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

Test Report

UKAS TESTING
0002

mCERTS

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:	**9th - 11th March 2020**
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:	**9th April 2020**
Report Author:	**Matthew Ellison**

Reference: XP3538LD/INTERTEK/SHLNG/MAR2020/SCV/PPC/Q1/V1

Report Approver: Kevin Blakley
MCERTS Registration: MM-03-317
Level & TEs Held: Level 2, TE1, TE2, TE3 & TE4
Signature: K C Blakley

NPL Authorised Signatory
Name: Mr R Robinson (for NPLML)
Signature: PP (C. DIMOPOULOS)

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. Two 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 9th and 11th March 2020. The report documents the results obtained.

1.2.1 SCV H (Phase One) Monitoring Results

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

Field	Units	Oxides of Nitrogen (as NO_2)	Carbon Monoxide	Oxygen	Moisture	Stack Flow
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	52.3	432	12.2	1.5	5.1
Uncertainty (95% Confidence Level)	**Reference Conditions**	5.8	38.0	0.4	N/A	1.1
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol	m^3/s
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis				
Date	**dd/mm/yyyy**	11/03/2020				
Sample Period	**From hh:mm**	12:00				
	To hh:mm	13:00				
Monitoring Method		BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017	BS EN ISO 16911-1:2013
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	115				
Process Status	**Burner Demand (%)**	31				

1.2.2 SCV G (Phase Two) Monitoring Results

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

Field	Units	Oxides of Nitrogen (as NO_2)	Carbon Monoxide	Oxygen	Moisture	Stack Flow
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	53.4	523	11.6	1.4	5.6
Uncertainty (95% Confidence Level)	**Reference Conditions**	5.9	45.5	0.4	N/A	1.1
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol	m^3/s
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis				
Date	**dd/mm/yyyy**	09/03/2020				
Sample Period	**From hh:mm**	13:00				
	To hh:mm	14:00				
Monitoring Method		BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017	BS EN ISO 16911-1:2013
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	160				
Process Status	**Burner Demand (%)**	52.4				

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 15259. 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="3">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 1H</td><td colspan="2">115</td><td>31.0</td></tr>
<tr><td colspan="2">SCV 2G</td><td colspan="2">160</td><td>52.4</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 1H</td><td>Oxides of Nitrogen</td><td>48.7</td><td>52.3</td><td>mg/Nm^3</td></tr>
<tr><td>SCV 1H</td><td>Oxygen</td><td>11.5</td><td>12.2</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 week. Two 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. Environment Agency - Manual Stack emission monitoring performance standard for Organisations.

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

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

5. 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	Apr-2023	Sep-2023	Sep-2023	Dec-2023	Sep-2023
Jonny Guy	Technician	MM-16-1388	Apr-2022	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 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017	BS EN ISO 16911-1:2013	BS EN ISO 16911-1:2013
Instrument	Horiba PG-250	Horiba PG-250	Horiba PG-250	N/A	S-Type Pitot	Type K Thermocouple
Instrument Serial No.	AS0208	AS0208	AS0208	N/A	AS0640	AS0640
Principle	Chemiluminescence	NDIR	Zirconia	Saturation chart	Flow	Temperature
Operational Range	0 - 100 ppm	0 - 200 ppm	0 - 25%	N/A	0 - 240mm H_2O	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%	10%	1%
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	183642SG	154.9 ppm	1%
Nitrogen Oxide		183642SG	79.4 ppm	1%
Oxygen		158247SG	15.13%	1%

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

The ranges of the Horiba PG-250 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	154.9 ppm
Oxides of Nitrogen (as NO_2)	0 - 100 ppm	79.4 ppm
Oxygen	0 - 25%	15.13%

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 INTK48MAR20/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:

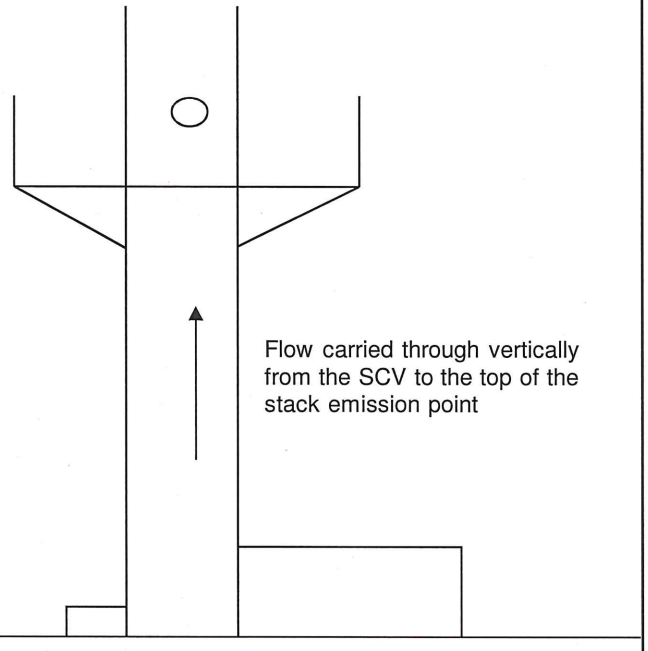
P:\Stack Emissions Team\South Hook LNG - Intertek\INTK48MAR20\7. Monitoring Record Sheets

APPENDIX TWO

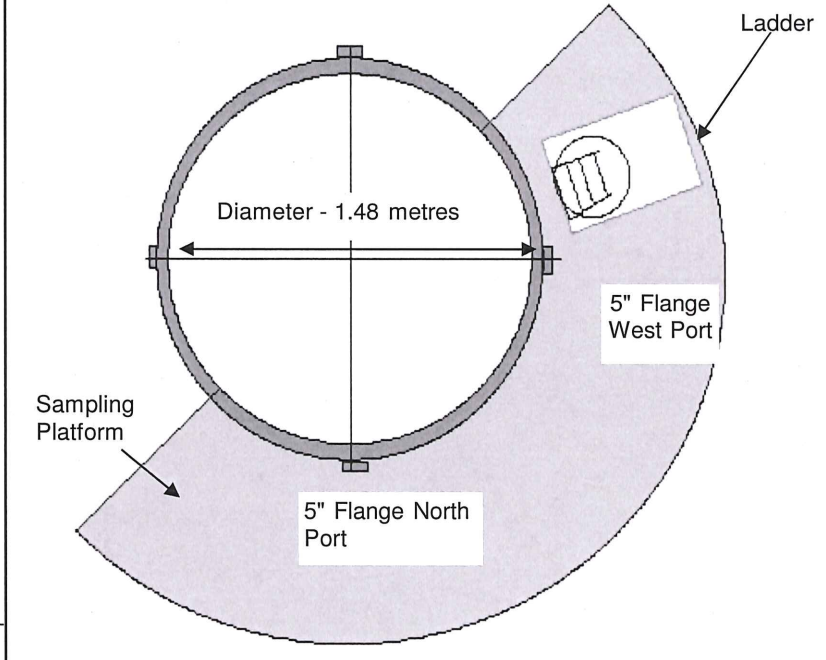
2.2.1 - Stack Diagram

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



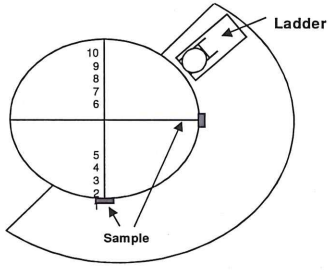
Position	1	2	3	4	5	6
% of Diameter	4.1	14.9	29.7	70.3	85.1	95.9
Insertion, m	0.06	0.22	0.44	1.04	1.26	1.42

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 10 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:	SCV1H
Date	11/03/2020	Site Team:	MRE/JG	Time of Survey:	10:35
Tape Measure ID	AS0589				
Laser Measurement Device ID	N/A				
Traverse Pitot Type	S-Type				
Traverse Pitot Tube ID	AS0687				
Pitot Assembly Visual Inspection (Pre)	Pass				
Pre Test Leak Check <2.5 mm H2O	Pass				
Traverse Manometer Type	Digital				
Traverse Manometer ID	AS0640				
Traverse Manometer Range	240				
Traverse Temp. Readout ID	AS0786				
Traverse Thermocouple ID	AS0451a				
Static Pressure	Δp (mmH20)				
	12.20				
	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	752.19	mmHg
Ref O_2 Value	3	%
Moisture Content	1.54	%
CO	165	ppm
CO_2	5.1	%
N_2	82.68	%
O_2	12.20	%
Dry Molecular wt	29.30	
Stack Molecular wt	29.13	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1001.4	mbar
Pbar	751	mmHg
Pitot tube coeft	0.84	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature	9	°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	12.20	12.60
Duct Diameter (m)	1.48		B	12.00	12.00
Duct Depth (m)			C		
Duct Width (m)			D		

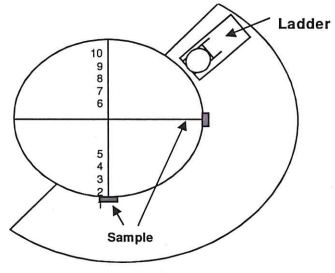
Post-Test Blockage Test (L	Traverse Point	Δp Reading ($mm H_2O$)	Δp Reading ($mm H_2O$)	Δp Reading ($mm H_2O$)	Δp Average ($mm H_2O$)
Reading 1					
Reading 2					

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	3.18	3.18	3.18	3.18	31.19	13.5	5.98	6	1.78
2	1.26	3.27	3.27	3.27	3.27	32.09	13.5	6.06	6	1.81
3	1.04	3.50	3.50	3.50	3.50	34.29	13.5	6.27	6	1.87
4	0.44	4.24	4.24	4.24	4.24	41.58	13.6	6.90	6	2.06
5	0.22	4.57	4.57	4.57	4.57	44.78	13.6	7.16	7	2.14
6	0.06	4.50	4.50	4.50	4.50	44.08	13.7	7.11	7	2.12
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	2.89	2.89	2.89	2.89	28.29	13.5	5.69	8	1.70
2	1.26	3.40	3.40	3.40	3.40	33.29	13.6	6.18	6	1.84
3	1.04	3.89	3.89	3.89	3.89	38.09	13.6	6.61	5	1.97
4	0.44	4.12	4.12	4.12	4.12	40.38	13.6	6.80	6	2.03
5	0.22	4.57	4.57	4.57	4.57	44.78	13.7	7.16	6	2.14
6	0.06	4.72	4.72	4.72	4.72	46.28	13.8	7.28	7	2.17
Average values		**3.9**	**3.9**	**3.9**	**3.9**	**38.3**	**13.6**	**6.6**	**6.3**	**2.0**

Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	6.60	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	5.12	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	11.35	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	11.17	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	10.70	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	5.20	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	1.3 :1
Any local negative flow?	NO
Flow <15° of duct axis?	YES
Minimum Δp detected > 0.5 mmH2O	YES

Monitoring Objective	Traverse	Site:	South Hook LNG	Stack ID:	SCV2G
Date	09/03/2020	Site Team:	MRE/JG	Time of Survey:	12:00
Tape Measure ID	AS0589	Diagram of Sample Location:			
Laser Measurement Device ID	N/A				
Traverse Pitot Type	S-Type				
Traverse Pitot Tube ID	AS0687				
Pitot Assembly Visual Inspection (Pre)	Pass				
Pre Test Leak Check <2.5 mm H2O	Pass				
Traverse Manometer Type	Digital				
Traverse Manometer ID	AS0640				
Traverse Manometer Range	240				
Traverse Temp. Readout ID	AS0786				
Traverse Thermocouple ID	AS0451a				
Static Pressure	Δp (mmH20)				
	18.15				
	Pass	Comments/Deviations:			
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				



Conditions	Value	Units
Stack pressure	753.01	mmHg
Ref O_2 Value	3	%
Moisture Content	1.42	%
CO	200	ppm
CO_2	5.4	%
N_2	82.98	%
O_2	11.60	%
Dry Molecular wt	29.33	
Stack Molecular wt	29.17	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1001.9	mbar
Pbar	752	mmHg
Pitot tube coeft	0.84	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature	11	°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	18.20	18.00
Duct Diameter (m)	1.48		B	18.20	18.20
Duct Depth (m)			C		
Duct Width (m)			D		

Post-Test Blockage Test (L-Type only)	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	3.23	3.23	3.23	3.23	31.7	12.4	6.01	7	1.80
2	1.26	3.84	3.84	3.84	3.84	37.7	12.3	6.55	7	1.96
3	1.04	4.00	4.00	4.00	4.00	39.2	12.3	6.68	7	2.00
4	0.44	4.48	4.48	4.48	4.48	43.9	12.2	7.07	6	2.12
5	0.22	4.57	4.57	4.57	4.57	44.8	12.4	7.14	6	2.14
6	0.06	4.86	4.86	4.86	4.86	47.7	12.5	7.37	6	2.21
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	3.23	3.23	3.23	3.23	31.7	11.9	6.00	5	1.80
2	1.26	3.32	3.32	3.32	3.32	32.6	12.1	6.09	6	1.82
3	1.04	3.60	3.60	3.60	3.60	35.3	12.1	6.33	6	1.90
4	0.44	4.56	4.56	4.56	4.56	44.7	12.2	7.13	5	2.13
5	0.22	4.67	4.67	4.67	4.67	45.8	11.9	7.21	6	2.16
6	0.06	4.77	4.77	4.77	4.77	46.8	12.0	7.29	7	2.18
Average values		**4.1**	**4.1**	**4.1**	**4.1**	**40.1**	**12.2**	**6.7**	**6.2**	**2.0**

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	6.74	ms^{-1}	Is the Flow Ratio 3:1 or less?	1.2 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	5.63	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	11.59	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	11.42	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	10.99	m^3s^{-1}	Minimum Δp detected > 0.5 mmH2O	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	5.71	m^3s^{-1}		

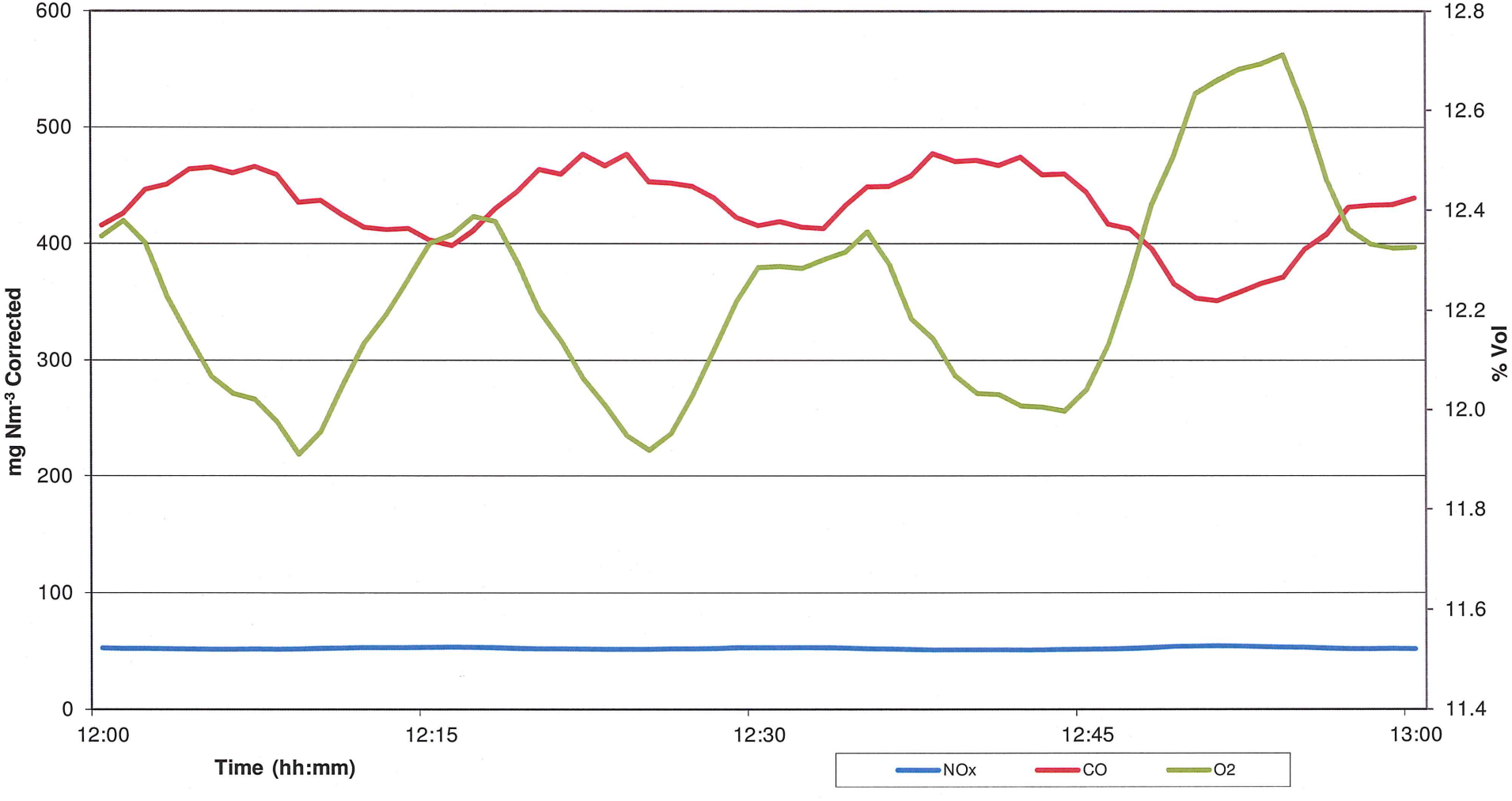
2.2.3 - One Minute Averaged Gaseous Emissions Data

Minute Averaged Gaseous Data from South Hook LNG 11th March 2020 SCV H - 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 (%)**
12:00	415	52.7	12.3
12:01	426	52.3	12.4
12:02	447	52.2	12.3
12:03	451	51.9	12.2
12:04	464	51.9	12.1
12:05	466	51.6	12.1
12:06	461	51.6	12.0
12:07	466	51.7	12.0
12:08	459	51.5	12.0
12:09	436	51.7	11.9
12:10	437	52.5	12.0
12:11	425	52.6	12.0
12:12	414	53.0	12.1
12:13	412	53.2	12.2
12:14	413	53.2	12.3
12:15	403	53.2	12.3
12:16	398	53.5	12.4
12:17	411	53.3	12.4
12:18	430	52.8	12.4
12:19	445	52.4	12.3
12:20	464	52.1	12.2
12:21	460	52.0	12.1
12:22	477	51.7	12.1
12:23	467	51.6	12.0
12:24	477	51.5	11.9
12:25	453	51.6	11.9
12:26	452	51.9	12.0
12:27	449	51.9	12.0
12:28	439	52.3	12.1
12:29	423	52.9	12.2
12:30	415	52.9	12.3
12:31	419	52.8	12.3
12:32	414	53.1	12.3
12:33	413	52.8	12.3
12:34	433	52.7	12.3
12:35	449	52.1	12.4
12:36	449	51.7	12.3
12:37	458	51.4	12.2
12:38	477	51.2	12.1
12:39	471	51.1	12.1
12:40	471	51.1	12.0
12:41	467	51.1	12.0
12:42	474	50.9	12.0
12:43	459	51.1	12.0
12:44	460	51.3	12.0
12:45	444	51.6	12.0
12:46	417	51.8	12.1
12:47	412	52.4	12.3
12:48	395	52.9	12.4
12:49	366	53.9	12.5
12:50	354	54.2	12.6
12:51	351	54.4	12.7
12:52	359	54.1	12.7
12:53	366	53.7	12.7
12:54	371	53.3	12.7
12:55	395	53.0	12.6
12:56	408	52.5	12.5
12:57	431	51.8	12.4
12:58	433	51.8	12.3
12:59	433	52.0	12.3
13:00	439	51.8	12.3
Min Value	**351**	**50.9**	**11.9**
Max Value	**477**	**54.4**	**12.7**
Average	**432**	**52.3**	**12.2**

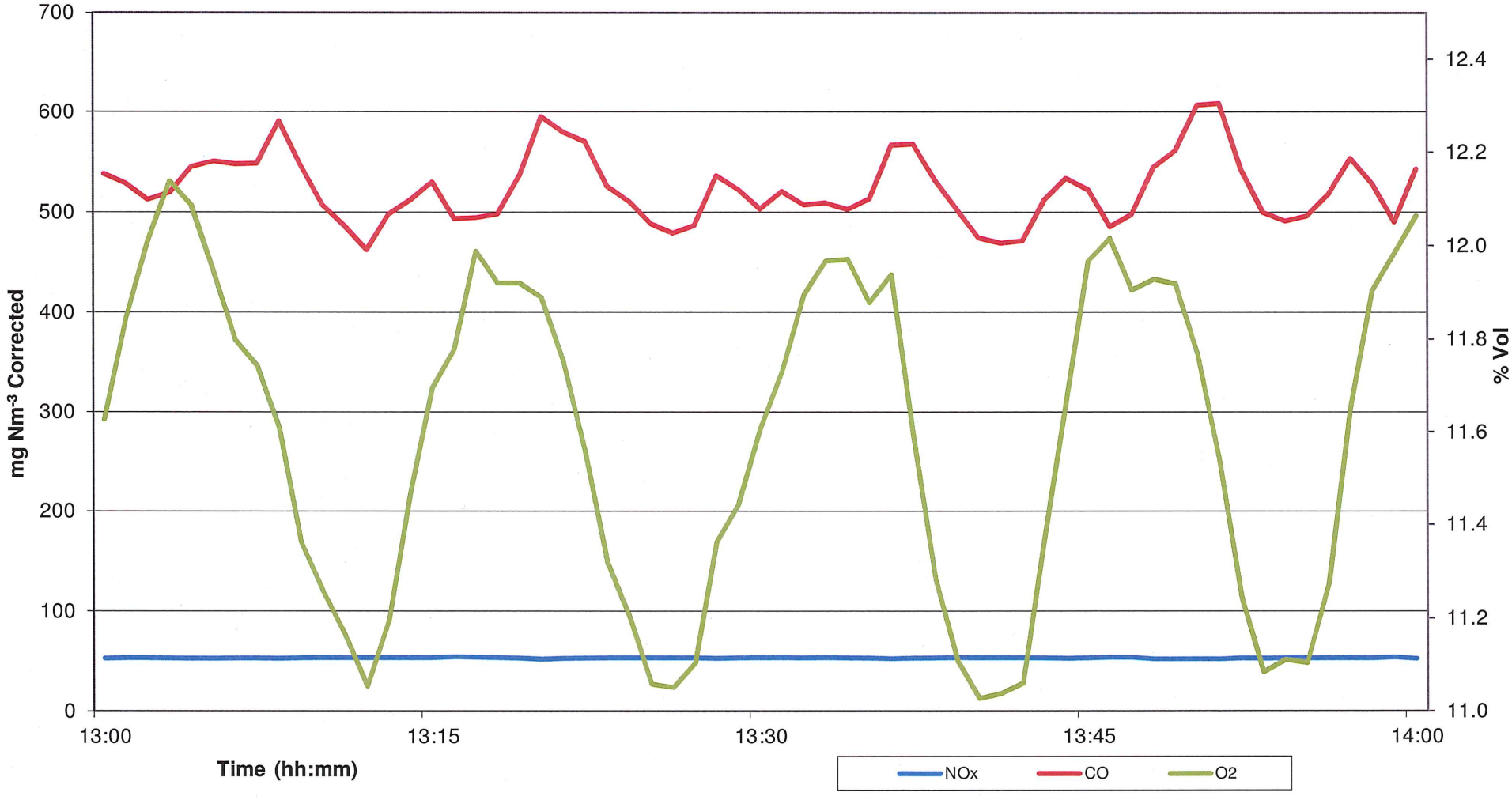
Minute Averaged Gaseous Data from South Hook LNG 9th March 2020 SCV G - Phase Two Referenced to 273K, 101.3kPa and 3% Oxygen on a Dry Basis			
Time (hh:mm)	**Carbon Monoxide (mg/Nm^3)**	**Oxides of Nitrogen (mg/Nm^3)**	**Oxygen (%)**
13:00	538	53.0	11.6
13:01	529	53.6	11.8
13:02	512	53.6	12.0
13:03	520	53.4	12.1
13:04	546	52.9	12.1
13:05	551	52.9	11.9
13:06	548	53.3	11.8
13:07	549	53.2	11.7
13:08	591	52.9	11.6
13:09	546	53.5	11.4
13:10	507	53.7	11.3
13:11	486	53.8	11.2
13:12	462	53.8	11.1
13:13	497	53.8	11.2
13:14	512	53.8	11.5
13:15	530	53.8	11.7
13:16	493	54.6	11.8
13:17	494	54.1	12.0
13:18	498	53.8	11.9
13:19	537	53.2	11.9
13:20	595	52.4	11.9
13:21	580	53.1	11.8
13:22	570	53.2	11.6
13:23	526	53.5	11.3
13:24	511	53.6	11.2
13:25	488	53.6	11.1
13:26	479	53.5	11.1
13:27	487	53.5	11.1
13:28	536	53.1	11.4
13:29	523	53.6	11.4
13:30	503	53.9	11.6
13:31	521	53.7	11.7
13:32	507	53.6	11.9
13:33	509	53.8	12.0
13:34	503	53.5	12.0
13:35	513	53.3	11.9
13:36	567	52.9	11.9
13:37	568	53.3	11.6
13:38	532	53.6	11.3
13:39	503	53.8	11.1
13:40	474	53.6	11.0
13:41	469	53.5	11.0
13:42	471	53.6	11.1
13:43	512	53.5	11.4
13:44	534	53.1	11.7
13:45	522	53.6	12.0
13:46	486	54.1	12.0
13:47	498	53.9	11.9
13:48	545	52.3	11.9
13:49	561	52.6	11.9
13:50	607	52.4	11.8
13:51	609	52.6	11.5
13:52	542	53.2	11.2
13:53	500	53.1	11.1
13:54	491	53.4	11.1
13:55	496	53.3	11.1
13:56	518	53.4	11.3
13:57	554	53.2	11.7
13:58	528	53.4	11.9
13:59	490	54.0	12.0
14:00	543	52.8	12.1
Min Value	**462**	**52.3**	**11.0**
Max Value	**609**	**54.6**	**12.1**
Average	**523**	**53.4**	**11.6**

2.2.4 - Gaseous Emissions Graphical Data

SCV 1H One Minute Averaged Gaseous Emissions Data - 11th March 2020
(273.15K, 101.325kPa, 3% O_2, on a Dry Gas basis) using the NPL Conventional Analysis Package



SCV 2G One Minute Averaged Gaseous Emissions Data - 9th March 2020
(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:	09/03/2020									
Site:	South Hook LNG	Job Number:	INTK48MAR20	CBISS auto ranges	0-26	0-200	0-60	0-200	0-100	0-250 (only NOx)	0-15	
Stack ID:	SCVs	Initial N_2 pressure bar:	180		0-700		0-400			0-400 (only NO)		
Reference oxygen %	3	Leak check method	Flow 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:			183642SG	183642SG		158247SG	158247SG		
Analyser type / Analyser ID			PG250 AS0208	PG250 AS0208		PG250 AS0208	PG250 AS0208		
Cylinder Concentration:		ppm	154.9 ppm	79.4 ppm	ppm	15.13 % Vol	15.21 % Vol	ppm C_3H_8	ppm
Span Value:		ppm	154.9 ppm	79.4 ppm	ppm	15.13 % Vol	15.21 % Vol	ppm C_3H_8	ppm
Analyser Range: 0 -		ppm	200 ppm	100 ppm	ppm	25 % Vol	20 % Vol	ppm C_3H_8	ppm
Check Zero	Time		12:22						
	Reading	ppm	-1.9 ppm	0.0 ppm	ppm	-0.07 % Vol	-0.01 % Vol	ppm C_3H_8	ppm
	Initial Gain		0	0		-8	-2		
Adjust Zero	Time		12:23						
	Reading	ppm	0.0 ppm	0.0 ppm	ppm	0.00 % Vol	0.00 % Vol	ppm C_3H_8	ppm
	Final Gain		-1	0		-9	-3		
Check Span	Time		12:33	12:33		12:28	12:28		
	Reading	ppm	157.7 ppm	81.6 ppm	ppm	15.29 % Vol	15.87 % Vol	ppm C_3H_8	ppm
	Initial Gain		1.425	1.129		1.003	0.982		
Adjust Span	Time		12:35	12:35		12:29	12:29		
	Reading	ppm	154.9 ppm	79.4 ppm	ppm	15.13 % Vol	15.21 % Vol	ppm C_3H_8	ppm
	Final Gain		1.405	1.095		0.993	0.962		
Check Zero	Time		12:38						
	Reading	ppm	0.6 ppm	0.4 ppm	ppm	-0.02 % Vol	0.02 % Vol	ppm C_3H_8	ppm
Zero Drift		0.0 ppm	0.6 ppm	0.4 ppm	0.0 ppm	-0.02 % 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

		SO_2	CO	NO	NOx	O_2			
Expected Flow:		l/min	0.40 l/min	0.40 l/min	l/min	0.40 l/min			
Leak check	Time		12:40	12:40		12:40			
	Reading	l/min	0.0 l/min	0.0 l/min	l/min	0.0 l/min			
	Pass/fail	PASS	PASS	PASS	PASS	PASS			

GAS CALIBRATION LOG - DRIFT CHECK

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Span Value:		0.0 ppm	154.9 ppm	79.4 ppm	0.0 ppm	15.13 % Vol	15.21 % Vol	0.0 ppm C_3H_8	0.0 ppm
Check Zero	Time		14:28						
	Reading	ppm	1.5 ppm	0.1 ppm	ppm	-0.02 % Vol	0.03 % Vol	ppm C_3H_8	ppm
Check Span	Time		14:38	14:38		14:33	14:33		
	Reading	ppm	151.9 ppm	80.6 ppm	ppm	15.07 % Vol	14.81 % Vol	ppm C_3H_8	ppm
Zero Drift (%)			1.0	0.1		0.1	0.2		
Span Drift (%)			1.9	1.5		0.4	2.6		
Acceptance zero			Accept	Accept		Accept	Accept		
Acceptance span			Accept	Accept		Accept	Correct for drift		

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/JG

GAS CALIBRATION MEASUREMENTS

Client:	Intertek Ltd	Date:	11/03/2020		SO_2 (ppm)		CO (ppm)		NO\NOx (ppm)		N_2O (ppm)	
Site:	South Hook LNG	Job Number:	INTK48MAR20	CBISS auto ranges	0-26	0-200	0-60	0-200	0-100	0-250 (only NOx)	0-15	
Stack ID:	SCVs	Initial N_2 pressure bar:	180		0-700		0-400			0-400 (only NO)		
Reference oxygen %	3	Leak check method	Flow 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:			183642SG	183642SG		158247SG	158247SG		
Analyser type / Analyser ID			PG250 AS0208	PG250 AS0208		PG250 AS0208	PG250 AS0208		
Cylinder Concentration:		ppm	154.9 ppm	79.4 ppm	ppm	15.13 % Vol	15.21 % Vol	ppm C_3H_8	ppm
Span Value:		ppm	154.9 ppm	79.4 ppm	ppm	15.13 % Vol	15.21 % Vol	ppm C_3H_8	ppm
Analyser Range: 0 -		ppm	200 ppm	100 ppm	ppm	25 % Vol	20 % Vol	ppm C_3H_8	ppm
Check Zero	Time		11:03						
	Reading	ppm	1.1 ppm	0.0 ppm	ppm	-0.13 % Vol	0.00 % Vol	ppm C_3H_8	ppm
	Initial Gain		-1	0		-9	-3		
Adjust Zero	Time		11:04						
	Reading	ppm	0.0 ppm	0.0 ppm	0.0 ppm	0.00 % Vol	0.00 % Vol	ppm C_3H_8	ppm
	Final Gain		0	0		-12	-3		
Check Span	Time		11:10	11:10		11:16	11:16		
	Reading	ppm	149.3 ppm	78.2 ppm	ppm	15.08 % Vol	14.96 % Vol	ppm C_3H_8	ppm
	Initial Gain		1.405	1.095		0.993	0.962		
Adjust Span	Time		11:12	11:12		11:17	11:17		
	Reading	ppm	154.9 ppm	79.4 ppm	ppm	15.13 % Vol	15.21 % Vol	ppm C_3H_8	ppm
	Final Gain		1.455	1.110		0.996	0.970		
Check Zero	Time		11:20						
	Reading	ppm	0.1 ppm	0.1 ppm	ppm	0.03 % Vol	0.05 % Vol	ppm C_3H_8	ppm
Zero Drift		0.0 ppm	0.1 ppm	0.1 ppm	0.0 ppm	0.03 % 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

		SO_2	CO	NO	NOx	O_2			
Expected Flow:		l/min	0.40 l/min	0.40 l/min	l/min	0.40 l/min			
Leak check	Time		11:39	11:39		11:39			
	Reading	l/min	0.0 l/min	0.0 l/min	l/min	0.0 l/min			
	Pass/fail	PASS	PASS	PASS	PASS	PASS			

GAS CALIBRATION LOG - DRIFT CHECK

		SO_2	CO	NO	NOx	O_2	CO_2	VOCs	N_2O
Span Value:		0.0 ppm	154.9 ppm	79.4 ppm	0.0 ppm	15.13 % Vol	15.21 % Vol	0.0 ppm C_3H_8	0.0 ppm
Check Zero	Time		13:20						
	Reading	ppm	-0.1 ppm	0.1 ppm	ppm	0.03 % Vol	0.03 % Vol	ppm C_3H_8	ppm
Check Span	Time		13:25	13:25		13:31	13:31		
	Reading	ppm	152.5 ppm	82.3 ppm	ppm	15.16 % Vol	14.90 % Vol	ppm C_3H_8	ppm
Zero Drift (%)			0.1	0.1		0.2	0.2		
Span Drift (%)			1.5	3.7		0.2	2.0		
Acceptance zero			Accept	Accept		Accept	Accept		
Acceptance span			Accept	Correct for drift		Accept	Correct for drift		

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/JG

2.2.6 - Uncertainty Calculations

SCV 1H Uncertainty Calculations

Uncertainty calculation for gaseous measurement of NOx BS EN 14792:2017 - PG-250 AS0208

v3.7 Sep-19

Limit value	107	mg/m³ (corrected)	**Cal gas conc**	163.01	mg.m⁻³
Measured concentration	25.94	mg/m3 (101.3kPa, 273K)	**Full Scale**	205.30	mg/m³
Measured concentration	53.26	mg/m³ (Corrected)			
			Gas	NO	
NO/NO2 ratio	100.00		**Full Scale**	100	ppm
			Cal gas conc	79.4	ppm
			Conversion	2.05	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.00	101.30	273.00
	measured	12.23	0.00	101.30	273.00
	Uncert	0.37	1.00	0.00	0.00
Factors		2.05	1.00	1.00	1.00
Uncertainty in factor		0.09	0.01	0.00	0.00
Correction Factor		**2.05**	uf	**0.09**	

Performance characteristics		**Value**			**specification**
Response time		70	seconds		≤200
Logger sampling interval		60	seconds		
Measurement period		60	minutes		
Number of readings in measurement		60			
Standard deviation of repeatability at zero		0.03	% full scale		≤±2% range
Standard deviation of repeatability at span level		0.15	% full scale		≤±2% range
Standard deviation of reproducibility		0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)		0.35	% full scale		≤±2 % range
Zero drift		0.21	mg/m3		<5% span value
Span drift		0	mg/m3		<5% span value
Influence of sample gas flow		2	% full scale/10l		≤±2% range
Influence of atmospheric pressure		2	% full scale /3kPa		≤±2% range
Influence of ambient temperature		0.18	% full scale/20K		≤±5% range
CO (mg/m3)	300	0.4	mg/m3		≤±4% range (Total)
HCl (mg/m3)	50	1.1	mg/m3		
SO2 (mg/m3)	1000	0.5	% vol		
N2O (mg/m3)	20	0.8	mg/m3		
Influence of voltage		0	% full scale/10V		≤±2% range/10V
Influence from vibration		0	% full scale		≤±2% range
Losses in the line (leak)		0	% value		≤± 5% of value
Converter efficiency		95.5	%		≥95%
Uncertainty of calibration gas		1	% value		≤± 2% of value

	ranges min	max	value at calib	
flow	0.40	0.4	0.4	l/min
pressure	101.4	101.5	101.4	kPa
temp	281.4	283.2	281.4	K
CO range	100	300	0	mg/m3
HCl range	0	0	0	mg/m3
SO2 range	0	5	0	mg/m3
N2O range	0	2	0	mg/m3
Voltage	110	110	110	V

Effect of drift
0.21 mg/m3

Performance characteristic			**Uncertainty**				**mg/m3**
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.04
Standard deviation of reproducibility			u_{rp}				0.00
Lack of fit			u_{lft}				0.41
Drift			u_{0dr}				0.12
Influence of sample gas flow			u_{spres}				0.00
Influence of atmospheric pressure			u_{apres}				0.08
Influence of ambient temperature			u_{temp}				0.02
CO (mg/m3)			u_{interf}				0.28
HCl (mg/m3)			u_{interf}				0.00
SO2 (mg/m3)			u_{interf}				0.00
N2O (mg/m3)			u_{interf}				0.05
Influence of voltage			u_{volt}				0.00
Influence from vibration			u_{vib}				0.00
Losses in the line (leak)			u_{leak}				0.00
Converter efficiency			u_{conv}				0.67
Uncertainty of calibration gas			u_{cal}				0.13
Uncertainty in factor			uf				2.26

Use largest of sum of all positive or all negative influences

0.33	all +ves
0.00	all -ves
0.33	largest

Criteria
sum <4% range
0.16 %

Value to use for interference uncertainty
u_{int} 0.33

Measurement uncertainty				
Combined uncertainty			0.88	mg/m³
Expanded uncertainty	k =	2	1.76	mg/m³
Uncertainty corrected to std conds			**5.79**	**mg/m³**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**5.79 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**10.87 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**1.65 % ELV**	

Uncertainty calculation for gaseous measurement of CO BS EN 15058:2017 - PG-250 AS0208

v4.3 Sep-18

Limit value	None	mg/m³ (corrected)	**Cal gas conc**	193.63	mg.m⁻³
Measured concentration	210.40	mg/m3 (101.3kPa, 273K)	**Full Scale**	250.00	mg/m³
Measured concentration	431.90	mg/m³ (Corrected)			

Gas	CO	
Full Scale	200	ppm
Cal gas conc	154.9	ppm
Conversion	1.25	

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.00	101.30	273.00
	measured	12.23	0.00	101.30	273.00
	Uncert	0.37	1.00	0.00	0.00
Factors		2.05	1.00	1.00	1.00
Uncertainty in factor		0.09	0.01	0.00	0.00
Correction Factor		**2.05**	uf	**0.09**	

Performance characteristics		**Value**			**specification**
Response time		60	seconds		≤200
Logger sampling interval		60	seconds		
Measurement period		60	minutes		
Number of readings in measurement		60			
Standard deviation of repeatability at zero		0.04	% full scale		≤±2% range
Standard deviation of repeatability at span level		0.1	% full scale		≤±2% range
Standard deviation of reproducibility		0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)		0.2	% full scale		≤±2 % range
Zero drift		0.13	mg/m3		<5% span value
Span drift		3.21	mg/m3		<5% span value
Influence of sample gas flow		2	% full scale/10l		≤±2% range
Influence of atmospheric pressure		2	% full scale /3kPa		≤±2% range
Influence of ambient temperature		0.05	% full scale/20K		≤±5% range
NO2 (mg/m3)	30	0.5	mg/m3		≤±4% range (Total)
N2O (mg/m3)	20	1.0	mg/m3		
CO2 (% vol)	15	0.5	% vol		
SO2 (mg/m3)	200	-1.3	mg/m3		
Influence of voltage		0	% full scale/10V		≤±2% range/10V
Influence from vibration		0	% full scale		≤±2% range
Losses in the line (leak)		0	% value		≤± 5% of value
Uncertainty of calibration gas		1	% value		≤± 2% of value

	ranges min	max	value at calib	
flow	0.40	0.4	0.4	l/min
pressure	101.4	101.5	101.4	kPa
temp	281.4	283.2	281.4	K
NO2 range	0	4	0	mg/m3
N2O range	0	2	0	mg/m3
CO2 range	10	15	0	% vol
SO2 range	0	5	0	mg/m3
Voltage	110	110	110	V

Effect of drift: 3.63 mg/m3

Performance characteristic			**Uncertainty**	**Value of uncertainty quantity**			**mg/m3**
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.03
Standard deviation of reproducibility			u_{rp}				0.00
Lack of fit			u_{lit}				0.29
Drift			u_{0dr}				2.09
Influence of sample gas flow			u_{spres}				0.00
Influence of atmospheric pressure			u_{apres}				0.10
Influence of ambient temperature			u_{temp}				0.01
NO2 (mg/m3)			u_{interf}				0.04
N2O (mg/m3)			u_{interf}				0.06
CO2 (% vol)			u_{interf}				0.42
SO2 (mg/m3)			u_{interf}				-0.02
Influence of voltage			u_{volt}				0.00
Influence from vibration			u_{vib}				0.00
Losses in the line (leak)			u_{leak}				0.00
Uncertainty of calibration gas			u_{cal}				1.05
Uncertainty in factor			uf				18.34

Use largest of sum of all positive or all negative influences

0.52	all +ves	Criteria
0.02	all -ves	sum <4% range
0.52	largest	0.21 %

Value to use for interference uncertainty: u_{int} 0.52

Measurement uncertainty				
Combined uncertainty			2.42	mg/m³
Expanded uncertainty	k =	2	4.84	mg/m³
Uncertainty corrected to std conds			**37.99**	**mg/m³**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**37.99 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**8.80 % value**	

Uncertainty calculation for gaseous measurement of O_2 BS EN 14789:2017 - PG-250 AS0208

v3.1 Sep-18

Limit value	N/A	**Cal gas conc**	15.13 **% vol**
Measured concentration	12.23 **% vol**	**Full Scale**	25.00 **% vol**

Performance characteristics	**Value**			**specification**
Response time	65	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	60	minutes		
Number of readings in measurement	60			
Standard deviation of repeatability at zero	0.05	% vol		<0.2 % vol
Standard deviation of repeatability at span level	0.1	% vol		<0.2 % vol
Standard deviation of reproducibility	0.15	% vol		<0.2 % vol
Deviation from linearity(lack of fit)	0.26	% vol		<0.3 % vol
Zero drift	0.03	% vol		<0.2 % vol
Span drift	0.03	% vol		<0.2 % vol
Influence of sample gas flow	0.2	% vol/10l/h		<0.2 % vol
Influence of atmospheric pressure	0.2	% vol/3kPa		<0.2 % vol
Influence of ambient temperature	-0.07	% vol/20K		<0.5 % vol
Cross sensitivity	0.14	% vol		<0.4 % vol
Influence of voltage	0	% vol/10V		<0.2 % vol
Influence from vibration	0	% vol		<0.2 % vol
Losses in the line (leak)	0	% value		≤± 2% of value
Uncertainty of calibration gas	1	% value		≤± 2% of value

Effect of drift
0.05 % vol

	ranges min	max	value at calib	
flow	0.40	0.4	0.4	l/min
pressure	101.4	101.5	101.4	kPa
temp	281.4	283.2	281.4	K
Voltage	110	110	110	V

Performance characteristic		**Uncertainty**	**Value of uncertainty quantity**	**% vol**
Standard deviation of repeatability at zero		u_{r0}		0.00
Standard deviation of repeatability at span level		u_{rs}		0.00
Standard deviation of reproducibility		u_{rp}		0.02
Lack of fit		u_{flt}		0.15
Drift		u_{0dr}		0.03
Influence of sample gas flow		u_{spres}		0.000
Influence of atmospheric pressure		u_{apres}		0.00
Influence of ambient temperature		u_{temp}		0.00
Cross sensitivity		u_{interf}		0.08
Influence of voltage		u_{volt}		0.00
Influence from vibration		u_{vib}		0.00
Losses in the line (leak)		u_{leak}		0.00
Uncertainty of calibration gas		u_{cal}		0.06

Measurement uncertainty				
Combined uncertainty			0.18	% vol
Expanded uncertainty	k =	2	0.37	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.37 % vol**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.02 % value**	

Uncertainty calculation for Velocity and Volume Flow Rate Measurement by Pitot tube EN ISO 16911-1

v1.3 Jan-16

Enter data in orange cells only

Constants

Gas constant	8.314	J/(K.mol)
Velocity meas. during calibration	3	m/s
Air density meas. during calibration	1.23	kg/m³
DP meas. during calibration	7.9	Pa
Uncertainty of velocity meas. at calibration	2.2	%
Uncertainty of air density meas. at calibration	0.075	%
Uncertainty of DP meas. at calibration	3.95	%
Pitot coefficient, K	0.834	-
Expanded uncertainty (95%, k=2) as % of value	9.0	%
Expanded uncertainty (95%, k=2)	0.08	

Characteristics of pressure sensor used for Delta P		
Enter uncertainties as (95%,k=2) where relevant		
Repeatability of Delta P transducer	1	% of value
Range of Delta P transducer	2451	Pa
Resolution of Delta P transducer	1.96	Pa
Drift of Delta P transducer	0.1	% of range between calibrations
Lack of fit of measurement system	0.1	% of range
Unertainty in Delta P transducer	10.0	Pa
Enter uncertainties as (95%,k=2) where relevant		
Uncertainty in temperature readout system	1	°C
Uncertainty in atmospheric pressure transducer	170	Pa
Uncertainty in duct area measurement	0.8	%

Uncertainty in stack gas composition		
Enter uncertainties as (95%,k=2) where relevant		
Water vapour measurement	20	% relative
CO content measurement	6	% relative
CO_2 content measurement	10	% relative
O_2 content measurement	6	% relative

Duct dimensions	Circular		Rectangular	
	Diameter	1.48 m	a	m
	Area	1.7 m2	b	m
			Area	0.0 m2

All Pressures should be entered in Pascals, Pa

Measurement Point	Atmospheric Pressure, Pa	Stack Pressure, Pa	Static Pressure, Pa	meas1, Pa	meas2, Pa	meas3, Pa	meas4, Pa	meas5, Pa	Delta P, Pa	Stack Temperature, C	Water Vapour Content, %	Dry gas basis: CO, ppm	Dry gas basis: CO_2, %	Dry gas basis: N_2, %	Dry gas basis: O_2, %	dry molecular wt, g/mol	stack molecular wt, g/mol
1	100140	100259.6	119.6	31.18825849					31.18825849	13.5	1.54	165	5.1	82.7	12.2	29.30	29.13
2	100140	100259.6	119.6	32.0879198					32	13.5	1.54	165	5.1	82.7	12.2	29.30	29.13
3	100140	100259.6	119.6	34.28709187					34	13.5	1.54	165	5.1	82.7	12.2	29.30	29.13
4	100140	100259.6	119.6	41.58434466					42	13.6	1.54	165	5.1	82.7	12.2	29.30	29.13
5	100140	100259.6	119.6	44.7831404					45	13.6	1.54	165	5.1	82.7	12.2	29.30	29.13
6	100140	100259.6	119.6	44.08340383					44	13.7	1.54	165	5.1	82.7	12.2	29.30	29.13
7	100140	100259.6	119.6	28.28934985					28	13.5	1.54	165	5.1	82.7	12.2	29.30	29.13
8	100140	100259.6	119.6	33.2874682					33	13.6	1.54	165	5.1	82.7	12.2	29.30	29.13
9	100140	100259.6	119.6	38.08566182					38	13.6	1.54	165	5.1	82.7	12.2	29.30	29.13
10	100140	100259.6	119.6	40.38479626					40	13.6	1.54	165	5.1	82.7	12.2	29.30	29.13
11	100140	100259.6	119.6	44.7831404					45	13.7	1.54	165	5.1	82.7	12.2	29.30	29.13
12	100140	100259.6	119.6	46.28257591					46	13.8	1.54	165	5.1	82.7	12.2	29.30	29.13
Mean	100140	100260	119.6	38.3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	38.3	13.6	1.5	165.0	5.1	82.7	12.2	29.30	29.13

$$\rho = \frac{molar\ mass\ .\ absolute\ pressure}{R.gas\ temperature}$$

Mean density	1.226 kg/m3

$$Velocity = K.\sqrt{\frac{2.\Delta_p}{\rho}}$$

Mean velocity	6.57 m/sec	
Standard uncertainty of velocity	0.31 m/sec	4.7 % of value
Expanded uncertainty in velocity	0.61 m/sec	9.3 % of value

	Circular duct	Rectangular duct
Flow rate	40684 m³/hour	0 m3/hour
Volume flow rate expanded uncertainty	3866 m³/hour	#DIV/0! m3/hour
Volume flow rate expanded uncertainty	9.5 % of value	#DIV/0! % of value

Developed for the STA by NPL, David Butterfield & Chris Dimopoulos

SCV 2G Uncertainty Calculations

Uncertainty calculation for gaseous measurement of NOx BS EN 14792:2017 - PG-250 AS0208

v3.7 Sep-19

Limit value	107	mg/m³ (corrected)	Cal gas conc	163.01	mg.m⁻³
Measured concentration	27.92	mg/m3 (101.3kPa, 273K)	Full Scale	205.30	mg/m³
Measured concentration	53.41	mg/m³ (Corrected)			

NO/NO2 ratio	100.00

Gas	NO	
Full Scale	100	ppm
Cal gas conc	79.4	ppm
Conversion	2.05	

Correction for reference conditions					
		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.00	101.30	273.00
	measured	11.59	0.00	101.30	273.00
	Uncert	0.37	1.00	0.00	0.00
Factors		1.91	1.00	1.00	1.00
Uncertainty in factor		0.08	0.01	0.00	0.00
Correction Factor		1.91	uf	0.08	

Effect of drift
0.63 mg/m3

Performance characteristics		Value			specification
Response time		70	seconds		≤200
Logger sampling interval		60	seconds		
Measurement period		60	minutes		
Number of readings in measurement		60			
Standard deviation of repeatability at zero		0.03	% full scale		≤±2% range
Standard deviation of repeatability at span level		0.15	% full scale		≤±2% range
Standard deviation of reproducibility		0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)		0.35	% full scale		≤±2 % range
Zero drift		0.21	mg/m3		<5% span value
Span drift		2.46	mg/m3		<5% span value
Influence of sample gas flow		2	% full scale/10l		≤±2% range
Influence of atmospheric pressure		2	% full scale /3kPa		≤±2% range
Influence of ambient temperature		0.18	% full scale/20K		≤±5% range
CO (mg/m3)	300	0.4	mg/m3		≤±4% range (Total)
HCl (mg/m3)	50	1.1	mg/m3		
SO2 (mg/m3)	1000	0.5	% vol		
N2O (mg/m3)	20	0.8	mg/m3		
Influence of voltage		0	% full scale/10V		≤±2% range/10V
Influence from vibration		0	% full scale		≤±2% range
Losses in the line (leak)		0	% value		≤± 5% of value
Converter efficiency		95.5	%		≥95%
Uncertainty of calibration gas		1	% value		≤± 2% of value

	ranges min	max	value at calib	
flow	0.40	0.4	0.4	l/min
pressure	101.3	101.8	101.3	kPa
temp	281.15	282.15	282.15	K
CO range	100	300	0	mg/m3
HCl range	0	0	0	mg/m3
SO2 range	0	5	0	mg/m3
N2O range	0	2	0	mg/m3
Voltage	110	110	110	V

Performance characteristic			Uncertainty	Value of uncertainty quantity			mg/m3
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.04
Standard deviation of reproducibility			u_{rp}				0.00
Lack of fit			u_{fit}				0.41
Drift			u_{0dr}				0.36
Influence of sample gas flow			u_{spres}				0.00
Influence of atmospheric pressure			u_{apres}				0.40
Influence of ambient temperature			u_{temp}				0.01
CO (mg/m3)			u_{interf}				0.28
HCl (mg/m3)			u_{interf}				0.00
SO2 (mg/m3)			u_{interf}				0.00
N2O (mg/m3)			u_{interf}				0.05
Influence of voltage			u_{volt}				0.00
Influence from vibration			u_{vib}				0.00
Losses in the line (leak)			u_{leak}				0.00
Converter efficiency			u_{conv}				0.73
Uncertainty of calibration gas			u_{cal}				0.14
Uncertainty in factor			uf				2.13

Use largest of sum of all positive or all negative influences		
0.33	all +ves	Criteria
0.00	all -ves	sum <4% range
0.33	largest	0.16 %

Value to use for interference uncertainty u_{int} 0.33

Measurement uncertainty				
Combined uncertainty			1.06	mg/m³
Expanded uncertainty	k =	2	2.11	mg/m³
Uncertainty corrected to std conds			**5.87**	**mg/m³**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**5.87 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**11.00 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**1.98 % ELV**	

Uncertainty calculation for gaseous measurement of CO BS EN 15058:2017 - PG-250 AS0208

v4.3 Sep-18

Limit value	None	mg/m^3 (corrected)	**Cal gas conc**	193.63	mg.m^{-3}
Measured concentration	273.55	mg/m3 (101.3kPa, 273K)	**Full Scale**	250.00	mg/m^3
Measured concentration	523.22	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200	ppm
Cal gas conc	154.9	ppm
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.00	101.30	273.00
	measured	11.59	0.00	101.30	273.00
	Uncert	0.37	1.00	0.00	0.00
Factors		1.91	1.00	1.00	1.00
Uncertainty in factor		0.08	0.01	0.00	0.00
Correction Factor		**1.91**	uf	**0.08**	

Performance characteristics		**Value**			**specification**
Response time		60	seconds		≤200
Logger sampling interval		60	seconds		
Measurement period		60	minutes		
Number of readings in measurement		60			
Standard deviation of repeatability at zero		0.04	% full scale		≤±2% range
Standard deviation of repeatability at span level		0.1	% full scale		≤±2% range
Standard deviation of reproducibility		0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)		0.2	% full scale		≤±2 % range
Zero drift		2.01	mg/m3		<5% span value
Span drift		4.02	mg/m3		<5% span value
Influence of sample gas flow		2	% full scale/10l		≤±2% range
Influence of atmospheric pressure		2	% full scale /3kPa		≤±2% range
Influence of ambient temperature		0.05	% full scale/20K		≤±5% range
NO2 (mg/m3)	30	0.5	mg/m3		≤±4% range (Total)
N2O (mg/m3)	20	1.0	mg/m3		
CO2 (% vol)	15	0.5	% vol		
SO2 (mg/m3)	200	-1.3	mg/m3		
Influence of voltage		0	% full scale/10V		≤±2% range/10V
Influence from vibration		0	% full scale		≤±2% range
Losses in the line (leak)		0	% value		≤± 5% of value
Uncertainty of calibration gas		1	% value		≤± 2% of value

	ranges min	max	value at calib	
flow	0.40	0.4	0.4	l/min
pressure	101.3	101.8	101.3	kPa
temp	281.15	282.15	282.15	K
NO2 range	0	4	0	mg/m3
N2O range	0	2	0	mg/m3
CO2 range	10	15	0	% vol
SO2 range	0	5	0	mg/m3
Voltage	110	110	110	V

Effect of drift
7.69 mg/m3

Performance characteristic			**Uncertainty**				mg/m3
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.03
Standard deviation of reproducibility			u_{rp}				0.00
Lack of fit			u_{flt}				0.29
Drift			u_{0dr}				4.44
Influence of sample gas flow			u_{spres}				0.00
Influence of atmospheric pressure			u_{apres}				0.48
Influence of ambient temperature			u_{temp}				0.00
NO2 (mg/m3)			u_{interf}				0.04
N2O (mg/m3)			u_{interf}				0.06
CO2 (% vol)			u_{interf}				0.42
SO2 (mg/m3)			u_{interf}				-0.02
Influence of voltage			u_{volt}				0.00
Influence from vibration			u_{vib}				0.00
Losses in the line (leak)			u_{leak}				0.00
Uncertainty of calibration gas			u_{cal}				1.37
Uncertainty in factor			uf				20.87

Use largest of sum of all positive or all negative influences		
0.52 all +ves	Criteria	
0.02 all -ves	sum <4% range	
0.52 largest	0.21 %	
Value to use for interference uncertainty		
u_{int} 0.52		

Measurement uncertainty				
Combined uncertainty			4.71	mg/m^3
Expanded uncertainty	k =	2	9.41	mg/m^3
Uncertainty corrected to std conds			**45.46**	**mg/m^3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**45.46 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**8.69 % value**	

Uncertainty calculation for gaseous measurement of O_2 BS EN 14789:2017 - PG-250 AS0208

v3.1 Sep-18

Limit value	N/A	**Cal gas conc**	15.13 **% vol**
Measured concentration	11.59 **% vol**	**Full Scale**	25.00 **% vol**

Performance characteristics	**Value**			**specification**
Response time	65	seconds		≤200
Logger sampling interval	60	seconds		
Measurement period	60	minutes		
Number of readings in measurement	60			
Standard deviation of repeatability at zero	0.05	% vol		<0.2 % vol
Standard deviation of repeatability at span level	0.1	% vol		<0.2 % vol
Standard deviation of reproducibility	0.15	% vol		<0.2 % vol
Deviation from linearity(lack of fit)	0.26	% vol		<0.3 % vol
Zero drift	0.02	% vol		<0.2 % vol
Span drift	0.06	% vol		<0.2 % vol
Influence of sample gas flow	0.2	% vol/10l/h		<0.2 % vol
Influence of atmospheric pressure	0.2	% vol/3kPa		<0.2 % vol
Influence of ambient temperature	-0.07	% vol/20K		<0.5 % vol
Cross sensitivity	0.14	% vol		<0.4 % vol
Influence of voltage	0	% vol/10V		<0.2 % vol
Influence from vibration	0	% vol		<0.2 % vol
Losses in the line (leak)	0	% value		≤± 2% of value
Uncertainty of calibration gas	1	% value		≤± 2% of value

Effect of drift
0.07 % vol

	ranges min	max	value at calib	
flow	0.40	0.4	0.4	l/min
pressure	101.3	101.8	101.3	kPa
temp	281.15	282.15	282.15	K
Voltage	110	110	110	V

Performance characteristic		**Uncertainty**	**Value of uncertainty quantity**			**% vol**
Standard deviation of repeatability at zero		u_{r0}				0.00
Standard deviation of repeatability at span level		u_{rs}				0.00
Standard deviation of reproducibility		u_{rp}				0.02
Lack of fit		u_{fit}				0.15
Drift		u_{0dr}				0.04
Influence of sample gas flow		u_{spres}				0.000
Influence of atmospheric pressure		u_{apres}				0.02
Influence of ambient temperature		u_{temp}				0.00
Cross sensitivity		u_{interf}				0.08
Influence of voltage		u_{volt}				0.00
Influence from vibration		u_{vib}				0.00
Losses in the line (leak)		u_{leak}				0.00
Uncertainty of calibration gas		u_{cal}				0.06

Measurement uncertainty				
Combined uncertainty			0.19	% vol
Expanded uncertainty	k =	2	0.37	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.37 % vol**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.21 % value**	

Uncertainty calculation for Velocity and Volume Flow Rate Measurement by Pitot tube EN ISO 16911-1

v1.3 Jan-16

Enter data in orange cells only

Constants

Gas constant	8.314	J/(K.mol)
Velocity meas. during calibration	3	m/s
Air density meas. during calibration	1.23	kg/m³
DP meas. during calibration	7.9	Pa
Uncertainty of velocity meas. at calibration	2.2	%
Uncertainty of air density meas. at calibration	0.075	%
Uncertainty of DP meas. at calibration	3.95	%
Pitot coefficient, K	0.834	-
Expanded uncertainty (95%, k=2) as % of value	9.0	%
Expanded uncertainty (95%, k=2)	0.08	

Characteristics of pressure sensor used for Delta P		
Enter uncertainties as (95%,k=2) where relevant		
Repeatability of Delta P transducer	1	% of value
Range of Delta P transducer	2451	Pa
Resolution of Delta P transducer	1.96	Pa
Drift of Delta P transducer	0.1	% of range between calibrations
Lack of fit of measurement system	0.1	% of range
Unertainty in Delta P transducer	10.0	Pa
Enter uncertainties as (95%,k=2) where relevant		
Uncertainty in temperature readout system	1	°C
Uncertainty in atmospheric pressure transducer	170	Pa
Uncertainty in duct area measurement	0.8	%

Uncertainty in stack gas composition		
Enter uncertainties as (95%,k=2) where relevant		
Water vapour measurement	20	% relative
CO content measurement	6	% relative
CO_2 content measurement	10	% relative
O_2 content measurement	6	% relative

Duct dimensions	Circular		Rectangular	
	Diameter	1.48 m	a	m
	Area	1.7 m2	b	m
			Area	0.0 m2

All Pressures should be entered in Pascals, Pa

Measurement Point	Atmospheric Pressure, Pa	Stack Pressure, Pa	Static Pressure, Pa	meas1, Pa	meas2, Pa	meas3, Pa	meas4, Pa	meas5, Pa	Delta P, Pa	Stack Temperature, C	Water Vapour Content, %	Dry gas basis: CO, ppm	CO_2, %	N_2, %	O_2, %	dry molecular wt, g/mol	stack molecular wt, g/mol
1	100190	100368	178	31.68807033					31.68807033	12.4	1.42	200	5.4	83.0	11.6	29.33	29.17
2	100190	100368	178	37.68581235					38	12.3	1.42	200	5.4	83.0	11.6	29.33	29.17
3	100190	100368	178	39.18524785					39	12.3	1.42	200	5.4	83.0	11.6	29.33	29.17
4	100190	100368	178	43.8834791					44	12.2	1.42	200	5.4	83.0	11.6	29.33	29.17
5	100190	100368	178	44.7831404					45	12.4	1.42	200	5.4	83.0	11.6	29.33	29.17
6	100190	100368	178	47.68204904					48	12.5	1.42	200	5.4	83.0	11.6	29.33	29.17
7	100190	100368	178	31.68807033					32	11.9	1.42	200	5.4	83.0	11.6	29.33	29.17
8	100190	100368	178	32.58773163					33	12.1	1.42	200	5.4	83.0	11.6	29.33	29.17
9	100190	100368	178	35.28671554					35	12.1	1.42	200	5.4	83.0	11.6	29.33	29.17
10	100190	100368	178	44.68317804					45	12.2	1.42	200	5.4	83.0	11.6	29.33	29.17
11	100190	100368	178	45.78276407					46	11.9	1.42	200	5.4	83.0	11.6	29.33	29.17
12	100190	100368	178	46.78238774					47	12	1.42	200	5.4	83.0	11.6	29.33	29.17
Mean	**100190**	**100368**	**178.0**	**40.1**	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	**40.1**	**12.2**	**1.4**	**200.0**	**5.4**	**83.0**	**11.6**	**29.33**	**29.17**

$$\rho = \frac{molar\ mass\ .\ absolute\ pressure}{R.gas\ temperature}$$

Mean density	**1.235 kg/m3**

$$Velocity = K.\sqrt{\frac{2.\Delta_p}{\rho}}$$

Mean velocity	**6.71 m/sec**	
Standard uncertainty of velocity	**0.31 m/sec**	**4.6 % of value**
Expanded uncertainty in velocity	**0.62 m/sec**	**9.3 % of value**

	Circular duct	Rectangular duct	
Flow rate	**41535 m³/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**3929 m³/hour**	**#DIV/0!**	**m3/hour**
Volume flow rate expanded uncertainty	**9.5 % of value**	**#DIV/0!**	**% of value**

Developed for the STA by NPL, David Butterfield & Chris Dimopoulos

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

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

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)