type / Analyser ID			PG250 AS0450	PG250 AS0450		PG250 AS0450	PG250 AS0450		
Cylinder Concentration:		ppm	153.2 ppm	152.8 ppm	ppm	14.86 % Vol	15.24 % Vol	ppm C_3H_8	ppm
Span Value:		ppm	153.2 ppm	152.8 ppm	ppm	14.86 % Vol	15.24 % Vol	ppm C_3H_8	ppm
Analyser Range: 0 -		ppm	200 ppm	250 ppm	ppm	25 % Vol	20 % Vol	ppm C_3H_8	ppm
Check Zero	Time			11:47					
	Reading	ppm	0.0 ppm	0.0 ppm	ppm	0.53 % Vol	-0.17 % Vol	ppm C_3H_8	ppm
	Initial Gain		2	0		13	4		
Adjust Zero	Time			11:49					
	Reading	ppm	0.0 ppm	0.0 ppm	ppm	0.00 % Vol	0.00 % Vol	ppm C_3H_8	ppm
	Final Gain		2	0		-1	1		
Check Span	Time		12:01	12:01		11:54	11:54		
	Reading	ppm	167.9 ppm	166.7 ppm	ppm	15.10 % Vol	16.50 % Vol	ppm C_3H_8	ppm
	Initial Gain		1.217	1.091		0.878	0.986		
Adjust Span	Time		12:03	12:03		11:56	11:56		
	Reading	ppm	153.0 ppm	152.8 ppm	ppm	14.86 % Vol	15.24 % Vol	ppm C_3H_8	ppm
	Final Gain		1.112	0.999		0.864	0.952		
Check Zero	Time			12:06					
	Reading	ppm	0.4 ppm	0.6 ppm	ppm	-0.06 % Vol	0.02 % Vol	ppm C_3H_8	ppm
Zero Drift		0.0 ppm	0.4 ppm	0.6 ppm	0.0 ppm	-0.06 % Vol	0.0 % Vol	0.0 ppm C_3H_8	0.0 ppm
Acceptance			Accept <2% of range	Accept <2% of range		Accept <2% of range	Accept <2% of range		

GAS CALIBRATION LOG - SAMPLING SYSTEM CHECK - FLOW METHOD

			CO	NO	NOx	O_2			
Expected Flow:			l/min	l/min	l/min	l/min			
Leak check	Time								
	Reading		l/min	l/min	l/min	l/min			
	Pass/fail		PASS	PASS	PASS	PASS			

GAS CALIBRATION LOG - SAMPLING SYSTEM CHECK - CYLINDER METHOD

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Span Value:		0.0 ppm	153.2 ppm	152.8 ppm	0.0 ppm	14.9 % Vol	15.2 % Vol	0.0 ppm C_3H_8	0.0 ppm
Check Zero	Time			12:10					
	Reading	ppm	-0.5 ppm	0.1 ppm	ppm	-0.04 % Vol	0.02 % Vol	ppm C_3H_8	ppm
	Pass/fail		PASS	PASS		PASS	PASS		
Check Span	Time		12:14	12:14		12:19	12:19		
	Reading	ppm	151.4 ppm	152.8 ppm	ppm	14.80 % Vol	15.20 % Vol	ppm C_3H_8	ppm
	Response Time/s	sec	55 sec	60 sec	sec	62 sec	60 sec	sec	sec
	Pass/fail		PASS	PASS		PASS	PASS		

GAS CALIBRATION LOG - DRIFT CHECK (direct to analyser)

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Span Value:		0.0 ppm	153.2 ppm	152.8 ppm	0.0 ppm	14.86 % Vol	15.24 % Vol	0.0 ppm C_3H_8	0.0 ppm
Check Zero	Time			15:16					
	Reading	ppm	0.8 ppm	0.0 ppm	ppm	-0.25 % Vol	0.04 % Vol	ppm C_3H_8	ppm
Reg Pressure (N_2)				170					
Check Span	Time		15:22	15:22		15:26	15:26		
	Reading	ppm	147.2 ppm	157.4 ppm	ppm	14.64 % Vol	15.21 % Vol	ppm C_3H_8	ppm
	Reg Pressure		145	145		135	135		
Zero Drift (%)		#DIV/0!	0.5	0.0	#DIV/0!	1.7	0.3	#DIV/0!	#DIV/0!
Span Drift (%)		#DIV/0!	3.8	3.0	#DIV/0!	1.5	0.2	#DIV/0!	#DIV/0!
Acceptance zero		#DIV/0!	Accept	Accept	#DIV/0!	Accept	Accept	#DIV/0!	#DIV/0!
Acceptance span		#DIV/0!	Correct for drift	Correct for drift	#DIV/0!	Accept	Accept	#DIV/0!	#DIV/0!

CALIBRATION TO BE CARRIED OUT BY OR UNDER THE SUPERVISION OF MCERTS QUALIFIED PERSONNEL WITH LEVEL TWO AND TE4

Name:	Matthew Ellison
MCERTS ID:	MM-05-682

Personnel Present:		MRE/RPL

GAS CALIBRATION MEASUREMENTS

Client:	Intertek Ltd	Date:	14/08/2018		SO_2 (ppm)		CO (ppm)		NO\NOx (ppm)		N_2O (ppm)	
Site:	South Hook LNG	Job Number:	INTK41AUG18	CBISS auto ranges	0-26	0-200	0-60	0-200	0-100	0-250 (only NOx)	0-15	
Stack ID:	SCV 2A	Initial N_2 pressure bar:	160		0-700		0-400			0-400 (only NO)		
Reference oxygen %	3	Leak check method	Cylinder method	Testo ranges	0-5000		0-10000			0-3000 (only NO)		

GAS CALIBRATION LOG - ANALYSER ADJUSTMENT

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Gas Cylinder ID:			146117	146117		172344	172344		
Initial Reg. Pressure bar			140	140		130	130		
Analyser type / Analyser ID			PG250 AS0450	PG250 AS0450		PG250 AS0450	PG250 AS0450		
Cylinder Concentration:		ppm	153.2 ppm	152.8 ppm	ppm	14.86 % Vol	15.24 % Vol	ppm C_3H_8	ppm
Span Value:		ppm	153.2 ppm	152.8 ppm	ppm	14.86 % Vol	15.24 % Vol	ppm C_3H_8	ppm
Analyser Range: 0 -		ppm	200 ppm	250 ppm	ppm	25 % Vol	20 % Vol	ppm C_3H_8	ppm
Check Zero	Time	11:12							
	Reading	ppm	0.8 ppm	0.0 ppm	ppm	0.25 % Vol	-0.05 % Vol	ppm C_3H_8	ppm
	Initial Gain		-1	0		-6	2		
Adjust Zero	Time	11:14							
	Reading	ppm	0.0 ppm	0.0 ppm	ppm	0.00 % Vol	0.00 % Vol	ppm C_3H_8	ppm
	Final Gain		0	0		0	1		
Check Span	Time		11:17	11:17		11:25	11:25		
	Reading	ppm	159.1 ppm	155.8 ppm	ppm	14.92 % Vol	15.86 % Vol	ppm C_3H_8	ppm
	Initial Gain		1.150	1.019		0.865	0.967		
Adjust Span	Time		11:19	11:19		11:27	11:27		
	Reading	ppm	152.9 ppm	152.8 ppm	ppm	14.86 % Vol	15.24 % Vol	ppm C_3H_8	ppm
	Final Gain		1.108	0.998		0.862	0.951		
Check Zero	Time	11:29							
	Reading	ppm	1.6 ppm	0.1 ppm	ppm	0.00 % Vol	0.08 % Vol	ppm C_3H_8	ppm
Zero Drift		0.0 ppm	1.6 ppm	0.1 ppm	0.0 ppm	0.00 % Vol	0.1 % Vol	0.0 ppm C_3H_8	0.0 ppm
Acceptance			Accept <2% of range	Accept <2% of range		Accept <2% of range	Accept <2% of range		

GAS CALIBRATION LOG - SAMPLING SYSTEM CHECK - FLOW METHOD

			CO	NO	NOx	O_2			
Expected Flow:			l/min	l/min	l/min	l/min			
Leak check	Time								
	Reading		l/min	l/min	l/min	l/min			
	Pass/fail		PASS	PASS	PASS	PASS			

GAS CALIBRATION LOG - SAMPLING SYSTEM CHECK - CYLINDER METHOD

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Span Value:		0.0 ppm	153.2 ppm	152.8 ppm	0.0 ppm	14.9 % Vol	15.2 % Vol	0.0 ppm C_3H_8	0.0 ppm
Check Zero	Time		11:32						
	Reading	ppm	0.6 ppm	0.1 ppm	ppm	0.08 % Vol	0.03 % Vol	ppm C_3H_8	ppm
	Pass/fail		PASS	PASS		PASS	PASS		
Check Span	Time		11:35	11:35		11:40	11:40		
	Reading	ppm	151.1 ppm	152.3 ppm	ppm	14.84 % Vol	15.07 % Vol	ppm C_3H_8	ppm
	Response Time/s	sec	60 sec	65 sec	sec	65 sec	65 sec	sec	sec
	Pass/fail		PASS	PASS		PASS	PASS		

GAS CALIBRATION LOG - DRIFT CHECK (direct to analyser)

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Span Value:		0.0 ppm	153.2 ppm	152.8 ppm	0.0 ppm	14.86 % Vol	15.24 % Vol	0.0 ppm C_3H_8	0.0 ppm
Check Zero	Time	13:06							
	Reading	ppm	1.5 ppm	0.0 ppm	ppm	-0.10 % Vol	0.03 % Vol	ppm C_3H_8	ppm
Reg Pressure (N_2)		155							
Check Span	Time		13:10	13:10		13:15	13:15		
	Reading	ppm	150.1 ppm	152.7 ppm	ppm	14.79 % Vol	15.19 % Vol	ppm C_3H_8	ppm
	Reg Pressure		135	135		125	125		
Zero Drift (%)		#DIV/0!	1.0	0.0	#DIV/0!	0.7	0.2	#DIV/0!	#DIV/0!
Span Drift (%)		#DIV/0!	1.8	0.1	#DIV/0!	0.5	0.3	#DIV/0!	#DIV/0!
Acceptance zero		#DIV/0!	Accept	Accept	#DIV/0!	Accept	Accept	#DIV/0!	#DIV/0!
Acceptance span		#DIV/0!	Accept	Accept	#DIV/0!	Accept	Accept	#DIV/0!	#DIV/0!

CALIBRATION TO BE CARRIED OUT BY OR UNDER THE SUPERVISION OF MCERTS QUALIFIED PERSONNEL WITH LEVEL TWO AND TE4

Name:	Matthew Ellison
MCERTS ID:	MM-05-682

Personnel Present:		MRE/RPL

GAS CALIBRATION MEASUREMENTS

					SO_2 (ppm)		CO (ppm)		NO\NOx (ppm)		N_2O (ppm)	
Client:	Intertek Ltd	Date:	13/08/2018									
Site:	South Hook LNG	Job Number:	INTK41AUG18	CBISS auto ranges	0-26	0-200	0-60	0-200	0-100	0-250 (only NOx)	0-15	
Stack ID:	SCV 2F	Initial N_2 pressure bar:	170		0-700		0-400			0-400 (only NO)		
Reference oxygen %	3	Leak check method	Cylinder method	Testo ranges	0-5000		0-10000			0-3000 (only NO)		

GAS CALIBRATION LOG - ANALYSER ADJUSTMENT

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Gas Cylinder ID:			146117	146117		172344	172344		
Initial Reg. Pressure bar			145	145		135	135		
Analyser type / Analyser ID			PG250 AS0450	PG250 AS0450		PG250 AS0450	PG250 AS0450		
Cylinder Concentration:		ppm	153.2 ppm	152.8 ppm	ppm	14.86 % Vol	15.24 % Vol	ppm C_3H_8	ppm
Span Value:		ppm	153.2 ppm	152.8 ppm	ppm	14.86 % Vol	15.24 % Vol	ppm C_3H_8	ppm
Analyser Range: 0 -		ppm	200 ppm	250 ppm	ppm	25 % Vol	20 % Vol	ppm C_3H_8	ppm
Check Zero	Time		15:48						
	Reading	ppm	-2.6 ppm	0.0 ppm	ppm	-0.20 % Vol	0.04 % Vol	ppm C_3H_8	ppm
	Initial Gain		2	0		-1	1		
Adjust Zero	Time		15:49						
	Reading	ppm	0.0 ppm	0.0 ppm	ppm	0.00 % Vol	0.00 % Vol	ppm C_3H_8	ppm
	Final Gain		-1	0		-6	2		
Check Span	Time		15:58	15:58		15:52	15:52		
	Reading	ppm	148.1 ppm	149.8 ppm	ppm	14.83 % Vol	14.69 % Vol	ppm C_3H_8	ppm
	Initial Gain		1.112	0.999		0.864	0.952		
Adjust Span	Time		16:00	16:00		15:54	15:54		
	Reading	ppm	153.2 ppm	152.8 ppm	ppm	14.86 % Vol	15.24 % Vol	ppm C_3H_8	ppm
	Final Gain		1.150	1.019		0.865	0.967		
Check Zero	Time		16:02						
	Reading	ppm	3.8 ppm	0.6 ppm	ppm	-0.06 % Vol	0.01 % Vol	ppm C_3H_8	ppm
Zero Drift		0.0 ppm	3.8 ppm	0.6 ppm	0.0 ppm	-0.06 % Vol	0.0 % Vol	0.0 ppm C_3H_8	0.0 ppm
Acceptance			Accept <2% of range	Accept <2% of range		Accept <2% of range	Accept <2% of range		

GAS CALIBRATION LOG - SAMPLING SYSTEM CHECK - FLOW METHOD

			CO	NO	NOx	O_2			
Expected Flow:			l/min	l/min	l/min	l/min			
Leak check	Time								
	Reading		l/min	l/min	l/min	l/min			
	Pass/fail		PASS	PASS	PASS	PASS			

GAS CALIBRATION LOG - SAMPLING SYSTEM CHECK - CYLINDER METHOD

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Span Value:		0.0 ppm	153.2 ppm	152.8 ppm	0.0 ppm	14.9 % Vol	15.2 % Vol	0.0 ppm C_3H_8	0.0 ppm
Check Zero	Time		16:08						
	Reading	ppm	2.8 ppm	0.1 ppm	ppm	-0.10 % Vol	0.00 % Vol	ppm C_3H_8	ppm
	Pass/fail		PASS	PASS		PASS	PASS		
Check Span	Time		16:12	16:12		16:16	16:16		
	Reading	ppm	156.2 ppm	153.2 ppm	ppm	14.85 % Vol	15.29 % Vol	ppm C_3H_8	ppm
	Response Time/s	sec	60 sec	65 sec	sec	64 sec	64 sec	sec	sec
	Pass/fail		PASS	PASS		PASS	PASS		

GAS CALIBRATION LOG - DRIFT CHECK (direct to analyser)

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Span Value:		0.0 ppm	153.2 ppm	152.8 ppm	0.0 ppm	14.86 % Vol	15.24 % Vol	0.0 ppm C_3H_8	0.0 ppm
Check Zero	Time		17:48						
	Reading	ppm	2.8 ppm	0.0 ppm	ppm	-0.03 % Vol	0.03 % Vol	ppm C_3H_8	ppm
Reg Pressure (N_2)			160						
Check Span	Time		17:53	17:53		17:56	17:56		
	Reading	ppm	155.1 ppm	153.2 ppm	ppm	14.83 % Vol	15.25 % Vol	ppm C_3H_8	ppm
	Reg Pressure		140	140		130	130		
Zero Drift (%)		#DIV/0!	1.8	0.0	#DIV/0!	0.2	0.2	#DIV/0!	#DIV/0!
Span Drift (%)		#DIV/0!	1.2	0.3	#DIV/0!	0.2	0.1	#DIV/0!	#DIV/0!
Acceptance zero		#DIV/0!	Accept	Accept	#DIV/0!	Accept	Accept	#DIV/0!	#DIV/0!
Acceptance span		#DIV/0!	Accept	Accept	#DIV/0!	Accept	Accept	#DIV/0!	#DIV/0!

CALIBRATION TO BE CARRIED OUT BY OR UNDER THE SUPERVISION OF MCERTS QUALIFIED PERSONNEL WITH LEVEL TWO AND TE4

Name:	Matthew Ellison
MCERTS ID:	MM-05-682

Personnel Present:		MRE/RPL

2.2.6 - Uncertainty Calculations

SCV 1A Uncertainty Calculations

Uncertainty calculation for Gaseous Measurement NOx EN14792 - PG-250 (AS0450)- SRM Version
v3.6 Feb-15

Limit value	107	mg/m³ (corrected) NOx	**Cal gas conc**	313.70	mg.m^{-3} (NO_2)
Measured concentration	50.95	mg/m3 (101.3kPa, 273K)	**Full Scale**	513.25	mg/m³ (NO_2)
Measured concentration	105.80	mg/m³ (Corrected)			

NO/NO2 ratio	100.00

Gas	NO	
Full Scale	250	ppm
Cal gas conc	152.8	ppm
Conversion	2.053	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.00	101.30	273.00
	measured	12.33	0.00	101.30	273.00
	Uncert	0.61	1.00	0.00	0.00
Factors		2.08	1.00	1.00	1.00
Uncertainty in factor		0.15	0.01	0.00	0.00
Correction Factor		**2.08**	uf	**0.15**	

Effect of drift
0.00 mg/m3

Performance characteristics	**Value**			**specification**
Response time	65	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	60	minutes		
Number of readings in measurement	60			
Repeatability at zero	0.02	% full scale		≤±1 % range
Repeatability at span level	0.02	% full scale		≤±2 % range
Deviation from linearity(lack of fit)	0.47	% full scale		≤±2 % range
Zero drift	0	mg/m3		<5% span value
Span drift	0	mg/m3		<5% span value
volume or pressure flow dependence	0.36	% full scale		
atmospheric pressure dependence	-0.16	% full scale /2kPa		≤±3 % range/2kPa
ambient temperature dependence	-2.43	% full scale/10K		≤±3 % range/10K
Cross sensitivity	0.5	% full scale		<4 % range
dependence on voltage	-0.1	% full scale/10V		≤±2% range/10V
losses in the line (leak)	0	% value		≤± 2% of value
Converter efficiency	95.1	%		≥95%
Uncertainty of calibration gas	1	% value		≤± 2% of value

	ranges min	max	value at calib	
flow	0.4	0.4	0.4	l/min
pressure	102.2	102.3	102.22	kPa
temp	290	294	290	K
Voltage	93	121	110	V

Performance characteristic		**Uncertainty**	**Value of uncertainty quantity**		**mg/m3**
Standard deviation of repeatability at zero		u_{r0}		for mean	use rep at span
Standard deviation of repeatability at span level		u_{rs}		for mean	0.01
Lack of fit		u_{lit}			1.39
Drift		u_{0dr}			0.00
volume or pressure flow dependence		u_{spres}			0.00
atmospheric pressure dependence		u_{apres}			-0.02
ambient temperature dependence		u_{itemp}			-2.88
Cross sensitivity		u_{intert}			1.48
Dependence on voltage		u_{volt}			-0.44
losses in the line (leak)		u_{leak}			0.00
Uncertainty of calibration gas		u_{cal}			0.29
converter efficiency		u_{conv}			1.44
Uncertainty in factor		uf			7.46

Measurement uncertainty				
Combined uncertainty			3.85	mg/m³
Expanded uncertainty	k =	2	7.69	mg/m³
Uncertainty corrected to std conds			**21.86**	**mg/m³**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**21.86 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**20.66 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**7.19 % ELV**	

Uncertainty calculation for gaseous measurement of CO under BS EN 15058:2017 - AS0450 (PG-250)

v4.2 Sep-17

Limit value	N/A	**mg/m³ (corrected)**	**Cal gas conc**	191.50	**mg.m⁻³**
Measured concentration	131.07	**mg/m3 (101.3kPa, 273K)**	**Full Scale**	250.00	**mg/m³**
Measured concentration	272.15	**mg/m³ (Corrected)**			

Gas	CO	
Full Scale	200	**ppm**
Cal gas conc	153.2	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.00	101.30	273.00
	measured	12.33	0.00	101.30	273.00
	Uncert	0.61	1.00	0.00	0.00
Factors		2.08	1.00	1.00	1.00
Uncertainty in factor		0.15	0.01	0.00	0.00
Correction Factor		**2.08**	uf	**0.15**	

Performance characteristics	**Value**			**specification**
Response time	60	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	60	minutes		
Number of readings in measurement	60			
Repeatability at zero	0.09	% full scale		≤±2 % range
Repeatability at span level	0.08	% full scale		≤±2 % range
Deviation from linearity(lack of fit)	0.71	% full scale		≤±2 % range
Zero drift	0	mg/m3		<5% span value
Span drift	0	mg/m3		<5% span value
Influence of sample flow	-0.27	% full scale		≤±2 % range
Influence of atmospheric pressure	0.09	% full scale /2kPa		≤±2 % range
Influence of ambient temperature at zero	1.48	% full scale/10K		≤±5 % range
Influence of ambient temperature at span	-1.33	% full scale/10K		≤±5 % range
Cross sensitivity	0.1	% full scale		<4 % range
Influence of voltage	0.33	% full scale/10V		≤±2 % range
Losses in the line (leak)	0	% value		≤± 2% of value
Uncertainty of calibration gas	1	% value		≤± 2% of value

Effect of drift
0.00 mg/m3

	ranges min	max	value at calib	
flow	0.4	0.4	0.4	l/min
pressure	102.2	102.3	102.22	kPa
spare				
temp	290	294	290	K
Voltage	93	121	110	V

Performance characteristic		**Uncertainty**	**Value of uncertainty quantity**		**mg/m3**
Standard deviation of repeatability at zero		u_{r0}		for mean	0.03
Standard deviation of repeatability at span level		u_{rs}		for mean	0.00
Lack of fit		u_{lft}			1.02
Drift		u_{0dr}			0.00
Influence of sample flow		u_{spres}			0.00
Influence of atmospheric pressure		u_{apres}			0.00
Influence of ambient temperature zero		u_{temp0}			0.85
Influence of ambient temperature span		u_{temps}			0.00
Cross sensitivity		u_{interf}			0.12
Influence of voltage		u_{volt}			0.71
Losses in the line (leak)		u_{leak}			0.00
Uncertainty of calibration gas		u_{cal}			0.76
Uncertainty in factor		uf			19.20

Measurement uncertainty				
Combined uncertainty			1.70	mg/m³
Expanded uncertainty	k =	2	3.39	mg/m³
Uncertainty corrected to std conds			**39.03**	**mg/m³**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**39.03 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**14.34 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

Uncertainty calculation for Gaseous Measurement O2 EN14789 - PG-250 AS0450 SRM
v3.0 Feb-15

Limit value	N/A	**Cal gas conc**	14.86 **% vol**
Measured concentration	12.33 **% vol**	**Full Scale**	25.00 **% vol**

Performance characteristics	**Value**			**specification**
Response time	65	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	61	minutes		
Number of readings in measurement	61			
Repeatability at zero	0.01	% range		≤±0.2 % range
Repeatability at span level	0.02	% range		≤±0.4 % range
Deviation from linearity(lack of fit)	0.2	% vol		<0.3 % vol
Zero drift	0.25	% vol		<5% span value
Span drift	0.22	% vol		<5% span value
volume or pressure flow dependence	0.08	% range		<1% range
atmospheric pressure dependence	0.91	% full scale /kPa		≤±1.5 % range/kPa
ambient temperature dependence	0.19	% vol/10K		≤±0.3 % vol/10K
Cross Sensitivity	0.2	% vol		≤±0.2 % vol
dependence on voltage	0.05	% vol/10V		≤±0.1% vol/10V
losses in the line (leak)	0	% value		≤± 2% of value
Uncertainty of calibration gas	1	% value		≤± 2% of value

Effect of drift
0.43 % vol

	ranges min	max	value at calib	
flow	0.4	0.4	0.4	l/min
pressure	102.2	102.3	102.22	kPa
temp	290	294	290	K
Voltage	93	121	110	V

Performance characteristic		**Uncertainty**		**Value of uncertainty quantity**		**% vol**
Standard deviation of repeatability at zero		u_{r0}		for mean		use rep at span
Standard deviation of repeatability at span level		u_{rs}		for mean		0.00
Lack of fit		u_{fit}				0.12
Drift		u_{0dr}				0.25
volume or pressure flow dependence		u_{spres}				0.00
atmospheric pressure dependence		u_{apres}				0.01
ambient temperature dependence		u_{temp}				0.04
Cross Sensitivity		u_{interf}				0.11
Dependence on voltage		u_{volt}				0.04
losses in the line (leak)		u_{leak}				0.00
Uncertainty of calibration gas		u_{cal}				0.07

Measurement uncertainty				
Combined uncertainty			0.31	% vol
Expanded uncertainty	k =	2	0.62	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.62 % vol**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**5.04 % value**	

SCV 2A Uncertainty Calculations

Uncertainty calculation for Gaseous Measurement NOx EN14792 - PG-250 (AS0450)- SRM Version
v3.6 Feb-15

Limit value	107	mg/m^3 (corrected) NOx	**Cal gas conc**	313.70	mg.m^{-3} (NO_2)
Measured concentration	17.72	mg/m3 (101.3kPa, 273K)	**Full Scale**	513.25	mg/m^3 (NO_2)
Measured concentration	36.61	mg/m^3 (Corrected)			

Gas	NO	
Full Scale	250	ppm
Cal gas conc	152.8	ppm
Conversion	2.053	

NO/NO2 ratio	100.00

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.00	101.30	273.00
	measured	12.29	0.00	101.30	273.00
	Uncert	0.41	1.00	0.00	0.00
Factors		2.07	1.00	1.00	1.00
Uncertainty in factor		0.10	0.01	0.00	0.00
Correction Factor		**2.07**	uf	**0.10**	

Effect of drift
0.01 mg/m3

Performance characteristics	**Value**			**specification**
Response time	65	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	61	minutes		
Number of readings in measurement	61			
Repeatability at zero	0.02	% full scale		≤±1 % range
Repeatability at span level	0.02	% full scale		≤±2 % range
Deviation from linearity(lack of fit)	0.47	% full scale		≤±2 % range
Zero drift	0	mg/m3		<5% span value
Span drift	0.21	mg/m3		<5% span value
volume or pressure flow dependence	0.36	% full scale		
atmospheric pressure dependence	-0.16	% full scale /2kPa		≤±3 % range/2kPa
ambient temperature dependence	-2.43	% full scale/10K		≤±3 % range/10K
Cross sensitivity	0.5	% full scale		<4 % range
dependence on voltage	-0.1	% full scale/10V		≤±2% range/10V
losses in the line (leak)	0	% value		≤± 2% of value
Converter efficiency	95.1	%		≥95%
Uncertainty of calibration gas	1	% value		≤± 2% of value

	ranges min	max	value at calib	
flow	0.4	0.4	0.4	l/min
pressure	102.2	102.3	102.22	kPa
temp	290	294	290	K
Voltage	93	121	110	V

Performance characteristic			**Uncertainty**		**Value of uncertainty quantity**		**mg/m3**
Standard deviation of repeatability at zero			u_{r0}		for mean		use rep at span
Standard deviation of repeatability at span level			u_{rs}		for mean		0.01
Lack of fit			u_{lft}				1.39
Drift			u_{0dr}				0.01
volume or pressure flow dependence			u_{spres}				0.00
atmospheric pressure dependence			u_{apres}				-0.02
ambient temperature dependence			u_{temp}				-2.88
Cross sensitivity			u_{interf}				1.48
Dependence on voltage			u_{volt}				-0.44
losses in the line (leak)			u_{leak}				0.00
Uncertainty of calibration gas			u_{cal}				0.10
converter efficiency			u_{conv}				0.50
Uncertainty in factor			uf				1.73

Measurement uncertainty				
Combined uncertainty			3.59	mg/m^3
Expanded uncertainty	k =	2	7.18	mg/m^3
Uncertainty corrected to std conds			**15.24**	**mg/m^3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**15.24 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**41.62 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.71 % ELV**	

Uncertainty calculation for gaseous measurement of CO under BS EN 15058:2017 - AS0450 (PG-250)

v4.2 Sep-17

Limit value	N/A	mg/m³ (corrected)	**Cal gas conc**	191.50	mg.m⁻³
Measured concentration	347.49	mg/m3 (101.3kPa, 273K)	**Full Scale**	250.00	mg/m³
Measured concentration	718.23	mg/m³ (Corrected)			

Gas	CO	
Full Scale	200	ppm
Cal gas conc	153.2	ppm
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.00	101.30	273.00
	measured	12.29	0.00	101.30	273.00
	Uncert	0.41	1.00	0.00	0.00
Factors		2.07	1.00	1.00	1.00
Uncertainty in factor		0.10	0.01	0.00	0.00
Correction Factor		**2.07**	uf	**0.10**	

Effect of drift
8.81 mg/m3

Performance characteristics	**Value**			**specification**
Response time	60	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	60	minutes		
Number of readings in measurement	60			
Repeatability at zero	0.09	% full scale		≤±2 % range
Repeatability at span level	0.08	% full scale		≤±2 % range
Deviation from linearity(lack of fit)	0.71	% full scale		≤±2 % range
Zero drift	2.01	mg/m3		<5% span value
Span drift	3.75	mg/m3		<5% span value
Influence of sample flow	-0.27	% full scale		≤±2 % range
Influence of atmospheric pressure	0.09	% full scale /2kPa		≤±2 % range
Influence of ambient temperature at zero	1.48	% full scale/10K		≤±5 % range
Influence of ambient temperature at span	-1.33	% full scale/10K		≤±5 % range
Cross sensitivity	0.1	% full scale		<4 % range
Influence of voltage	0.33	% full scale/10V		≤±2 % range
Losses in the line (leak)	0	% value		≤± 2% of value
Uncertainty of calibration gas	1	% value		≤± 2% of value

	ranges min	max	value at calib	
flow	0.4	0.4	0.4	l/min
pressure	102.2	102.3	102.22	kPa
spare				
temp	290	294	290	K
Voltage	93	121	110	V

Performance characteristic		**Uncertainty**		**Value of uncertainty quantity**		**mg/m3**
Standard deviation of repeatability at zero		u_{r0}		for mean		0.03
Standard deviation of repeatability at span level		u_{rs}		for mean		0.00
Lack of fit		u_{lit}				1.02
Drift		u_{0dr}				5.09
Influence of sample flow		u_{spres}				0.00
Influence of atmospheric pressure		u_{apres}				0.00
Influence of ambient temperature zero		u_{temp0}				0.85
Influence of ambient temperature span		u_{temps}				0.00
Cross sensitivity		u_{interf}				0.12
Influence of voltage		u_{volt}				0.71
Losses in the line (leak)		u_{leak}				0.00
Uncertainty of calibration gas		u_{cal}				2.01
Uncertainty in factor		uf				33.99

Measurement uncertainty				
Combined uncertainty			5.68	mg/m³
Expanded uncertainty	k =	2	11.35	mg/m³
Uncertainty corrected to std conds			**71.92**	**mg/m³**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**71.92 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**10.01 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

Uncertainty calculation for Gaseous Measurement O2 EN14789 - PG-250 AS0450 SRM
v3.0 Feb-15

Limit value	N/A		**Cal gas conc**	14.86 **% vol**
Measured concentration	12.29 **% vol**		**Full Scale**	25.00 **% vol**

Performance characteristics	**Value**			**specification**
Response time	65	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	61	minutes		
Number of readings in measurement	61			
Repeatability at zero	0.01	% range		≤±0.2 % range
Repeatability at span level	0.02	% range		≤±0.4 % range
Deviation from linearity(lack of fit)	0.2	% vol		<0.3 % vol
Zero drift	0.1	% vol		<5% span value
Span drift	0.07	% vol		<5% span value
volume or pressure flow dependence	0.08	% range		<1% range
atmospheric pressure dependence	0.91	% full scale /kPa		≤±1.5 % range/kPa
ambient temperature dependence	0.19	% vol/10K		≤±0.3 % vol/10K
Cross Sensitivity	0.2	% vol		≤±0.2 % vol
dependence on voltage	0.05	% vol/10V		≤±0.1% vol/10V
losses in the line (leak)	0	% value		≤± 2% of value
Uncertainty of calibration gas	1	% value		≤± 2% of value

Effect of drift
0.16 % vol

	ranges min	max	value at calib	
flow	0.4	0.4	0.4	l/min
pressure	102.2	102.3	102.22	kPa
temp	290	294	290	K
Voltage	93	121	110	V

Performance characteristic		**Uncertainty**		**Value of uncertainty quantity**		**% vol**
Standard deviation of repeatability at zero		u_{r0}		for mean		use rep at span
Standard deviation of repeatability at span level		u_{rs}		for mean		0.00
Lack of fit		u_{fit}				0.12
Drift		u_{0dr}				0.09
volume or pressure flow dependence		u_{spres}				0.00
atmospheric pressure dependence		u_{apres}				0.01
ambient temperature dependence		u_{temp}				0.04
Cross Sensitivity		u_{interf}				0.11
Dependence on voltage		u_{volt}				0.04
losses in the line (leak)		u_{leak}				0.00
Uncertainty of calibration gas		u_{cal}				0.07

Measurement uncertainty				
Combined uncertainty			0.21	% vol
Expanded uncertainty	k =	2	0.41	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.41 % vol**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.36 % value**	

SCV 2F Uncertainty Calculations

Uncertainty calculation for Gaseous Measurement NOx EN14792 - PG-250 (AS0450)- SRM Version
v3.6 Feb-15

Limit value	107	mg/m^3 (corrected) NOx	**Cal gas conc**	313.70	mg.m^{-3} (NO_2)
Measured concentration	19.20	mg/m3 (101.3kPa, 273K)	**Full Scale**	513.25	mg/m^3 (NO_2)
Measured concentration	42.43	mg/m^3 (Corrected)			

Gas	NO		
Full Scale	250	ppm	
Cal gas conc	152.8	ppm	
Conversion	2.053		

NO/NO2 ratio	100.00

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.00	101.30	273.00
	measured	12.85	0.00	101.30	273.00
	Uncert	0.38	1.00	0.00	0.00
Factors		2.21	1.00	1.00	1.00
Uncertainty in factor		0.10	0.01	0.00	0.00
Correction Factor		**2.21**	uf	**0.10**	

Effect of drift
0.05 mg/m3

Performance characteristics	**Value**			**specification**
Response time	65	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	61	minutes		
Number of readings in measurement	61			
Repeatability at zero	0.02	% full scale		≤±1 % range
Repeatability at span level	0.02	% full scale		≤±2 % range
Deviation from linearity(lack of fit)	0.47	% full scale		≤±2 % range
Zero drift	0	mg/m3		<5% span value
Span drift	0.82	mg/m3		<5% span value
volume or pressure flow dependence	0.36	% full scale		
atmospheric pressure dependence	-0.16	% full scale /2kPa		≤±3 % range/2kPa
ambient temperature dependence	-2.43	% full scale/10K		≤±3 % range/10K
Cross sensitivity	0.5	% full scale		<4 % range
dependence on voltage	-0.1	% full scale/10V		≤±2% range/10V
losses in the line (leak)	0	% value		≤± 2% of value
Converter efficiency	95.1	%		≥95%
Uncertainty of calibration gas	1	% value		≤± 2% of value

	ranges min	max	value at calib	
flow	0.4	0.4	0.4	l/min
pressure	102.2	102.3	102.22	kPa
temp	290	294	290	K
Voltage	93	121	110	V

Performance characteristic		**Uncertainty**	**Value of uncertainty quantity**		**mg/m3**
Standard deviation of repeatability at zero		u_{r0}		for mean	use rep at span
Standard deviation of repeatability at span level		u_{rs}		for mean	0.01
Lack of fit		u_{lft}			1.39
Drift		u_{0dr}			0.03
volume or pressure flow dependence		u_{spres}			0.00
atmospheric pressure dependence		u_{apres}			-0.02
ambient temperature dependence		u_{temp}			-2.88
Cross sensitivity		u_{interf}			1.48
Dependence on voltage		u_{volt}			-0.44
losses in the line (leak)		u_{leak}			0.00
Uncertainty of calibration gas		u_{cal}			0.11
converter efficiency		u_{conv}			0.54
Uncertainty in factor		uf			1.99

Measurement uncertainty				
Combined uncertainty			3.60	mg/m^3
Expanded uncertainty	k =	2	7.19	mg/m^3
Uncertainty corrected to std conds			**16.39**	**mg/m^3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**16.39 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**38.61 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.72 % ELV**	

Uncertainty calculation for gaseous measurement of CO under BS EN 15058:2017 - AS0450 (PG-250)

v4.2 Sep-17

Limit value	N/A	mg/m^3 (corrected)	**Cal gas conc**	191.50	mg.m^{-3}
Measured concentration	233.01	mg/m3 (101.3kPa, 273K)	**Full Scale**	250.00	mg/m^3
Measured concentration	514.89	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200	ppm
Cal gas conc	153.2	ppm
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.00	101.30	273.00
	measured	12.85	0.00	101.30	273.00
	Uncert	0.38	1.00	0.00	0.00
Factors		2.21	1.00	1.00	1.00
Uncertainty in factor		0.10	0.01	0.00	0.00
Correction Factor		**2.21**	uf	**0.10**	

Effect of drift
6.84 mg/m3

Performance characteristics	**Value**			**specification**
Response time	60	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	61	minutes		
Number of readings in measurement	61			
Repeatability at zero	0.09	% full scale		≤±2 % range
Repeatability at span level	0.08	% full scale		≤±2 % range
Deviation from linearity(lack of fit)	0.71	% full scale		≤±2 % range
Zero drift	3.75	mg/m3		<5% span value
Span drift	2.54	mg/m3		<5% span value
Influence of sample flow	-0.27	% full scale		≤±2 % range
Influence of atmospheric pressure	0.09	% full scale /2kPa		≤±2 % range
Influence of ambient temperature at zero	1.48	% full scale/10K		≤±5 % range
Influence of ambient temperature at span	-1.33	% full scale/10K		≤±5 % range
Cross sensitivity	0.1	% full scale		<4 % range
Influence of voltage	0.33	% full scale/10V		≤±2 % range
Losses in the line (leak)	0	% value		≤± 2% of value
Uncertainty of calibration gas	1	% value		≤± 2% of value

	ranges min	max	value at calib	
flow	0.4	0.4	0.4	l/min
pressure	102.2	102.3	102.22	kPa
spare				
temp	290	294	290	K
Voltage	93	121	110	V

Performance characteristic			**Uncertainty**	**Value of uncertainty quantity**			**mg/m3**
Standard deviation of repeatability at zero			u_{r0}		for mean		0.03
Standard deviation of repeatability at span level			u_{rs}		for mean		0.00
Lack of fit			u_{lit}				1.02
Drift			u_{0dr}				3.95
Influence of sample flow			u_{spres}				0.00
Influence of atmospheric pressure			u_{apres}				0.00
Influence of ambient temperature zero			u_{temp0}				0.85
Influence of ambient temperature span			u_{temps}				0.00
Cross sensitivity			u_{interf}				0.12
Influence of voltage			u_{volt}				0.71
Losses in the line (leak)			u_{leak}				0.00
Uncertainty of calibration gas			u_{cal}				1.35
Uncertainty in factor			uf				24.13

Measurement uncertainty				
Combined uncertainty			4.44	mg/m^3
Expanded uncertainty	k =	2	8.88	mg/m^3
Uncertainty corrected to std conds			**52.10**	**mg/m^3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**52.10 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**10.12 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

Uncertainty calculation for Gaseous Measurement O2 EN14789 - PG-250 AS0450 SRM
v3.0 Feb-15

Limit value	N/A	**Cal gas conc**	14.86 **% vol**
Measured concentration	12.85 **% vol**	**Full Scale**	25.00 **% vol**

Performance characteristics	**Value**			**specification**
Response time	64	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	61	minutes		
Number of readings in measurement	61			
Repeatability at zero	0.01	% range		≤±0.2 % range
Repeatability at span level	0.02	% range		≤±0.4 % range
Deviation from linearity(lack of fit)	0.2	% vol		<0.3 % vol
Zero drift	0.03	% vol		<5% span value
Span drift	0.03	% vol		<5% span value
volume or pressure flow dependence	0.08	% range		<1% range
atmospheric pressure dependence	0.91	% full scale /kPa		≤±1.5 % range/kPa
ambient temperature dependence	0.19	% vol/10K		≤±0.3 % vol/10K
Cross Sensitivity	0.2	% vol		≤±0.2 % vol
dependence on voltage	0.05	% vol/10V		≤±0.1% vol/10V
losses in the line (leak)	0	% value		≤± 2% of value
Uncertainty of calibration gas	1	% value		≤± 2% of value

Effect of drift
0.06 % vol

	ranges min	max	value at calib	
flow	0.4	0.4	0.4	l/min
pressure	102.2	102.3	102.22	kPa
temp	290	294	290	K
Voltage	93	121	110	V

Performance characteristic		**Uncertainty**	**Value of uncertainty quantity**			**% vol**
Standard deviation of repeatability at zero		u_{r0}		for mean		use rep at span
Standard deviation of repeatability at span level		u_{rs}		for mean		0.00
Lack of fit		u_{flt}				0.12
Drift		u_{0dr}				0.03
volume or pressure flow dependence		u_{spres}				0.00
atmospheric pressure dependence		u_{apres}				0.01
ambient temperature dependence		u_{temp}				0.04
Cross Sensitivity		u_{interf}				0.11
Dependence on voltage		u_{volt}				0.04
losses in the line (leak)		u_{leak}				0.00
Uncertainty of calibration gas		u_{cal}				0.07

Measurement uncertainty				
Combined uncertainty			0.19	% vol
Expanded uncertainty	k =	2	0.38	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.38 % vol**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.94 % value**	

2.2.7 - Calculations Used in Reporting Results

Nozzle Selection

For isokinetic sampling, the pressure difference of the orifice meter must equal the pressure difference of the Pitot tube pressure multiplied by the K-factor. Where:

$$K = \text{Constant} \times C_p^{\,2} \times D_n^{\,4} \times DH_@ \times \left(\frac{M_d}{M_s}\right)\left(\frac{1-B_{wm}}{1-B_{ws}}\right)^2\left(\frac{T_m+273}{T_s+273}\right)\left(\frac{P_s}{P_m}\right)$$

$$DH = K \times Dp$$

Where:-

Constant: is a constant dependent on the units used to measure the nozzle (8.038×10^{-5} for mm)

D_n the nozzle diameter mm

$DH_@$ a constant dependent on the sampler control box orifice and gas meter

B_{ws} the percent water vapour in the emission as a fraction i.e.12% = 0.12

B_{wm} the percentage water vapour in the air around the meter box often assumed to be zero

C_p Pitot tube coefficient dependent on the Pitot tube type

T_m the meter temperature in °C

T_s the stack temperature in °C

P_s the stack pressure

P_m the meter pressure

M_d dry gas molecular weight

M_s apparent stack gas molecular weight

DH pressure drop across the orifice (mm water)

DP differential Pitot pressure (mm water)

From this the correct nozzle size can be determined.

$$D_n = \sqrt{\left(\frac{\text{Constant}.Q_m.P_m}{(T_m+273)C_p}\right)\left(\frac{1-B_{wm}}{1-B_{ws}}\right)\sqrt{\frac{(T_s+273)M_s}{(P_s.(\Delta P)_{avg})}}}$$

Where the Constant = 0.6071 Metric

Qm = Orifice flow rate normally 21.2 actual $lmin^{-1}$

$$= K_m\sqrt{\frac{(T_m+273)\Delta H}{P_m M_m}}$$

Where Km =Orifice meter coefficient

$$Km = Qm\sqrt{\frac{P_m M_m}{\Delta H(T_m+273)}} = Const\sqrt{\frac{1}{\Delta H_@}}$$

Where Const = 183.7 metric

Moisture Determination Calculations

These calculations are based at 273K and 101.325kPa

To calculate moisture the following equation is used:

$$B_{ws} = \frac{0.001245 \times W_I \times 100}{(0.001245 \times W_I) + 0.359V_m \left(\frac{P_b + \frac{\Delta H_{avg}}{13.6}}{(T_m + 273)} \right)}$$

Particulate Concentration C_s in stack Gases
At 273K and 101.325kPa and dry gas

$$C_s = \frac{W_t}{V_m} \times \frac{T_m + 273}{273} \times \frac{760}{\left(P_b + \frac{\Delta H_{avg}}{13.6} \right)} \times 1000 \quad mg/Nm^3$$

Oxygen Concentration Correction C_{oxy} to Particulate concentration

$$C_{oxy} = C \times \frac{(20.9 - \%O_2 ref)}{(20.9 - \%O_2 Meas)} \quad mg/Nm^3$$

Dry Molecular Weight of gases

$M_D = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%CO + \%N)$

Stack Molecular Weight of gases

$$M_s = 0.18(B_{ws}) + \frac{M_d}{100}(100 - B_{ws})$$

Stack Gas Velocity

$$(V_s)_{avg} = 34.96 \times C_p \times \sqrt{(\Delta P)_{avg}} \sqrt{\frac{T_s + 273}{P_s M_s}} \quad m/s$$

Mass Emission Rate M_R

$$M_R = \frac{C_m \times (V_s)_{avg} \times A \times 3600}{10^6} \quad kg/hr$$

IsoKinicity

$$I = \frac{2.12 \times 10^{8} \times Vm \times Y \times \left(P_b + \left(\frac{\Delta H_{avg}}{13.6} \right) \right) \left(\frac{273 + T_s}{273 + T_m} \right)}{\Theta P_s \pi D_n^2 (Vs)avg \ (100 - B_{ws})} \ \%$$

W_I = the weight change of the impingers during sampling in g
V_m = volume of dry gas sample in litres at temperature of the meter box
B_{ws} = the percent water vapour in the emission
Q = length of time sampling in minutes
Y = Gas Meter Calibration correction factor
Vs = Velocity of stack gas m/s
C_M = measured concentration of particulate matter (mg/m^3)
T_m = average temperature at dry gas meter (^oC)
P_b = atmospheric pressure (mmHg)
$\%O_{2ref}$ = % oxygen at standard temperature & pressure
$\%O_{2Meas}$ = % oxygen measured on site
C_P = Pitot tube coefficient
DP = mean differential Pitot pressure drop (mm H_2O)
DH = mean orifice pressure drop (mm H_2O)
D_s = diameter of stack (m)
D_n = Nozzle diameter (mm)
T_s = stack temperature (^oC)
M_d = molecular weight of dry stack gas
B_W = moisture fraction
P_s = stack pressure (mmHg)
A = duct c.s.a. (m^2)
M_s = molecular weight of wet stack gas
M_d = molecular weight of dry stack gas
W_t = total weight of particulate matter (g)