NATIONAL PHYSICAL LABORATORY
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Test Report

UKAS TESTING
0002

MCERTS
THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

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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:	**11th October - 18th November 2021**
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:	**6th December 2021**
Report Author	**Matthew Ellison**

Reference: XP3538LD/INTERTEK/SHLNG/OCT2021/SCV/PPC/Q4/V1

Report Approver:	Richard Harvey	NPL Authorised Signatory
MCERTS Registration:	MM-02-020	Name: Mr R Robinson (for NPLML)
Level & TEs Held:	Level 2, TE1, TE2, TE3 & TE4	Signature:
Signature:		

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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. Six 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 11th October and 18th November 2021. The report documents the results obtained.

1.2.1 SCV C (Phase One) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV C (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**	53.3	166	9.5	1.7
Uncertainty (95% Confidence Level)	**Reference Conditions**	10.9	24.7	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	7.5			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	11/10/2021			
Sample Period	**From hh:mm**	14:30			
	To hh:mm	15:30			
Monitoring Method		BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	150			
Process Status	**Burner Demand (%)**	41			

1.2.2 SCV E (Phase One) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV E (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**	74.7	32.2	10.3	1.7
Uncertainty (95% Confidence Level)	**Reference Conditions**	13.7	17.0	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	7.4			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	11/10/2021			
Sample Period	**From hh:mm**	16:05			
	To hh:mm	17:05			
Monitoring Method		BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	155			
Process Status	**Burner Demand (%)**	41			

1.2.3 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
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	43.3	450	12.0	1.6
Uncertainty (95% Confidence Level)	**Reference Conditions**	10.6	40.4	0.4	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	6.6			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	12/10/2021			
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
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	125			
Process Status	**Burner Demand (%)**	34.3			

1.2.4 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**	56.0	372	11.3	1.4
Uncertainty (95% Confidence Level)	**Reference Conditions**	13.4	57.6	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	7.0			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	17/11/2021			
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
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	145			
Process Status	**Burner Demand (%)**	34.6			

1.2.5 SCV B (Phase Two) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV B (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**	65.3	265	10.9	1.4
Uncertainty (95% Confidence Level)	**Reference Conditions**	13.6	39.6	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	6.3			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	18/11/2021			
Sample Period	**From hh:mm**	10:45			
	To hh:mm	11:45			
Monitoring Method		BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	145			
Process Status	**Burner Demand (%)**	39.9			

1.2.6 SCV D (Phase Two) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV D (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**	57.4	291	10.2	1.4
Uncertainty (95% Confidence Level)	**Reference Conditions**	12.0	39.3	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	7.4			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	18/11/2021			
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
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	145			
Process Status	**Burner Demand (%)**	36.8			

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.

Continuous or Batch Process?	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.				
What part of the batch process was sampled? (If applicable)	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.				
What fuel was used during monitoring? (If applicable)	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.				
What feedstock was used during monitoring? (If applicable)	N/A				
What was the load during monitoring?	**Emission Point**	**Load (Ton/hr)**	**Burner Demand (%)**		
	SCV 1C	150	41.0		
	SCV 1E	155	41.0		
	SCV 1H	125	34.3		
	SCV 2A	145	34.6		
	SCV 2B	145	39.9		
	SCV 2D	145	36.8		
What abatement systems are present? Were they in operation?	Each SCV uses water injection to abate NOx emissions. The system was in operation during the periodic monitoring of each SCV.				
Periodic monitoring results and corresponding CEM values	**Emission Point**	**Substance Monitored**	**CEM Result**	**Periodic Monitoring Result**	**Units**
	SCV 1H	Oxides of Nitrogen	43.0	43.3	mg/Nm^3
	SCV 1H	Oxygen	12.0	12.0	% Vol
	SCV 2A	Oxides of Nitrogen	49.7	56.0	mg/Nm^3
	SCV 2A	Oxygen	11.3	11.3	% Vol

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.

Appendix One - Emissions Testing Personnel & Methods

2.1.1 - Emissions Testing Personnel Details

Name	Role on Site	MCERTS Number	Certification Level
Matthew Ellison	Team Leader	MM-05-682	Level 2, TEs 1- 4
Richard Harvey	Technician	MM-02-020	Level 2, TEs 1- 4
Ann-Marie Leman	Trainee	MM-19-1562	Trainee

2.1.2 - Emissions Testing Procedures

Determinand	Standard	NPL Procedure	Analysis Technique
Moisture	BS EN 14790:2017	QPAS-B-540	Saturation Chart
Stack Velocity	BS EN ISO 16911-1:2013	QPAS-B-567	Differential Pressure
Carbon Monoxide	BS EN 15058:2017	QPAS-B-538	NDIR
Oxides of Nitrogen (as NO_2)	BS EN 14792:2017	QPAS-B-538	Chemiluminesence
Oxygen	BS EN 14789:2017	QPAS-B-538	Zirconia Cell

2.1.3 - Equipment Checklist Reference

See workfile INTK55OCT21/Equipment Checklist.

2.1.4 - Raw Data Reference

P:\Stack Emissions Team\South Hook LNG - Intertek\INTK55OCT21\7. Monitoring Record Sheets

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.

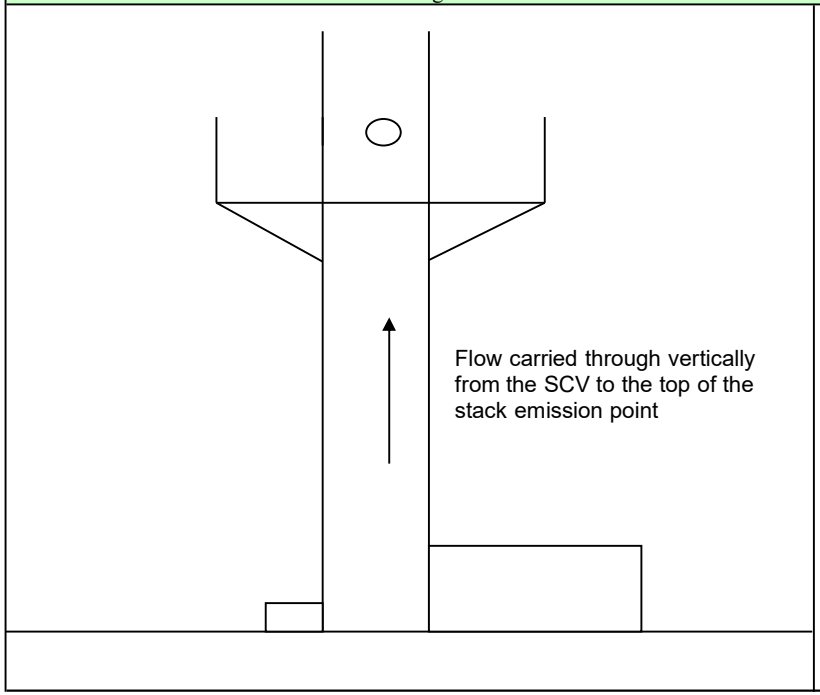
Reference - XP3538LD/INTERTEK/SHLNG/JULY2011/SCV/HOMOGENEITY.

APPENDIX TWO

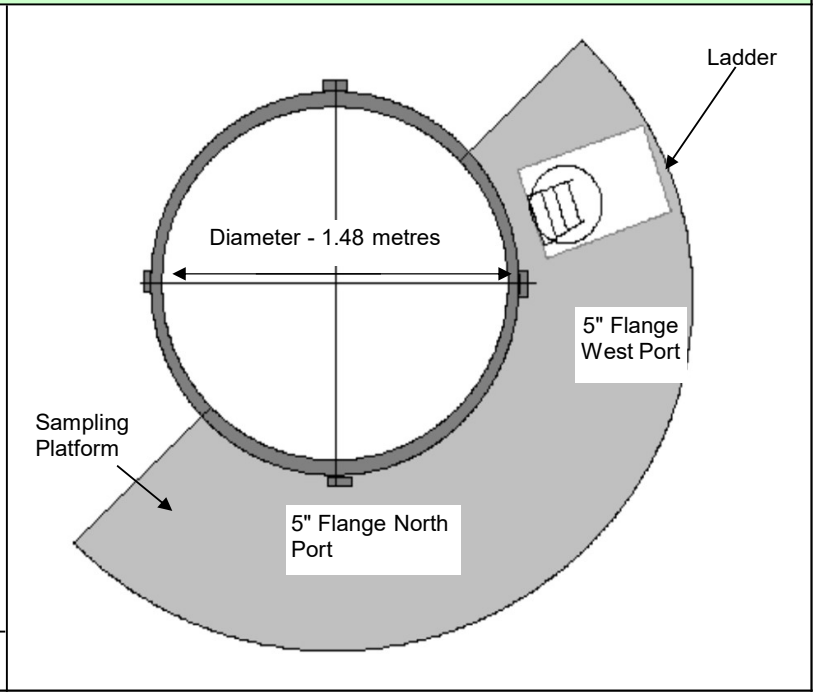
2.2.1 - Stack Diagram

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
Insertion plus offset, m	0.16	0.32	0.54	1.14	1.36	1.52

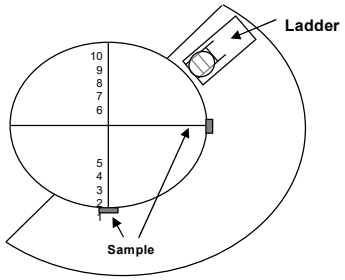
Notes - The circular stack diameter was measured as 1.48 metres, whilst the port offset (distance between the edge of the stack to the end of the port) was measured as 23 centimetres. Access to the top of the stack was by a series of three ladders. Each one had a resting platform in-between with a self 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 Terminal	Stack ID:	SCV 1C
Date	11/10/2021	Site Team:	MRE/RH	Time of Survey:	15:15

Tape Measure ID	AS0589
Barometer ID	AS0500
Traverse Pitot Type	S-Type
Traverse Pitot Tube ID	AS0681
Pitot Assembly Visual Inspection (Pre)	Pass
Pre Test Leak Check <2.5 mm H2O	Pass
Traverse Manometer Type	Digital
Traverse Manometer ID	AS0639
Traverse Manometer Range	255
Traverse Temp. Readout ID	AS0639
Traverse Thermocouple ID	AS0451a
	Δp (mmH20)
Static Pressure	22.65
	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:

None

Conditions	Value	Units
Stack pressure	758.21	mmHg
Ref O_2 Value	3	%
Moisture Content	1.66	%
CO	83	ppm
CO_2	6.6	%
N_2	83.89	%
O_2	9.50	%
Dry Molecular wt	29.44	
Stack Molecular wt	29.25	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1008.4	mbar
Pbar	756.5	mmHg
Pitot tube coeft	0.83	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature		° 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)		

Static Measurement	Δp (mmH20)	
Measurement Line	Reading 1	Reading 2(180°)
A	22.50	22.80
B	22.60	22.70
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	5.22	5.22	5.22	5.22	51.17	14.5	7.55	6	2.28
2	1.26	6.30	6.30	6.30	6.30	61.76	14.6	8.30	6	2.51
3	1.04	5.40	5.40	5.40	5.40	52.94	14.8	7.68	6	2.32
4	0.44	4.30	4.30	4.30	4.30	42.15	14.9	6.86	7	2.07
5	0.22	3.40	3.40	3.40	3.40	33.33	14.9	6.10	8	1.84
6	0.06	4.50	4.50	4.50	4.50	44.11	14.9	7.02	9	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	3.40	3.40	3.40	3.40	33.33	14.5	6.09	4	1.84
2	1.26	4.30	4.30	4.30	4.30	42.15	14.8	6.86	5	2.07
3	1.04	4.80	4.80	4.80	4.80	47.05	14.8	7.24	5	2.19
4	0.44	6.00	6.00	6.00	6.00	58.82	14.8	8.10	4	2.45
5	0.22	5.90	5.90	5.90	5.90	57.84	14.7	8.03	6	2.43
6	0.06	6.80	6.80	6.80	6.80	66.66	14.5	8.62	9	2.61
Average values		**5.0**	**5.0**	**5.0**	**5.0**	**49.3**	**14.7**	**7.4**	**6.3**	**2.2**

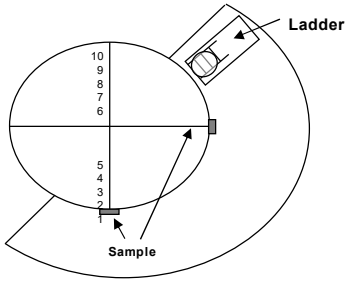
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	7.37	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	7.51	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	12.67	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	12.46	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	12.00	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	7.64	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	2.0 :1
Any local negative flow?	NO
Flow <15° of duct axis?	YES
Minimum Δp detected > 5 Pa	YES

Monitoring Objective	Traverse	Site:	South Hook LNG Terminal	Stack ID:	SCV 1E
Date	11/10/2021	Site Team:	MRE/RH	Time of Survey:	16:15

Tape Measure ID	AS0589
Barometer ID	AS0500
Traverse Pitot Type	S-Type
Traverse Pitot Tube ID	AS0681
Pitot Assembly Visual Inspection (Pre)	Pass
Pre Test Leak Check <2.5 mm H2O	Pass
Traverse Manometer Type	Digital
Traverse Manometer ID	AS0639
Traverse Manometer Range	255
Traverse Temp. Readout ID	AS0639
Traverse Thermocouple ID	AS0451a
	Δp (mmH20)
Static Pressure	27.90
	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:

None

Conditions	Value	Units
Stack pressure	759.35	mmHg
Ref O_2 Value	3	%
Moisture Content	1.71	%
CO	18.4	ppm
CO_2	5.9	%
N_2	83.50	%
O_2	10.60	%
Dry Molecular wt	29.37	
Stack Molecular wt	29.17	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1009.4	mbar
Pbar	757.3	mmHg
Pitot tube coeft	0.83	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature		° 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	27.80	27.90
Duct Diameter (m)	1.48		B	27.80	28.10
Duct Depth (m)			C		
Duct Width (m)			D		

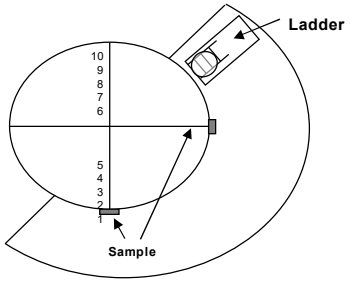
SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	6.20	6.20	6.20	6.20	60.78	15.5	8.25	6	2.49
2	1.26	5.60	5.60	5.60	5.60	54.90	15.4	7.84	6	2.37
3	1.04	6.80	6.80	6.80	6.80	66.66	15.3	8.63	7	2.61
4	0.44	5.70	5.70	5.70	5.70	55.88	15.2	7.90	8	2.39
5	0.22	4.50	4.50	4.50	4.50	44.11	15.0	7.02	8	2.12
6	0.06	5.90	5.90	5.90	5.90	57.84	15.0	8.04	6	2.43
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	4.80	4.80	4.80	4.80	47.05	15.1	7.25	8	2.19
2	1.26	4.90	4.90	4.90	4.90	48.04	15.1	7.33	8	2.21
3	1.04	5.60	5.60	5.60	5.60	54.90	15.1	7.83	6	2.37
4	0.44	7.10	7.10	7.10	7.10	69.60	15.2	8.82	7	2.66
5	0.22	6.90	6.90	6.90	6.90	67.64	15.1	8.69	8	2.63
6	0.06	7.90	7.90	7.90	7.90	77.44	15.1	9.30	8	2.81
Average values		**6.0**	**6.0**	**6.0**	**6.0**	**58.7**	**15.2**	**8.1**	**7.2**	**2.4**

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	8.08	ms^{-1}	Is the Flow Ratio 3:1 or less?	1.8 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	7.43	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	13.89	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	13.65	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	13.14	m^3s^{-1}	Minimum Δp detected > 5 Pa	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	7.56	m^3s^{-1}		

Monitoring Objective	Traverse	Site:	South Hook LNG Terminal	Stack ID:	SCV 1H
Date	12/10/2021	Site Team:	MRE/RH	Time of Survey:	11:15

Tape Measure ID	AS0589
Barometer ID	AS0500
Traverse Pitot Type	S-Type
Traverse Pitot Tube ID	AS0681
Pitot Assembly Visual Inspection (Pre)	Pass
Pre Test Leak Check <2.5 mm H2O	Pass
Traverse Manometer Type	Digital
Traverse Manometer ID	AS0639
Traverse Manometer Range	255
Traverse Temp. Readout ID	AS0639
Traverse Thermocouple ID	AS0451a
	Δp (mmH20)
Static Pressure	25.73
	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:

None

Conditions	Value	Units
Stack pressure	761.07	mmHg
Ref O_2 Value	3	%
Moisture Content	1.57	%
CO	185	ppm
CO_2	5	%
N_2	82.98	%
O_2	12.00	%
Dry Molecular wt	29.28	
Stack Molecular wt	29.10	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1011.9	mbar
Pbar	759.2	mmHg
Pitot tube coeft	0.83	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature		° 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	26.00	25.70
Duct Diameter (m)	1.48		B	25.90	25.30
Duct Depth (m)			C		
Duct Width (m)			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	5.20	5.20	5.20	5.20	50.98	14.0	7.53	4	2.28
2	1.26	6.20	6.20	6.20	6.20	60.78	14.0	8.23	5	2.49
3	1.04	6.30	6.30	6.30	6.30	61.76	14.1	8.29	5	2.51
4	0.44	6.80	6.80	6.80	6.80	66.66	14.0	8.62	7	2.61
5	0.22	7.70	7.70	7.70	7.70	75.48	14.0	9.17	8	2.77
6	0.06	6.60	6.60	6.60	6.60	64.70	14.0	8.49	9	2.57
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	3.30	3.30	3.30	3.30	32.35	14.0	6.00	2	1.82
2	1.26	5.70	5.70	5.70	5.70	55.88	13.9	7.89	4	2.39
3	1.04	6.20	6.20	6.20	6.20	60.78	13.8	8.22	6	2.49
4	0.44	6.60	6.60	6.60	6.60	64.70	13.7	8.48	6	2.57
5	0.22	6.70	6.70	6.70	6.70	65.68	13.6	8.55	6	2.59
6	0.06	7.50	7.50	7.50	7.50	73.52	13.5	9.04	8	2.74
Average values		**6.2**	**6.2**	**6.2**	**6.2**	**61.1**	**13.9**	**8.2**	**5.8**	**2.5**

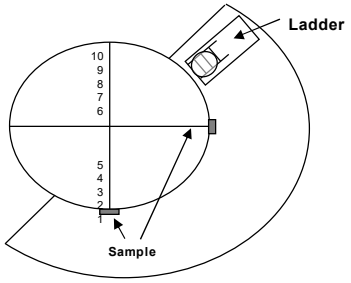
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	8.21	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	6.58	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	14.12	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	13.89	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	13.45	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	6.69	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	2.3 :1
Any local negative flow?	NO
Flow <15° of duct axis?	YES
Minimum Δp detected > 5 Pa	YES

Monitoring Objective	Traverse	Site:	South Hook LNG Terminal	Stack ID:	SCV 2A
Date	17/11/2021	Site Team:	MRE/AML	Time of Survey:	09:45

Tape Measure ID	AS0589
Barometer ID	AS0500
Traverse Pitot Type	S-Type
Traverse Pitot Tube ID	AS0681
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	255
Traverse Temp. Readout ID	AS0638
Traverse Thermocouple ID	AS0451a
	Δp (mmH20)
Static Pressure	25.18
	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:

None

Conditions	Value	Units
Stack pressure	767.18	mmHg
Ref O_2 Value	3	%
Moisture Content	1.35	%
CO	150	ppm
CO_2	5.7	%
N_2	82.89	%
O_2	11.40	%
Dry Molecular wt	29.37	
Stack Molecular wt	29.21	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1020.1	mbar
Pbar	765.3	mmHg
Pitot tube coeft	0.83	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature		° 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	25.30	25.20
Duct Diameter (m)	1.48		B	25.00	25.20
Duct Depth (m)			C		
Duct Width (m)			D		

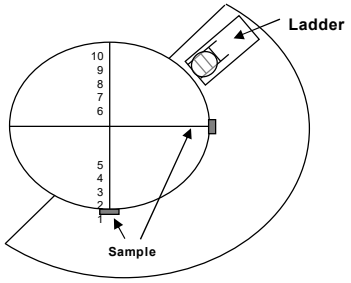
SAMPLING LINE: South										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	3.90	3.90	3.90	3.90	38.23	11.4	6.46	5	1.97
2	1.26	5.60	5.60	5.60	5.60	54.90	11.8	7.74	6	2.37
3	1.04	5.60	5.60	5.60	5.60	54.90	12.0	7.75	6	2.37
4	0.44	7.20	7.20	7.20	7.20	70.58	12.1	8.78	7	2.68
5	0.22	7.20	7.20	7.20	7.20	70.58	11.8	8.78	6	2.68
6	0.06	7.90	7.90	7.90	7.90	77.44	11.7	9.19	8	2.81
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	3.30	3.30	3.30	3.30	32.35	11.1	5.94	4	1.82
2	1.26	5.40	5.40	5.40	5.40	52.94	11.5	7.60	5	2.32
3	1.04	5.80	5.80	5.80	5.80	56.86	11.4	7.87	4	2.41
4	0.44	7.10	7.10	7.10	7.10	69.60	11.4	8.71	4	2.66
5	0.22	7.70	7.70	7.70	7.70	75.48	11.0	9.07	6	2.77
6	0.06	7.10	7.10	7.10	7.10	69.60	10.9	8.70	6	2.66
Average values		**6.2**	**6.2**	**6.2**	**6.2**	**60.3**	**11.5**	**8.0**	**5.6**	**2.5**

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	8.05	ms^{-1}	Is the Flow Ratio 3:1 or less?	2.4 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	7.02	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	13.84	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	13.65	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	13.41	m^3s^{-1}	Minimum Δp detected > 5 Pa	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	7.12	m^3s^{-1}		

Monitoring Objective	Traverse	Site:	South Hook LNG Terminal	Stack ID:	SCV 2B
Date	18/11/2021	Site Team:	MRE/AML	Time of Survey:	10:00

Tape Measure ID	AS0589
Barometer ID	AS0500
Traverse Pitot Type	S-Type
Traverse Pitot Tube ID	AS0681
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	255
Traverse Temp. Readout ID	AS0638
Traverse Thermocouple ID	AS0451a
	Δp (mmH20)
Static Pressure	20.08
	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:

None

Conditions	Value	Units
Stack pressure	765.90	mmHg
Ref O_2 Value	3	%
Moisture Content	1.4	%
CO	109	ppm
CO_2	6	%
N_2	83.09	%
O_2	10.90	%
Dry Molecular wt	29.40	
Stack Molecular wt	29.24	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1018.9	mbar
Pbar	764.4	mmHg
Pitot tube coeft	0.83	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature		° 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	20.00	20.10
Duct Diameter (m)	1.48		B	20.00	20.20
Duct Depth (m)			C		
Duct Width (m)			D		

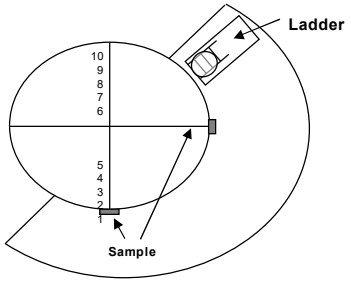
SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	2.30	2.30	2.30	2.30	22.55	11.8	4.96	6	1.52
2	1.26	4.30	4.30	4.30	4.30	42.15	12.0	6.79	6	2.07
3	1.04	4.60	4.60	4.60	4.60	45.09	12.1	7.02	6	2.14
4	0.44	5.50	5.50	5.50	5.50	53.92	12.1	7.68	7	2.35
5	0.22	4.80	4.80	4.80	4.80	47.05	12.0	7.17	7	2.19
6	0.06	4.30	4.30	4.30	4.30	42.15	11.9	6.79	8	2.07
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	2.90	2.90	2.90	2.90	28.43	12.0	5.58	7	1.70
2	1.26	3.50	3.50	3.50	3.50	34.31	12.1	6.13	7	1.87
3	1.04	4.60	4.60	4.60	4.60	45.09	12.1	7.02	7	2.14
4	0.44	5.20	5.20	5.20	5.20	50.98	12.4	7.47	7	2.28
5	0.22	5.80	5.80	5.80	5.80	56.86	12.3	7.89	7	2.41
6	0.06	6.80	6.80	6.80	6.80	66.66	12.0	8.54	9	2.61
Average values		**4.6**	**4.6**	**4.6**	**4.6**	**44.6**	**12.1**	**6.9**	**7.0**	**2.1**

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	6.92	ms^{-1}	Is the Flow Ratio 3:1 or less?	3.0 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	6.33	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	11.90	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	11.73	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	11.49	m^3s^{-1}	Minimum Δp detected > 5 Pa	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	6.42	m^3s^{-1}		

Monitoring Objective	Traverse	Site:	South Hook LNG Terminal	Stack ID:	SCV 2D
Date	18/11/2021	Site Team:	MRE/AML	Time of Survey:	13:00

Tape Measure ID	AS0589
Barometer ID	AS0500
Traverse Pitot Type	S-Type
Traverse Pitot Tube ID	AS0681
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	255
Traverse Temp. Readout ID	AS0638
Traverse Thermocouple ID	AS0451a
	Δp (mmH20)
Static Pressure	18.28
	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:

None

Conditions	Value	Units
Stack pressure	765.77	mmHg
Ref O_2 Value	3	%
Moisture Content	1.44	%
CO	130	ppm
CO_2	6.5	%
N_2	83.49	%
O_2	10.00	%
Dry Molecular wt	29.44	
Stack Molecular wt	29.28	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1018.9	mbar
Pbar	764.4	mmHg
Pitot tube coeft	0.83	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature		° 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	18.80	18.40
Duct Diameter (m)	1.48		B	18.00	17.90
Duct Depth (m)			C		
Duct Width (m)			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	5.10	5.10	5.10	5.10	50.00	12.5	7.40	5	2.26
2	1.26	6.20	6.20	6.20	6.20	60.78	12.6	8.16	5	2.49
3	1.04	5.70	5.70	5.70	5.70	55.88	12.7	7.82	6	2.39
4	0.44	3.00	3.00	3.00	3.00	29.41	12.8	5.68	6	1.73
5	0.22	4.40	4.40	4.40	4.40	43.13	12.8	6.87	7	2.10
6	0.06	5.50	5.50	5.50	5.50	53.92	12.8	7.69	6	2.35
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	3.40	3.40	3.40	3.40	33.33	12.7	6.04	8	1.84
2	1.26	5.00	5.00	5.00	5.00	49.02	12.7	7.33	6	2.24
3	1.04	4.50	4.50	4.50	4.50	44.11	12.6	6.95	6	2.12
4	0.44	5.70	5.70	5.70	5.70	55.88	12.5	7.82	8	2.39
5	0.22	5.60	5.60	5.60	5.60	54.90	12.5	7.75	8	2.37
6	0.06	8.10	8.10	8.10	8.10	79.41	12.4	9.32	7	2.85
Average values		**5.2**	**5.2**	**5.2**	**5.2**	**50.8**	**12.6**	**7.4**	**6.5**	**2.3**

Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	7.40	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	7.36	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	12.73	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	12.54	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	12.26	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	7.46	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	2.7 :1
Any local negative flow?	NO
Flow <15° of duct axis?	YES
Minimum Δp detected > 5 Pa	YES

2.2.3 - One Minute Averaged Gaseous Emissions Data

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 1C				
273K, 101.3 kPa, 3% Oxygen on a dry basis				
Species	**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**	**Carbon Dioxide**
Units	**mg/m3**	**mg/m3**	**%**	**%**
11/10/2021 14:30	171.1	50.7	9.5	6.6
11/10/2021 14:31	180.4	50.9	9.5	6.6
11/10/2021 14:32	169.4	51.3	9.5	6.6
11/10/2021 14:33	169.0	51.2	9.5	6.6
11/10/2021 14:34	175.3	51.4	9.5	6.6
11/10/2021 14:35	172.1	51.9	9.5	6.6
11/10/2021 14:36	139.1	54.4	9.6	6.6
11/10/2021 14:37	171.7	51.9	9.5	6.6
11/10/2021 14:38	173.8	51.8	9.5	6.6
11/10/2021 14:39	172.0	52.0	9.5	6.6
11/10/2021 14:40	168.6	52.1	9.5	6.6
11/10/2021 14:41	172.6	52.3	9.5	6.6
11/10/2021 14:42	160.6	53.3	9.5	6.6
11/10/2021 14:43	141.3	54.9	9.5	6.6
11/10/2021 14:44	169.9	52.8	9.5	6.6
11/10/2021 14:45	166.5	52.7	9.5	6.6
11/10/2021 14:46	172.7	52.8	9.5	6.6
11/10/2021 14:47	174.8	52.8	9.5	6.6
11/10/2021 14:48	171.8	52.8	9.5	6.6
11/10/2021 14:49	163.8	53.1	9.4	6.6
11/10/2021 14:50	170.9	53.1	9.4	6.6
11/10/2021 14:51	174.2	53.1	9.5	6.6
11/10/2021 14:52	168.6	53.0	9.4	6.6
11/10/2021 14:53	161.5	53.2	9.5	6.6
11/10/2021 14:54	162.1	53.2	9.5	6.6
11/10/2021 14:55	167.0	53.3	9.4	6.6
11/10/2021 14:56	173.1	53.2	9.4	6.6
11/10/2021 14:57	167.8	53.2	9.4	6.6
11/10/2021 14:58	149.2	54.7	9.4	6.6
11/10/2021 14:59	140.3	55.2	9.4	6.7
11/10/2021 15:00	164.9	53.5	9.4	6.6
11/10/2021 15:01	174.7	53.5	9.5	6.6
11/10/2021 15:02	175.5	53.4	9.5	6.6
11/10/2021 15:03	172.8	53.5	9.5	6.6
11/10/2021 15:04	171.9	53.6	9.5	6.6
11/10/2021 15:05	170.3	53.4	9.5	6.6
11/10/2021 15:06	168.2	53.6	9.5	6.6
11/10/2021 15:07	168.7	53.6	9.5	6.6
11/10/2021 15:08	170.3	53.7	9.5	6.6
11/10/2021 15:09	163.8	53.6	9.5	6.6
11/10/2021 15:10	168.9	53.7	9.5	6.6
11/10/2021 15:11	166.6	53.7	9.6	6.6
11/10/2021 15:12	168.2	53.7	9.6	6.6
11/10/2021 15:13	168.1	53.9	9.5	6.6
11/10/2021 15:14	129.3	56.1	9.5	6.6
11/10/2021 15:15	153.8	55.0	9.5	6.6
11/10/2021 15:16	165.1	53.8	9.5	6.6
11/10/2021 15:17	174.8	53.9	9.4	6.6
11/10/2021 15:18	166.8	53.6	9.5	6.6
11/10/2021 15:19	168.0	53.7	9.5	6.6
11/10/2021 15:20	172.0	53.9	9.4	6.6
11/10/2021 15:21	166.3	53.8	9.5	6.6
11/10/2021 15:22	163.7	53.9	9.4	6.6
11/10/2021 15:23	170.4	54.0	9.5	6.6
11/10/2021 15:24	159.0	53.9	9.4	6.6
11/10/2021 15:25	161.2	54.0	9.4	6.6
11/10/2021 15:26	169.5	53.7	9.4	6.6
11/10/2021 15:27	173.9	53.7	9.4	6.6
11/10/2021 15:28	168.7	53.7	9.4	6.6
11/10/2021 15:29	169.4	53.6	9.4	6.6
11/10/2021 15:30	139.8	56.2	9.4	6.6
Minimum	129.3	50.7	9.4	6.6
Maximum	180.4	56.2	9.6	6.7
Average	166.2	53.3	9.5	6.6

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 1E				
273K, 101.3 kPa, 3% Oxygen on a dry basis				
Species	**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**	**Carbon Dioxide**
Units	**mg/m3**	**mg/m3**	**%**	**%**
11/10/2021 16:05	26.8	75.7	10.2	6.1
11/10/2021 16:06	33.7	73.6	10.2	6.1
11/10/2021 16:07	32.3	73.5	10.2	6.2
11/10/2021 16:08	31.2	73.5	10.2	6.2
11/10/2021 16:09	30.6	73.5	10.1	6.2
11/10/2021 16:10	31.0	73.8	10.1	6.2
11/10/2021 16:11	28.8	73.8	10.1	6.2
11/10/2021 16:12	30.8	74.0	10.2	6.2
11/10/2021 16:13	30.5	74.1	10.1	6.2
11/10/2021 16:14	28.3	74.1	10.1	6.2
11/10/2021 16:15	29.3	74.3	10.2	6.2
11/10/2021 16:16	29.7	74.5	10.2	6.2
11/10/2021 16:17	31.3	74.5	10.2	6.2
11/10/2021 16:18	32.1	74.3	10.3	6.1
11/10/2021 16:19	32.0	74.2	10.3	6.1
11/10/2021 16:20	31.3	74.5	10.3	6.1
11/10/2021 16:21	26.1	77.4	10.3	6.1
11/10/2021 16:22	31.4	74.4	10.2	6.2
11/10/2021 16:23	30.9	74.1	10.3	6.1
11/10/2021 16:24	41.1	73.7	10.6	6.0
11/10/2021 16:25	45.9	73.6	10.7	5.9
11/10/2021 16:26	48.5	73.4	10.8	5.8
11/10/2021 16:27	51.9	73.0	11.0	5.8
11/10/2021 16:28	47.1	73.4	10.9	5.8
11/10/2021 16:29	43.6	73.3	10.8	5.9
11/10/2021 16:30	40.7	73.4	10.6	5.9
11/10/2021 16:31	38.9	74.0	10.5	6.0
11/10/2021 16:32	32.1	74.1	10.3	6.1
11/10/2021 16:33	29.4	74.5	10.1	6.2
11/10/2021 16:34	25.9	75.0	10.1	6.3
11/10/2021 16:35	26.3	75.0	10.0	6.4
11/10/2021 16:36	25.6	75.2	9.9	6.4
11/10/2021 16:37	19.4	77.6	9.9	6.4
11/10/2021 16:38	22.4	76.5	9.9	6.4
11/10/2021 16:39	26.2	75.2	10.0	6.3
11/10/2021 16:40	26.7	75.5	10.1	6.3
11/10/2021 16:41	27.9	75.4	10.1	6.3
11/10/2021 16:42	28.8	75.2	10.1	6.2
11/10/2021 16:43	32.2	75.1	10.2	6.2
11/10/2021 16:44	34.5	74.9	10.3	6.1
11/10/2021 16:45	36.4	74.8	10.5	6.1
11/10/2021 16:46	40.9	74.6	10.6	6.0
11/10/2021 16:47	41.9	74.5	10.7	5.9
11/10/2021 16:48	37.9	76.9	10.9	5.8
11/10/2021 16:49	41.8	75.0	10.9	5.8
11/10/2021 16:50	41.9	74.4	10.7	5.9
11/10/2021 16:51	38.1	74.2	10.5	6.0
11/10/2021 16:52	32.1	74.6	10.2	6.1
11/10/2021 16:53	28.8	74.8	10.1	6.2
11/10/2021 16:54	27.4	75.2	10.0	6.3
11/10/2021 16:55	21.7	77.8	9.9	6.3
11/10/2021 16:56	20.3	76.8	9.8	6.4
11/10/2021 16:57	21.2	75.6	9.8	6.4
11/10/2021 16:58	25.1	75.2	9.9	6.4
11/10/2021 16:59	26.3	75.1	9.9	6.3
11/10/2021 17:00	26.1	75.2	9.9	6.3
11/10/2021 17:01	27.8	75.1	10.0	6.3
11/10/2021 17:02	29.8	75.3	10.1	6.3
11/10/2021 17:03	32.8	75.2	10.2	6.2
11/10/2021 17:04	36.1	74.8	10.3	6.1
11/10/2021 17:05	37.5	74.7	10.4	6.1
Minimum	19.4	73.0	9.8	5.8
Maximum	51.9	77.8	11.0	6.4
Average	32.2	74.7	10.3	6.2

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 1H				
273K, 101.3 kPa, 3% Oxygen on a dry basis				
Species	**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**	**Carbon Dioxide**
Units	**mg/m3**	**mg/m3**	**%**	**%**
12/10/2021 13:00	405	45.8	12.2	5.1
12/10/2021 13:01	381	46.3	12.4	5.0
12/10/2021 13:02	392	45.9	12.4	5.0
12/10/2021 13:03	359	46.8	12.4	5.0
12/10/2021 13:04	417	45.6	12.5	5.0
12/10/2021 13:05	485	43.4	12.5	4.9
12/10/2021 13:06	497	43.1	12.4	5.0
12/10/2021 13:07	519	42.7	12.3	5.0
12/10/2021 13:08	543	42.5	12.2	5.1
12/10/2021 13:09	501	43.2	11.9	5.2
12/10/2021 13:10	471	43.7	11.7	5.4
12/10/2021 13:11	463	43.9	11.7	5.4
12/10/2021 13:12	430	44.1	11.5	5.5
12/10/2021 13:13	418	44.4	11.5	5.5
12/10/2021 13:14	410	44.7	11.4	5.5
12/10/2021 13:15	396	44.8	11.4	5.6
12/10/2021 13:16	408	44.9	11.5	5.5
12/10/2021 13:17	434	44.2	11.7	5.4
12/10/2021 13:18	448	44.0	11.9	5.3
12/10/2021 13:19	375	46.0	12.2	5.2
12/10/2021 13:20	458	43.7	12.3	5.1
12/10/2021 13:21	459	43.2	12.4	5.0
12/10/2021 13:22	446	43.0	12.5	5.0
12/10/2021 13:23	435	43.2	12.5	4.9
12/10/2021 13:24	455	42.5	12.5	4.9
12/10/2021 13:25	490	42.0	12.5	4.9
12/10/2021 13:26	547	40.8	12.5	4.9
12/10/2021 13:27	546	41.1	12.3	5.0
12/10/2021 13:28	545	41.3	12.1	5.1
12/10/2021 13:29	538	41.6	12.0	5.2
12/10/2021 13:30	487	42.2	11.8	5.3
12/10/2021 13:31	424	43.2	11.6	5.4
12/10/2021 13:32	318	45.8	11.4	5.5
12/10/2021 13:33	344	46.3	11.3	5.6
12/10/2021 13:34	389	44.8	11.3	5.6
12/10/2021 13:35	400	44.7	11.4	5.6
12/10/2021 13:36	416	44.5	11.6	5.4
12/10/2021 13:37	367	46.1	11.7	5.4
12/10/2021 13:38	473	43.4	12.0	5.2
12/10/2021 13:39	471	42.7	12.3	5.1
12/10/2021 13:40	402	43.7	12.4	5.0
12/10/2021 13:41	394	43.6	12.5	4.9
12/10/2021 13:42	433	42.6	12.6	4.9
12/10/2021 13:43	477	41.3	12.6	4.9
12/10/2021 13:44	500	40.9	12.5	4.9
12/10/2021 13:45	534	40.3	12.4	5.0
12/10/2021 13:46	551	40.1	12.3	5.0
12/10/2021 13:47	547	40.1	12.1	5.1
12/10/2021 13:48	494	41.3	11.8	5.3
12/10/2021 13:49	488	41.8	11.7	5.4
12/10/2021 13:50	453	42.2	11.6	5.4
12/10/2021 13:51	445	42.8	11.5	5.5
12/10/2021 13:52	413	43.2	11.5	5.5
12/10/2021 13:53	330	46.0	11.4	5.5
12/10/2021 13:54	414	43.7	11.4	5.5
12/10/2021 13:55	437	43.2	11.6	5.5
12/10/2021 13:56	474	42.7	11.8	5.3
12/10/2021 13:57	509	41.9	12.1	5.2
12/10/2021 13:58	511	41.2	12.2	5.1
12/10/2021 13:59	435	42.3	12.2	5.1
12/10/2021 14:00	437	42.5	12.4	5.0
Minimum	318	40.1	11.3	4.9
Maximum	551	46.8	12.6	5.6
Average	450	43.3	12.0	5.2

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 2A				
273K, 101.3 kPa, 3% Oxygen on a dry basis				
Species	**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**	**Carbon Dioxide**
Units	**mg/m3**	**mg/m3**	**%**	**%**
17/11/2021 13:00	441	55.1	11.6	5.7
17/11/2021 13:01	447	54.9	11.6	5.7
17/11/2021 13:02	400	56.1	11.4	5.8
17/11/2021 13:03	416	55.7	11.5	5.8
17/11/2021 13:04	366	56.3	11.3	5.8
17/11/2021 13:05	345	57.0	11.2	5.9
17/11/2021 13:06	348	57.0	11.2	5.9
17/11/2021 13:07	343	57.6	11.3	5.9
17/11/2021 13:08	282	60.0	11.2	5.9
17/11/2021 13:09	344	57.2	11.2	5.9
17/11/2021 13:10	360	56.7	11.3	5.9
17/11/2021 13:11	399	56.3	11.4	5.8
17/11/2021 13:12	451	55.1	11.6	5.7
17/11/2021 13:13	447	55.2	11.6	5.7
17/11/2021 13:14	432	55.3	11.6	5.7
17/11/2021 13:15	428	55.5	11.5	5.7
17/11/2021 13:16	430	55.5	11.5	5.7
17/11/2021 13:17	412	55.9	11.4	5.8
17/11/2021 13:18	388	56.1	11.4	5.8
17/11/2021 13:19	371	56.6	11.3	5.9
17/11/2021 13:20	367	56.5	11.3	5.9
17/11/2021 13:21	303	57.4	11.0	6.0
17/11/2021 13:22	286	57.6	10.9	6.1
17/11/2021 13:23	320	56.8	11.1	6.0
17/11/2021 13:24	376	56.0	11.3	5.8
17/11/2021 13:25	429	55.2	11.5	5.7
17/11/2021 13:26	468	54.7	11.6	5.7
17/11/2021 13:27	377	57.1	11.6	5.7
17/11/2021 13:28	356	57.1	11.4	5.8
17/11/2021 13:29	405	55.2	11.4	5.8
17/11/2021 13:30	396	54.9	11.3	5.8
17/11/2021 13:31	339	55.9	11.1	5.9
17/11/2021 13:32	310	56.3	10.9	6.0
17/11/2021 13:33	308	56.2	10.9	6.0
17/11/2021 13:34	323	55.9	11.0	5.9
17/11/2021 13:35	352	55.8	11.1	5.9
17/11/2021 13:36	382	54.9	11.3	5.8
17/11/2021 13:37	364	55.3	11.2	5.8
17/11/2021 13:38	380	55.3	11.3	5.8
17/11/2021 13:39	412	54.7	11.4	5.7
17/11/2021 13:40	398	54.6	11.3	5.8
17/11/2021 13:41	339	55.6	11.1	5.8
17/11/2021 13:42	328	56.0	11.1	5.9
17/11/2021 13:43	356	55.5	11.2	5.8
17/11/2021 13:44	342	55.9	11.1	5.9
17/11/2021 13:45	336	55.9	11.0	5.9
17/11/2021 13:46	361	55.7	11.2	5.8
17/11/2021 13:47	319	58.2	11.3	5.8
17/11/2021 13:48	425	54.8	11.3	5.7
17/11/2021 13:49	402	54.9	11.3	5.8
17/11/2021 13:50	397	55.0	11.3	5.8
17/11/2021 13:51	378	55.1	11.2	5.8
17/11/2021 13:52	358	55.4	11.1	5.8
17/11/2021 13:53	322	56.2	10.9	5.9
17/11/2021 13:54	356	55.3	11.1	5.9
17/11/2021 13:55	363	55.5	11.2	5.8
17/11/2021 13:56	380	55.4	11.3	5.8
17/11/2021 13:57	314	56.9	11.0	6.0
17/11/2021 13:58	317	56.8	11.0	6.0
17/11/2021 13:59	374	55.9	11.3	5.9
17/11/2021 14:00	400	55.4	11.3	5.8
Minimum	282	54.6	10.9	5.7
Maximum	468	60.0	11.6	6.1
Average	372	56.0	11.3	5.8

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 2B				
273K, 101.3 kPa, 3% Oxygen on a dry basis				
Species	**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**	**Carbon Dioxide**
Units	**mg/m3**	**mg/m3**	**%**	**%**
18/11/2021 10:45	261	65.8	11.0	6.0
18/11/2021 10:46	243	66.2	10.8	6.1
18/11/2021 10:47	242	65.9	10.8	6.1
18/11/2021 10:48	258	65.5	10.9	6.0
18/11/2021 10:49	271	64.9	11.0	6.0
18/11/2021 10:50	289	64.5	11.1	5.9
18/11/2021 10:51	305	64.2	11.2	5.8
18/11/2021 10:52	361	62.6	11.3	5.8
18/11/2021 10:53	393	62.3	11.5	5.7
18/11/2021 10:54	415	61.7	11.6	5.6
18/11/2021 10:55	408	61.8	11.5	5.6
18/11/2021 10:56	283	66.4	11.5	5.6
18/11/2021 10:57	350	63.3	11.4	5.7
18/11/2021 10:58	339	63.2	11.3	5.8
18/11/2021 10:59	310	64.0	11.2	5.8
18/11/2021 11:00	299	64.2	11.1	5.9
18/11/2021 11:01	284	64.1	11.1	5.9
18/11/2021 11:02	286	64.2	11.1	5.9
18/11/2021 11:03	287	64.4	11.1	5.9
18/11/2021 11:04	275	64.2	11.0	5.9
18/11/2021 11:05	274	64.5	10.9	5.9
18/11/2021 11:06	266	64.6	10.8	6.0
18/11/2021 11:07	257	64.7	10.8	6.0
18/11/2021 11:08	245	65.1	10.7	6.1
18/11/2021 11:09	236	65.2	10.7	6.1
18/11/2021 11:10	235	65.4	10.7	6.1
18/11/2021 11:11	232	65.7	10.7	6.1
18/11/2021 11:12	238	65.5	10.7	6.1
18/11/2021 11:13	238	65.6	10.7	6.1
18/11/2021 11:14	237	65.6	10.8	6.1
18/11/2021 11:15	243	65.6	10.9	6.0
18/11/2021 11:16	266	65.1	10.9	6.0
18/11/2021 11:17	260	65.5	10.9	6.0
18/11/2021 11:18	198	68.9	10.9	6.0
18/11/2021 11:19	251	65.8	10.9	6.0
18/11/2021 11:20	240	65.8	10.7	6.1
18/11/2021 11:21	227	66.5	10.7	6.1
18/11/2021 11:22	228	66.5	10.7	6.1
18/11/2021 11:23	236	66.1	10.7	6.1
18/11/2021 11:24	240	66.1	10.8	6.1
18/11/2021 11:25	248	66.0	10.9	6.0
18/11/2021 11:26	256	65.8	10.9	6.0
18/11/2021 11:27	262	65.7	10.9	6.0
18/11/2021 11:28	267	65.5	11.0	5.9
18/11/2021 11:29	262	65.5	10.9	6.0
18/11/2021 11:30	261	65.8	10.9	6.0
18/11/2021 11:31	253	66.0	10.9	6.0
18/11/2021 11:32	243	66.2	10.8	6.0
18/11/2021 11:33	232	66.5	10.8	6.0
18/11/2021 11:34	238	66.4	10.8	6.0
18/11/2021 11:35	235	66.5	10.8	6.0
18/11/2021 11:36	232	66.5	10.7	6.0
18/11/2021 11:37	234	66.2	10.7	6.1
18/11/2021 11:38	241	66.2	10.8	6.0
18/11/2021 11:39	247	66.0	10.9	6.0
18/11/2021 11:40	254	66.1	10.9	6.0
18/11/2021 11:41	242	66.1	10.9	6.0
18/11/2021 11:42	239	66.2	10.8	6.0
18/11/2021 11:43	240	66.2	10.8	6.0
18/11/2021 11:44	243	66.4	10.8	6.0
18/11/2021 11:45	240	66.1	10.8	6.0
Minimum	198	61.7	10.7	5.6
Maximum	415	68.9	11.6	6.1
Average	265	65.3	10.9	6.0

One Minute Averaged Gaseous Emissions Results

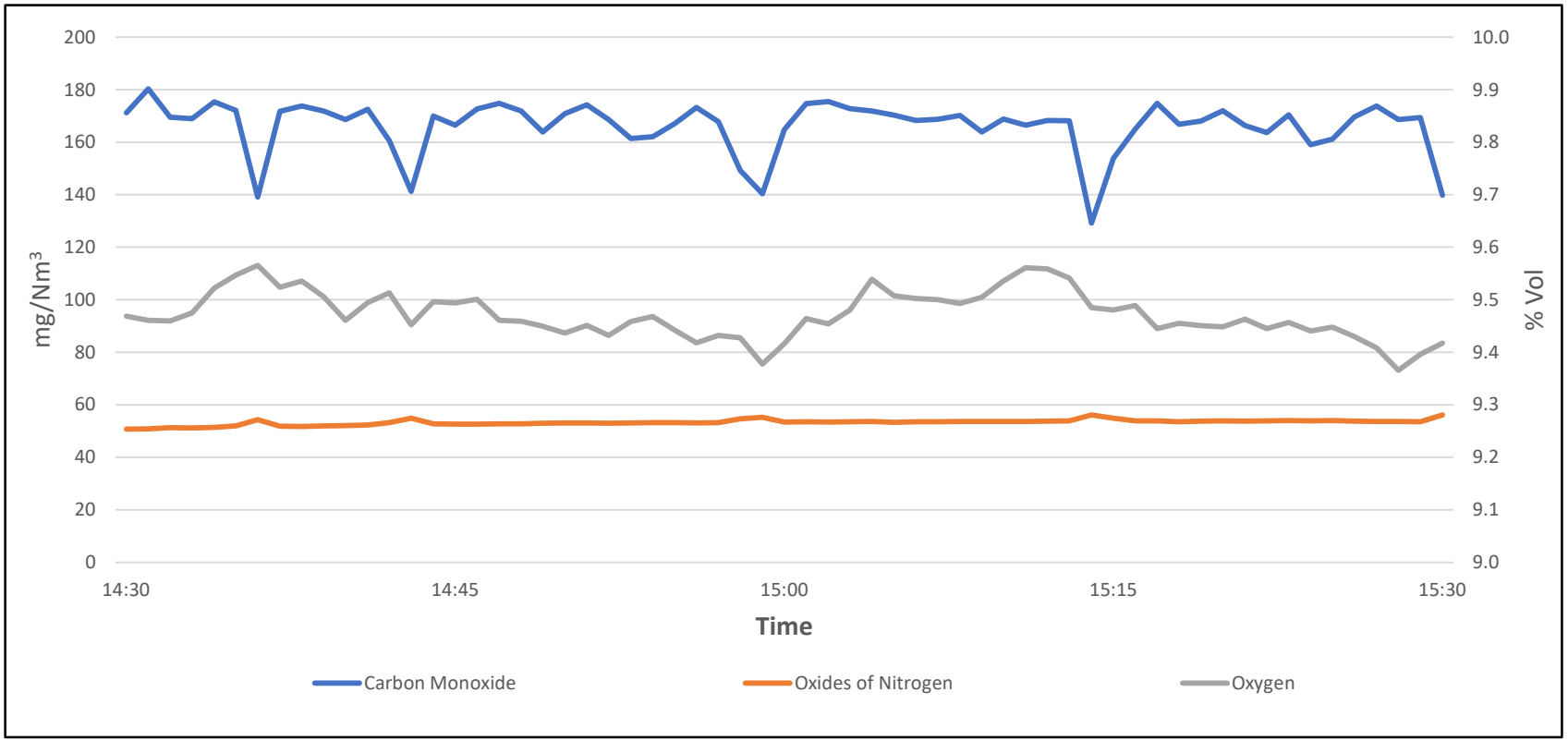
South Hook LNG - SCV 2D				
273K, 101.3 kPa, 3% Oxygen on a dry basis				
Species	Carbon Monoxide	Oxides of Nitrogen	Oxygen	Carbon Dioxide
Units	mg/m3	mg/m3	%	%
18/11/2021 13:00	282	56.7	10.1	6.4
18/11/2021 13:01	286	56.7	10.1	6.4
18/11/2021 13:02	282	57.1	10.1	6.4
18/11/2021 13:03	278	57.1	10.1	6.4
18/11/2021 13:04	277	57.2	10.1	6.4
18/11/2021 13:05	267	57.4	10.1	6.4
18/11/2021 13:06	269	57.5	10.1	6.4
18/11/2021 13:07	272	57.4	10.0	6.5
18/11/2021 13:08	265	57.5	10.0	6.5
18/11/2021 13:09	271	57.5	10.0	6.5
18/11/2021 13:10	268	57.4	10.1	6.5
18/11/2021 13:11	271	57.4	10.1	6.5
18/11/2021 13:12	267	57.7	10.0	6.5
18/11/2021 13:13	281	57.5	10.1	6.4
18/11/2021 13:14	286	57.3	10.1	6.4
18/11/2021 13:15	278	57.5	10.1	6.4
18/11/2021 13:16	276	57.8	10.1	6.4
18/11/2021 13:17	285	57.4	10.2	6.4
18/11/2021 13:18	283	57.4	10.2	6.4
18/11/2021 13:19	290	57.3	10.2	6.4
18/11/2021 13:20	286	57.0	10.1	6.4
18/11/2021 13:21	263	57.5	10.0	6.5
18/11/2021 13:22	251	57.9	9.9	6.5
18/11/2021 13:23	248	58.1	9.9	6.6
18/11/2021 13:24	250	57.7	9.9	6.6
18/11/2021 13:25	248	57.9	9.9	6.6
18/11/2021 13:26	238	57.9	9.9	6.6
18/11/2021 13:27	247	58.0	9.9	6.5
18/11/2021 13:28	274	57.7	10.1	6.5
18/11/2021 13:29	288	57.3	10.2	6.4
18/11/2021 13:30	282	57.0	10.1	6.4
18/11/2021 13:31	279	57.4	10.1	6.4
18/11/2021 13:32	273	57.3	10.1	6.5
18/11/2021 13:33	272	57.3	10.0	6.5
18/11/2021 13:34	266	57.4	9.9	6.5
18/11/2021 13:35	249	57.5	9.9	6.6
18/11/2021 13:36	242	58.1	9.9	6.6
18/11/2021 13:37	246	58.1	9.9	6.6
18/11/2021 13:38	251	57.7	9.9	6.6
18/11/2021 13:39	257	57.7	10.0	6.5
18/11/2021 13:40	277	57.0	10.1	6.5
18/11/2021 13:41	270	57.0	10.1	6.5
18/11/2021 13:42	294	56.6	10.2	6.4
18/11/2021 13:43	292	56.5	10.2	6.4
18/11/2021 13:44	287	56.7	10.2	6.4
18/11/2021 13:45	276	56.8	10.1	6.4
18/11/2021 13:46	275	56.8	10.1	6.5
18/11/2021 13:47	255	57.2	10.0	6.5
18/11/2021 13:48	263	57.2	10.0	6.5
18/11/2021 13:49	268	57.0	10.1	6.5
18/11/2021 13:50	276	56.9	10.1	6.5
18/11/2021 13:51	278	56.8	10.1	6.5
18/11/2021 13:52	273	57.1	10.0	6.5
18/11/2021 13:53	309	57.1	10.3	6.4
18/11/2021 13:54	376	57.7	10.9	6.0
18/11/2021 13:55	405	56.3	11.4	5.8
18/11/2021 13:56	427	55.8	11.5	5.7
18/11/2021 13:57	427	57.8	11.7	5.6
18/11/2021 13:58	456	59.5	11.7	5.6
18/11/2021 13:59	508	58.1	11.7	5.5
18/11/2021 14:00	488	59.6	11.6	5.6
Minimum	238	55.8	9.9	5.5
Maximum	508	59.6	11.7	6.6
Average	291	57.4	10.2	6.4

2.2.4 - Gaseous Emissions Graphical Data

South Hook LNG - SCV 1C

Gaseous Emissions Graphical Data for Carbon Monoxide, and Oxides of Nitrogen

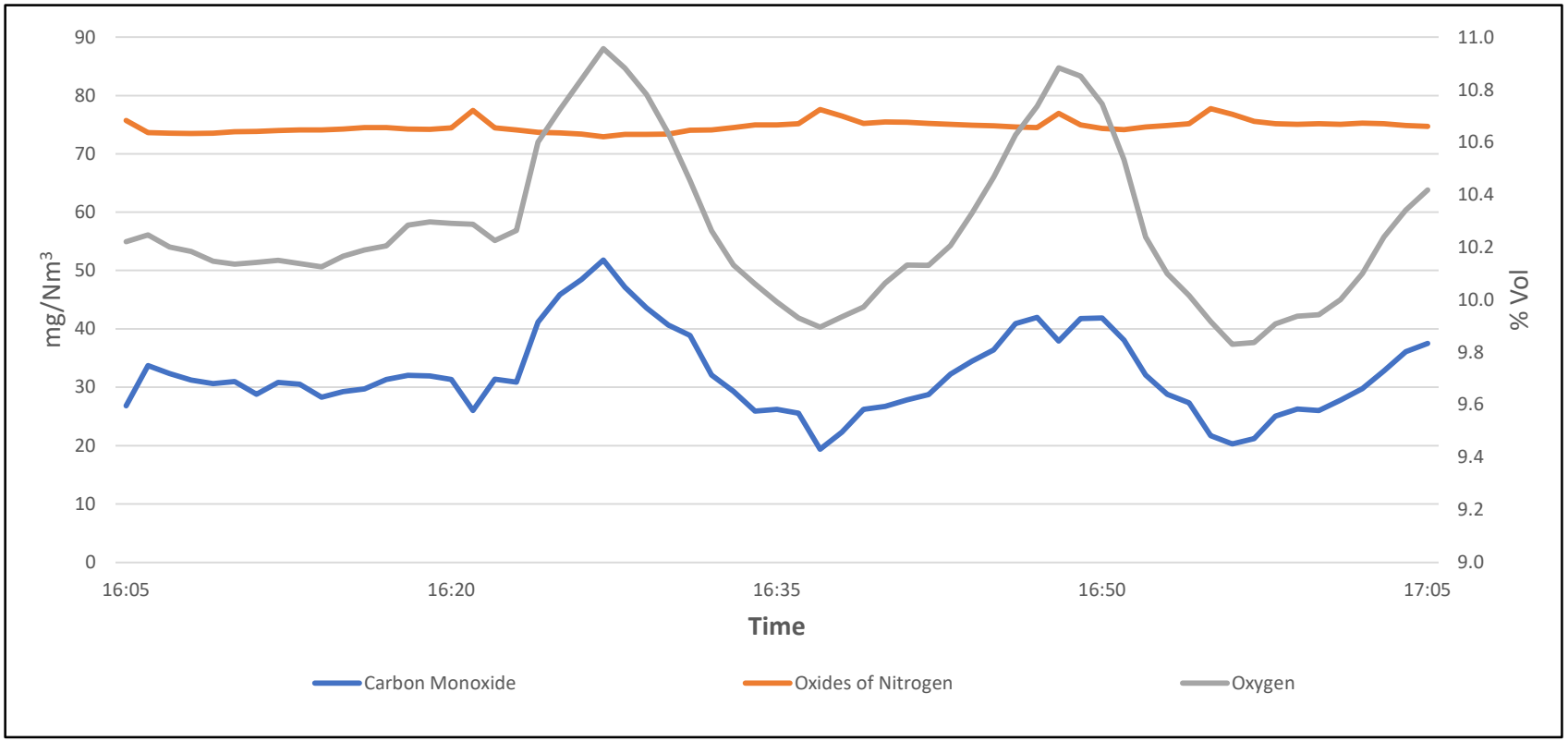
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 1E

Gaseous Emissions Graphical Data for Carbon Monoxide, and Oxides of Nitrogen

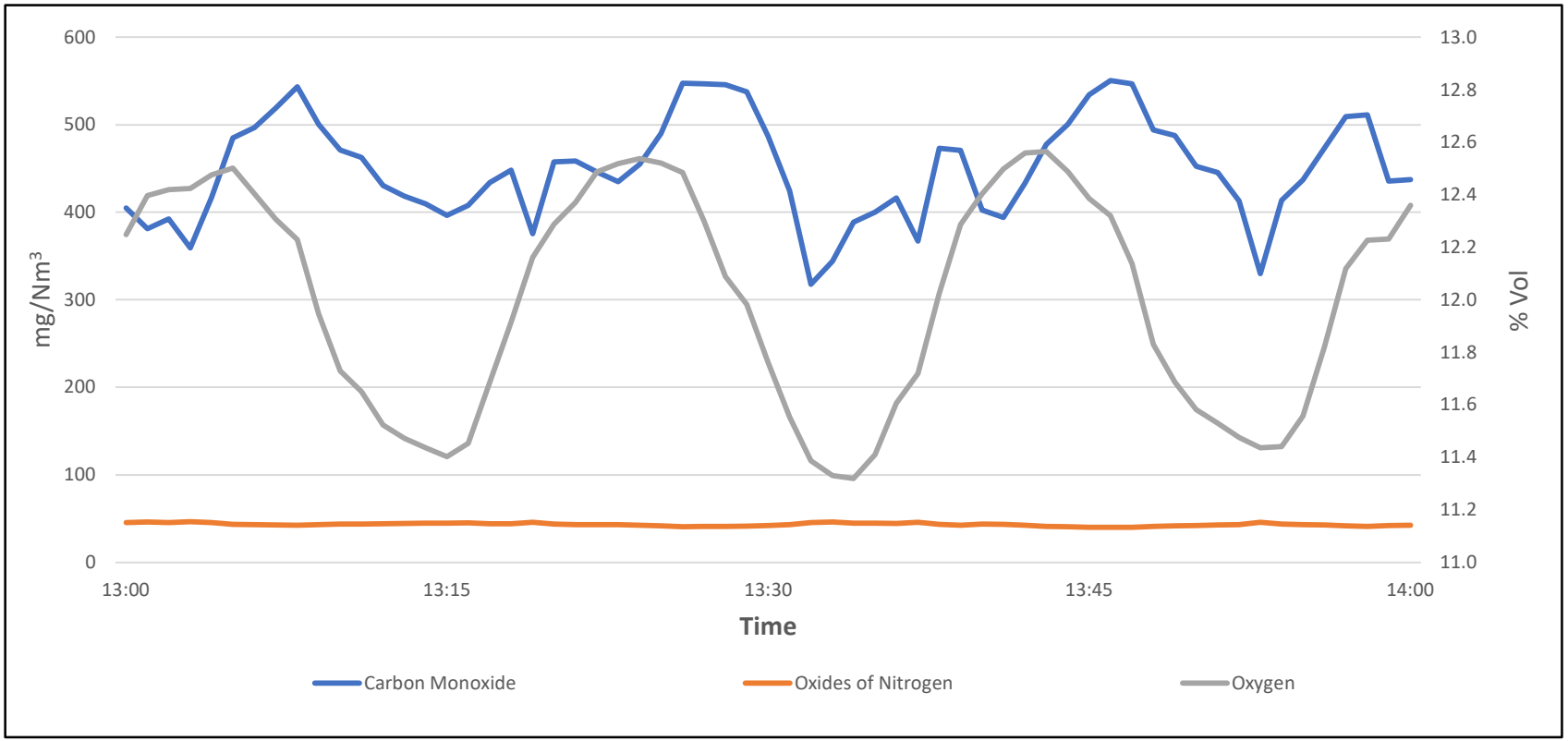
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 1H

Gaseous Emissions Graphical Data for Carbon Monoxide, and Oxides of Nitrogen

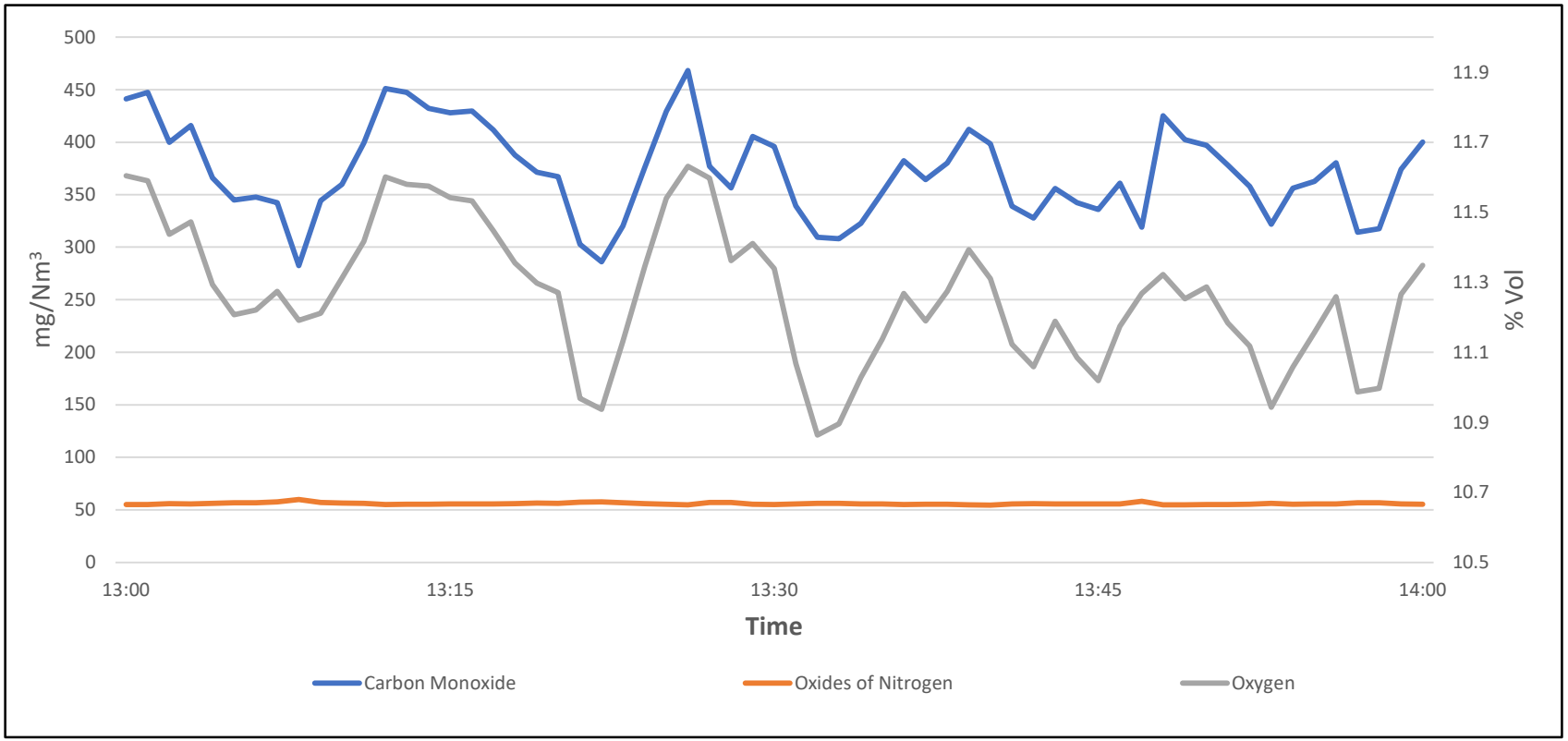
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 2A

Gaseous Emissions Graphical Data for Carbon Monoxide, and Oxides of Nitrogen

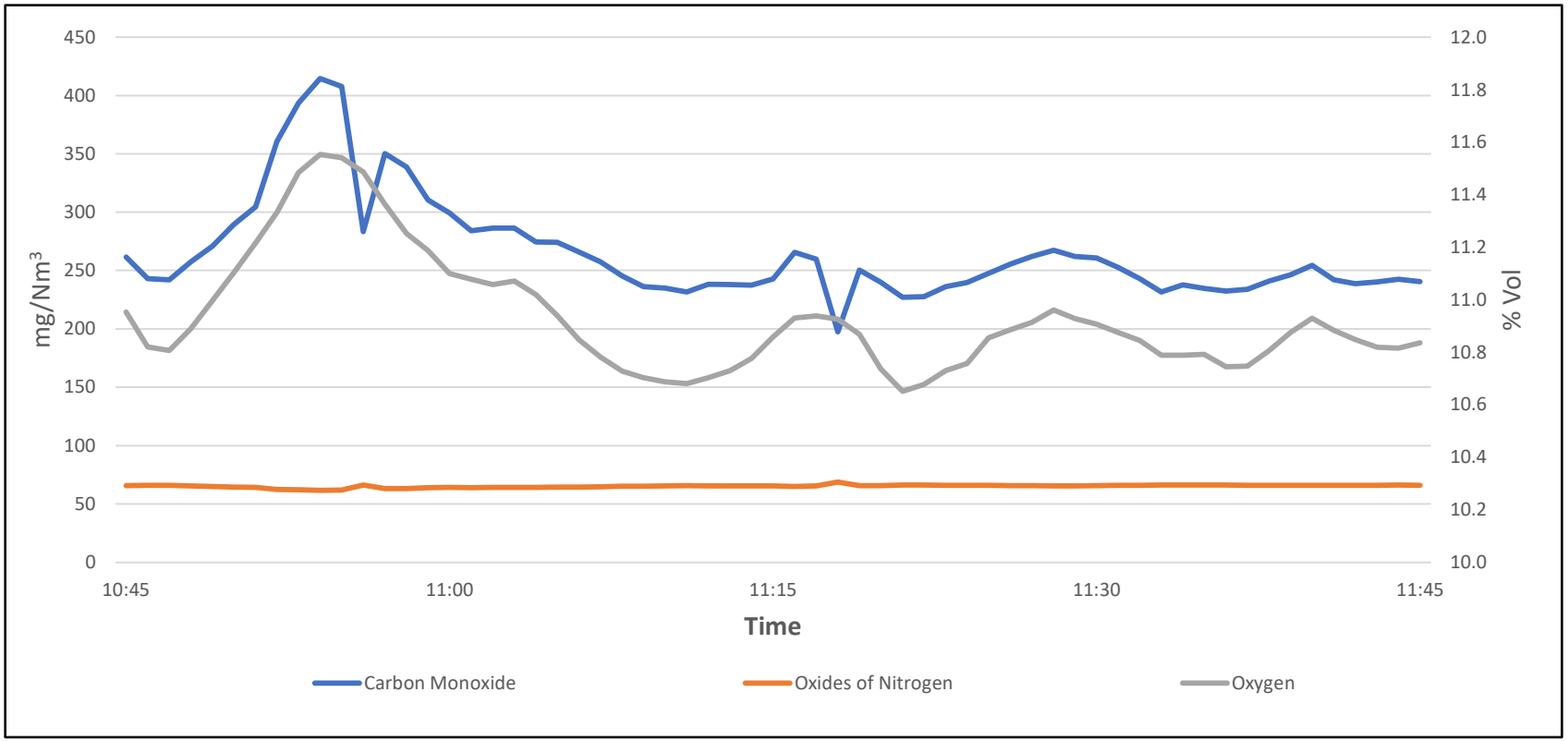
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 2B

Gaseous Emissions Graphical Data for Carbon Monoxide, and Oxides of Nitrogen

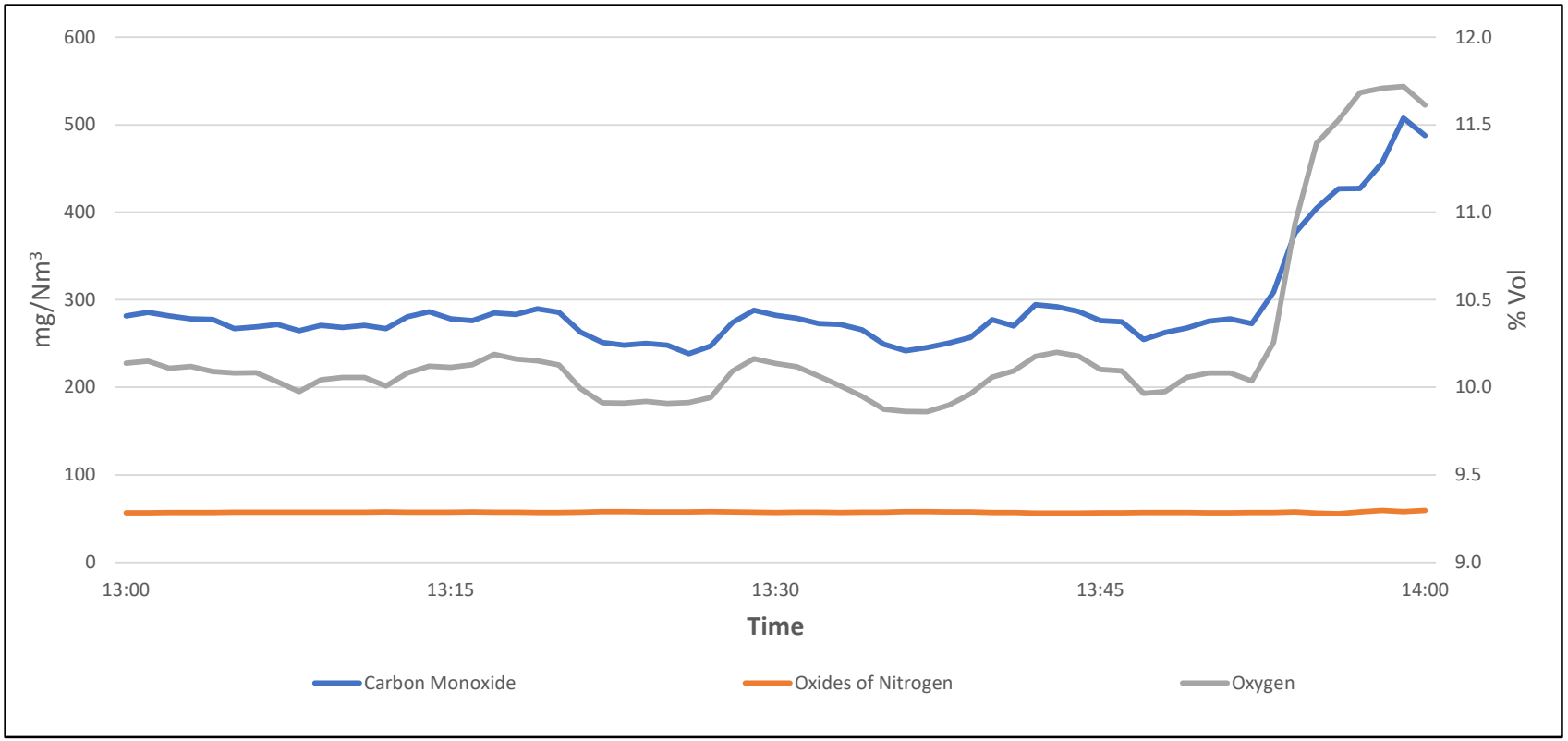
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 2D

Gaseous Emissions Graphical Data for Carbon Monoxide, and Oxides of Nitrogen

Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



2.2.5 - Gas Calibration Log

GAS CALIBRATION RECORD

Client:		Intertek Ltd		Job Reference:		INTK54OCT21	Calibration By:	M Ellison	Comments:	
Site:		South Hook LNG		Date:		11/10/2021	MCERTs ID:	MM-05-682		
Stack:		SCV 1C & 1E		Leak Check Method:		Flow Method	Test Team :	MRE/RH		
Species		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**	**Carbon Dioxide**			
Analyser Type/ID		Horiba PG250 AS0208		Horiba PG250 AS0208		Horiba PG250 AS0208	Horiba PG250 AS0208			
Gas Cylinder ID		256776SG		256776SG		232869SG	232869SG			
Gas Cylinder Concentration		140.3 ppm		75.2 ppm		15.3 % Vol	15.22 % Vol			
Concentration Uncertainty		1 %		1 %		1 %	1 %			
Span Value		140.3 ppm		75.2 ppm		15.3 % Vol	15.22 % Vol			
Analyser Range 0 -		200 ppm		250 ppm		25 % Vol	20 % Vol			
ANALYSER ADJUSTMENT										
Check Zero	Time	14:10		14:10		14:10	14:10			
	Reading	0.6 ppm		0 ppm		-0.05 % Vol	-0.01 % Vol			
	Gain	0		0		-15	-3			
Adjust Zero	Time	14:11		14:11		14:11	14;11			
	Reading	0 ppm		0 ppm		0 % Vol	0 % Vol			
	Gain	0		0		-16	-3			
Check Span	Time	14:21		14:21		14:15	14:15			
	Reading	147.7 ppm		75.1 ppm		15.39 % Vol	15.62 % Vol			
	Gain	1.427		1.074		0.988	0.976			
Adjust Span	Time	14:22		14:22		14:16	14:16			
	Reading	140.3 ppm		75.2 ppm		15.3 % Vol	15.22 % Vol			
	Gain	1.369		1.074		0.983	0.964			
Check Zero	Time	14:25		14:25		14:25	14:25			
	Reading	1 ppm		0.5 ppm		-0.04 % Vol	0.03 % Vol			
Zero Drift		1.00 ppm		0.50 ppm		0.04 % Vol	0.03 % Vol			
Acceptance		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**	**Accept <2% Range**			
SAMPLING SYSTEM CHECK - FLOW METHOD		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**	**Carbon Dioxide**			
Expected Flow		0.4 l/min		0.4 l/min		0.4 l/min	0.4 l/min			
Time		14:05		14:05		14:05	14:05			
Reading		0		0		0	0			
PASS/FAIL		**PASS**		**PASS**		**PASS**	**PASS**			
POST TEST DRIFT CHECK		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**	**Carbon Dioxide**			
Span Value		140.3 ppm		75.2 ppm		15.3 % Vol	15.22 % Vol			
Check Zero	Time	17:10		17:10		17:10	17:10			
	Reading	0.1 ppm		0.1 ppm		0.04 % Vol	0.06 % Vol			
	Drift (%)	**0.1**		**0.1**		**0.3**	**0.4**			
	Acceptance	**Accept**		**Accept**		**Accept**	**Accept**			
Check Span	Time	17:20		17:20		17:15	17:15			
	Reading	134.6 ppm		76.8 ppm		15.31 % Vol	14.99 % Vol			
	Drift (%)	**4.1**		**2.1**		**0.1**	**1.5**			
	Acceptance	**Drift Correct**		**Drift Correct**		**Accept**	**Accept**			

GAS CALIBRATION RECORD

Client:		Intertek Ltd		Job Reference:		INTK54OCT21		Calibration By:	M Ellison	Comments:	
Site:		South Hook LNG		Date:		12/10/2021		MCERTs ID:	MM-05-682		
Stack:		SCV 1H		Leak Check Method:		Flow Method		Test Team :	MRE/RH		
Species		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**		**Carbon Dioxide**			
Analyser Type/ID		Horiba PG250 SRM AS0450		Horiba PG250 SRM AS0450		Horiba PG250 SRM AS0450		Horiba PG250 SRM AS0450			
Gas Cylinder ID		256776SG		256776SG		232869SG		232869SG			
Gas Cylinder Concentration		140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
Concentration Uncertainty		1 %		1 %		1 %		1 %			
Span Value		140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
Analyser Range 0 -		200 ppm		250 ppm		25 % Vol		20 % Vol			
ANALYSER ADJUSTMENT											
Check Zero	Time	12:19		12:19		12:19		12:19			
	Reading	-0.8 ppm		0 ppm		-0.1 % Vol		0 % Vol			
	Gain	-1		1		9		0			
Adjust Zero	Time	12:20		12:20		12:20		12:20			
	Reading	0 ppm		0 ppm		0 % Vol		0 % Vol			
	Gain	-2		1		6		0			
Check Span	Time	12:30		12:30		12:25		12:25			
	Reading	141.8 ppm		74.9 ppm		15.5 % Vol		15.57 % Vol			
	Gain	1.058		1.009		0.885		0.95			
Adjust Span	Time	12:31		12:31		12:26		12:26			
	Reading	140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
	Gain	1.052		0.997		0.873		0.94			
Check Zero	Time			12:34							
	Reading	0.8 ppm		0.3 ppm		-0.03 % Vol		0.02 % Vol			
Zero Drift		0.80 ppm		0.30 ppm		0.03 % Vol		0.02 % Vol			
Acceptance		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**			
SAMPLING SYSTEM CHECK - FLOW METHOD		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**		**Carbon Dioxide**			
Expected Flow		0.5 l/min		0.5 l/min		0.5 l/min		0.5 l/min			
Time		12:01		12:01		12:01		12:01			
Reading		0		0		0		0			
PASS/FAIL		**PASS**		**PASS**		**PASS**		**PASS**			
POST TEST DRIFT CHECK		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**		**Carbon Dioxide**			
Span Value		140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
Check Zero	Time	17:42		17:42		17:42		17:42			
	Reading	2 ppm		0.1 ppm		-0.08 % Vol		0.07 % Vol			
	Drift (%)	**1.4**		**0.1**		**0.5**		**0.5**			
	Acceptance	**Accept**		**Accept**		**Accept**		**Accept**			
Check Span	Time	17:46		17:46		17:51		17:51			
	Reading	136.8 ppm		73.6 ppm		15.12 % Vol		15.12 % Vol			
	Drift (%)	**2.5**		**2.1**		**1.2**		**0.7**			
	Acceptance	**Drift Correct**		**Drift Correct**		**Accept**		**Accept**			

GAS CALIBRATION RECORD

Client:		Intertek Ltd		Job Reference:		INTK54OCT21		Calibration By:		M Ellison	Comments:
Site:		South Hook LNG		Date:		17/11/2021		MCERTs ID:		MM-05-682	
Stack:		SCV 2A		Leak Check Method:		Flow Method		Test Team :		MRE/AML	
Species		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**		**Carbon Dioxide**			
Analyser Type/ID		Horiba PG250 AS0208		Horiba PG250 AS0208		Horiba PG250 AS0208		Horiba PG250 AS0208			
Gas Cylinder ID		256776SG		256776SG		232869SG		232869SG			
Gas Cylinder Concentration		140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
Concentration Uncertainty		1 %		1 %		1 %		1 %			
Span Value		140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
Analyser Range 0 -		200 ppm		250 ppm		25 % Vol		20 % Vol			
ANALYSER ADJUSTMENT											
Check Zero	Time	09:56		09:56		09:56		09:56			
	Reading	0.1 ppm		0 ppm		0 % Vol		0 % Vol			
	Gain	0		0		-13		-3			
Adjust Zero	Time	09:57		09:57		09:57		09:57			
	Reading	0 ppm		ppm		0 % Vol		0 % Vol			
	Gain	0		0		-14		-3			
Check Span	Time	09:59		09:59		10:05		10:05			
	Reading	145.8 ppm		74.7 ppm		15.18 % Vol		15.08 % Vol			
	Gain	1.442		1.172		1.014		0.964			
Adjust Span	Time	10:00		10:00		10:06		10:06			
	Reading	140.4 ppm		75.3 ppm		15.31 % Vol		15.24 % Vol			
	Gain	1.384		1.177		1.02		0.967			
Check Zero	Time	10:08		10:08		10:08		10:08			
	Reading	1.8 ppm		0.2 ppm		-0.05 % Vol		0.08 % Vol			
Zero Drift		1.80 ppm		0.20 ppm		0.05 % Vol		0.08 % Vol			
Acceptance		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**			
SAMPLING SYSTEM CHECK - FLOW METHOD		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**		**Carbon Dioxide**			
Expected Flow		0.4 l/min		0.4 l/min		0.4 l/min		0.4 l/min			
Time		09:40		09:40		09:40		09:40			
Reading		0		0		0		0			
PASS/FAIL		**PASS**		**PASS**		**PASS**		**PASS**			
POST TEST DRIFT CHECK		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**		**Carbon Dioxide**			
Span Value		140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
Check Zero	Time	17:13		17:13		17:13		17:13			
	Reading	1.5 ppm		0.8 ppm		0.05 % Vol		0.07 % Vol			
	Drift (%)	**1.1**		**0.0**		**0.3**		**0.5**			
	Acceptance	**Accept**		**Accept**		**Accept**		**Accept**			
Check Span	Time	17:16		17:16		17:23		17:23			
	Reading	134.5 ppm		78.9 ppm		15.53 % Vol		14.95 % Vol			
	Drift (%)	**4.2**		**4.8**		**1.4**		**1.9**			
	Acceptance	**Drift Correct**		**Drift Correct**		**Accept**		**Accept**			

GAS CALIBRATION RECORD

Client:		Intertek Ltd		Job Reference:		INTK54OCT21		Calibration By:		M Ellison	Comments:
Site:		South Hook LNG		Date:		18/11/2021		MCERTs ID:		MM-05-682	
Stack:		SCV 2B & 2D		Leak Check Method:		Flow Method		Test Team :		MRE/AML	
Species		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**		**Carbon Dioxide**			
Analyser Type/ID		Horiba PG250 AS0208		Horiba PG250 AS0208		Horiba PG250 AS0208		Horiba PG250 AS0208			
Gas Cylinder ID		256776SG		256776SG		232869SG		232869SG			
Gas Cylinder Concentration		140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
Concentration Uncertainty		1 %		1 %		1 %		1 %			
Span Value		140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
Analyser Range 0 -		200 ppm		250 ppm		25 % Vol		20 % Vol			
ANALYSER ADJUSTMENT											
Check Zero	Time	09:13		09:13		09:13		09:13			
	Reading	1.7 ppm		0.1 ppm		0.02 % Vol		0 % Vol			
	Gain	0		0		-14		-3			
Adjust Zero	Time	09:14		09:14		09:14		09:14			
	Reading	0 ppm		0 ppm		0 % Vol		0 % Vol			
	Gain	0		0		-14		-3			
Check Span	Time	09:16		09:16		09:20		09:20			
	Reading	136.2 ppm		76.4 ppm		15.46 % Vol		15.3 % Vol			
	Gain	1.384		1.177		1.02		0.967			
Adjust Span	Time	09:17		09:17		09:21		09:21			
	Reading	140.6 ppm		75.7 ppm		15.31 % Vol		15.22 % Vol			
	Gain	1.426		1.169		1.009		0.965			
Check Zero	Time	09:24		09:24		09:24		09:24			
	Reading	0.6 ppm		0.1 ppm		-0.05 % Vol		0.06 % Vol			
Zero Drift		0.60 ppm		0.10 ppm		0.05 % Vol		0.06 % Vol			
Acceptance		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**			
SAMPLING SYSTEM CHECK - FLOW METHOD		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**		**Carbon Dioxide**			
Expected Flow		0.4 l/min		0.4 l/min		0.4 l/min		0.4 l/min			
Time		09:25		09:25		09:25		09:25			
Reading		0		0		0		0			
PASS/FAIL		**PASS**		**PASS**		**PASS**		**PASS**			
POST TEST DRIFT CHECK		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**		**Carbon Dioxide**			
Span Value		140.3 ppm		75.2 ppm		15.3 % Vol		15.22 % Vol			
Check Zero	Time	13:19		13:19		13:19		13:19			
	Reading	1.1 ppm		0.7 ppm		-0.06 % Vol		0.04 % Vol			
	Drift (%)	**0.8**		**0.9**		**0.4**		**0.3**			
	Acceptance	**Accept**		**Accept**		**Accept**		**Accept**			
Check Span	Time	13:22		13:22		13:29		13:29			
	Reading	137.3 ppm		79.4 ppm		15.34 % Vol		14.85 % Vol			
	Drift (%)	**2.4**		**4.9**		**0.2**		**2.4**			
	Acceptance	**Drift Correct**		**Drift Correct**		**Accept**		**Drift Correct**			

2.2.6 - Uncertainty Calculations

SCV 1C Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0208

v1.0 May-20

		Cal gas conc	15.30	**% vol**
Measured concentration	9.47	**% vol**	**Full Scale**	25.00	**% vol**

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% range		≤0.2 % vol
Standard deviation of repeatability at span level	0.1	% range		≤0.2 % vol
Deviation from linearity(lack of fit)	0.3	% range		≤0.3 % vol
Zero drift	0.3	% of span value		≤±5% span value
Span drift	0.1	% of span value		≤±5% span value
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	-0.1	% vol/20K		≤0.5 % vol
Cross sensitivity	0.6	% vol		≤0.4 % vol
Influence of voltage	0.0	% vol/10V		≤0.2 % vol
Influence from vibration	0.0	% vol		≤0.2 % vol
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges			
	min	max	value at calib	
flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
temp	290	292	290	K
Voltage	105	115	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}				0.02
Lack of fit			u_{fit}				0.04
Zero drift			u_{0dr}				0.02
Span drift			u_{sdr}				0.01
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.004
Cross sensitivity			u_{interf}				0.32
Influence of voltage			u_{volt}				0.000
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.05

Measurement uncertainty				
Combined uncertainty			0.33	% vol
Expanded uncertainty	k =	2	0.66	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.66**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**7.01**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	N/A	**mg/m^3 (Corrected)**	**Cal gas conc.**	175.44	**mg.m^{-3}**
Measured concentration	106.69	**mg/m3 (101.3kPa, 273K)**	**Range**	250.09	**mg/m^3**
Measured concentration	166.60	**mg/m^3 (Corrected)**			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	140.3	**ppm**
Conversion	1.25	

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.0	101.3	273.0
	measured	9.47	0.0	101.3	273.0
	Uncert	0.66	0.0	0.0	0.0
Factors		1.56	1.00	1.00	1.00
Uncertainty in factor		0.09	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.56**	uf	**0.09**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.1	% of range		≤±1% range
Standard deviation of repeatability at span level	0.1	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.8	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.1	% full scale/20K		≤±5% range
Cross sensitivity	2.9	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.3	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	290	292	290	K
Voltage	105	115	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}		0.26
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		2.56
Zero drift		u_{0dr}		0.00
Span drift		u_{sdr}		0.00
Influence of sample gas flow		u_{spres}		0.03
Influence of atmospheric pressure		u_{apres}		0.51
Influence of ambient temperature		u_{temp}		0.01
Cross sensitivity		u_{interf}		4.19
Influence of voltage		u_{volt}		0.00
Influence from vibration		u_{vib}		0.00
Uncertainty of calibration gas		u_{cal}		0.53
Uncertainty in std conditions correction factor (no O_2 factor)		u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}		9.59

Measurement uncertainty				
Combined uncertainty			4.97	mg/m^3
Expanded uncertainty	k =	2	9.93	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.93	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**24.67**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**24.67 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**14.81 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

Uncertainty calculation for gaseous measurement of NOx according to BS EN 14792:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	154.4	mg.m^{-3}
Measured concentration	34.12	mg/m3 (101.3kPa, 273K)	**Range**	513.4	mg/m^3
Measured concentration	53.28	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	250	ppm
Cal gas conc	75.2	ppm
Conversion	2.05	

NO/NO2 ratio	99

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.0	101.3	273.0
	measured	9.47	0.0	101.3	273.0
	Uncert	0.66	0.0	0.0	0.0
Factors		1.56	1.00	1.00	1.00
Uncertainty in factor		0.09	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.56**	uf	**0.09**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.5	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.2	% full scale/20K		≤±5% range
Cross sensitivity	0.7	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.0	%		≥95%
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	290	292	290	K
Voltage	105	115	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}		0.24
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{fit}		1.36
Zero drift		u_{0dr}		0.00
Span drift		u_{sdr}		0.00
Influence of sample gas flow		u_{spres}		0.06
Influence of atmospheric pressure		u_{apres}		1.05
Influence of ambient temperature		u_{temp}		0.05
Cross sensitivity		u_{interf}		2.07
Influence of voltage		u_{volt}		0.00
Influence from vibration		u_{vib}		0.00
Converter efficiency		u_{conv}		0.98
Uncertainty of calibration gas		u_{cal}		0.17
Uncertainty in std conditions correction factor (no O_2 factor)		u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}		3.07

Measurement uncertainty				
Combined uncertainty			2.88	mg/m^3
Expanded uncertainty	k =	2	5.76	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			5.76	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**10.89**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**10.89**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**20.44**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**5.39**	**% ELV**

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	3.086	m/s
Air density meas. during calibration	1.213	kg/m^3
DP meas. during calibration	8.05	Pa
Uncertainty of velocity meas. at calibration	2.1	%
Uncertainty of air density meas. at calibration	0.075	%
Uncertainty of DP meas. at calibration	3.88	%
Pitot coefficient, K	0.833	-
Expanded uncertainty (95%, k=2) as % of value	8.8	%
Expanded uncertainty (95%, k=2)	0.07	

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	100840	101062.2	222.2	51.2					51.2	14.5	1.66	83	6.6	83.9	9.5	29.44	29.25
2	100840	101062.2	222.2	61.8					61.8	14.6	1.66	83	6.6	83.9	9.5	29.44	29.25
3	100840	101062.2	222.2	52.9					52.9	14.8	1.66	83	6.6	83.9	9.5	29.44	29.25
4	100840	101062.2	222.2	42.2					42.2	14.9	1.66	83	6.6	83.9	9.5	29.44	29.25
5	100840	101062.2	222.2	33.3					33.3	14.9	1.66	83	6.6	83.9	9.5	29.44	29.25
6	100840	101062.2	222.2	44.1					44.1	14.9	1.66	83	6.6	83.9	9.5	29.44	29.25
7	100840	101062.2	222.2	33.3					33.3	14.5	1.66	83	6.6	83.9	9.5	29.44	29.25
8	100840	101062.2	222.2	42.2					42.2	14.8	1.66	83	6.6	83.9	9.5	29.44	29.25
9	100840	101062.2	222.2	47.1					47.1	14.8	1.66	83	6.6	83.9	9.5	29.44	29.25
10	100840	101062.2	222.2	58.8					58.8	14.8	1.66	83	6.6	83.9	9.5	29.44	29.25
11	100840	101062.2	222.2	57.8					57.8	14.7	1.66	83	6.6	83.9	9.5	29.44	29.25
12	100840	101062.2	222.2	66.7					66.7	14.5	1.66	83	6.6	83.9	9.5	29.44	29.25
Mean	**100840**	**60726**	**222.2**	**49.3**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**49.3**	**14.7**	**1.7**	**83.0**	**6.6**	**90.3**	**9.5**	**28.86**	**28.75**

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

Mean density	**0.730**	**kg/m3**

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

Mean velocity	**9.63**	**m/sec**		
Standard uncertainty of velocity	**0.43**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.87**	**m/sec**	**9.0**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**59612**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**5480**	**m^3/hour**	**#DIV/0!**	**m3/hour**
Volume flow rate expanded uncertainty	**9.2**	**% of value**	**#DIV/0!**	**% of value**

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

SCV 1E Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0208

v1.0 May-20

		Cal gas conc	15.30	**% vol**
Measured concentration	10.27	**% vol**	**Full Scale**	25.00	**% vol**

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% range		≤0.2 % vol
Standard deviation of repeatability at span level	0.1	% range		≤0.2 % vol
Deviation from linearity(lack of fit)	0.3	% range		≤0.3 % vol
Zero drift	0.3	% of span value		≤±5% span value
Span drift	0.1	% of span value		≤±5% span value
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	-0.1	% vol/20K		≤0.5 % vol
Cross sensitivity	0.6	% vol		≤0.4 % vol
Influence of voltage	0.0	% vol/10V		≤0.2 % vol
Influence from vibration	0.0	% vol		≤0.2 % vol
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges			
	min	max	value at calib	
flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
temp	285	288	285	K
Voltage	105	115	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}				0.02
Lack of fit			u_{fit}				0.04
Zero drift			u_{0dr}				0.02
Span drift			u_{sdr}				0.01
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.006
Cross sensitivity			u_{interf}				0.32
Influence of voltage			u_{volt}				0.000
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.05

Measurement uncertainty				
Combined uncertainty			0.33	% vol
Expanded uncertainty	k =	2	0.66	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.66**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.48**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	N/A	**mg/m^3 (Corrected)**	**Cal gas conc.**	175.44	**mg.m^{-3}**
Measured concentration	19.15	**mg/m3 (101.3kPa, 273K)**	**Range**	250.09	**mg/m^3**
Measured concentration	32.13	**mg/m^3 (Corrected)**			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	140.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	10.27	0.0	101.3	273.0
	Uncert	0.66	0.0	0.0	0.0
Factors		1.68	1.00	1.00	1.00
Uncertainty in factor		0.10	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.68**	uf	**0.10**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.1	% of range		≤±1% range
Standard deviation of repeatability at span level	0.1	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.8	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.1	% full scale/20K		≤±5% range
Cross sensitivity	2.9	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.3	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	285	288	285	K
Voltage	105	115	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}		0.26
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{flt}		2.56
Zero drift	u_{0dr}		0.00
Span drift	u_{sdr}		0.00
Influence of sample gas flow	u_{spres}		0.03
Influence of atmospheric pressure	u_{apres}		0.51
Influence of ambient temperature	u_{temp}		0.01
Cross sensitivity	u_{interf}		4.19
Influence of voltage	u_{volt}		0.00
Influence from vibration	u_{vib}		0.00
Uncertainty of calibration gas	u_{cal}		0.10
Uncertainty in std conditions correction factor (no O_2 factor)	u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)	u_{of}		1.99

Measurement uncertainty				
Combined uncertainty			4.94	mg/m^3
Expanded uncertainty	k =	2	9.88	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.88	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**17.04**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**17.04 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**53.04 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

Uncertainty calculation for gaseous measurement of NOx according to BS EN 14792:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	154.4	mg.m^{-3}
Measured concentration	44.56	mg/m3 (101.3kPa, 273K)	**Range**	513.4	mg/m^3
Measured concentration	74.73	mg/m^3 (Corrected)			

NO/NO2 ratio	99

Gas	NOx	
Full Scale	250	ppm
Cal gas conc	75.2	ppm
Conversion	2.05	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	10.27	0.0	101.3	273.0
	Uncert	0.66	0.0	0.0	0.0
Factors		1.68	1.00	1.00	1.00
Uncertainty in factor		0.10	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.68**	uf	**0.10**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.5	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.2	% full scale/20K		≤±5% range
Cross sensitivity	0.7	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.0	%		≥95%
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	285	288	285	K
Voltage	105	115	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}		0.24
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{fit}		1.36
Zero drift	u_{0dr}		0.00
Span drift	u_{sdr}		0.00
Influence of sample gas flow	u_{spres}		0.06
Influence of atmospheric pressure	u_{apres}		1.05
Influence of ambient temperature	u_{temp}		0.08
Cross sensitivity	u_{interf}		2.07
Influence of voltage	u_{volt}		0.00
Influence from vibration	u_{vib}		0.00
Converter efficiency	u_{conv}		1.27
Uncertainty of calibration gas	u_{cal}		0.22
Uncertainty in std conditions correction factor (no O_2 factor)	u_r		0.00
Uncertainty in std conditions correction factor (including O_2 factor)	u_{of}		4.63

Measurement uncertainty				
Combined uncertainty			3.00	mg/m^3
Expanded uncertainty	k =	2	6.00	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			6.00	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**13.67**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**13.67**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**18.30**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**5.61**	**% ELV**

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	3.086	m/s
Air density meas. during calibration	1.213	kg/m^3
DP meas. during calibration	8.05	Pa
Uncertainty of velocity meas. at calibration	2.1	%
Uncertainty of air density meas. at calibration	0.075	%
Uncertainty of DP meas. at calibration	3.88	%
Pitot coefficient, K	0.833	-
Expanded uncertainty (95%, k=2) as % of value	8.8	%
Expanded uncertainty (95%, k=2)	0.07	

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	100940	101213.7	273.7	60.8					60.8	15.5	1.71	18.4	5.9	83.5	10.6	29.37	29.17
2	100940	101213.7	273.7	54.9					54.9	15.4	1.71	18.4	5.9	83.5	10.6	29.37	29.17
3	100940	101213.7	273.7	66.7					66.7	15.3	1.71	18.4	5.9	83.5	10.6	29.37	29.17
4	100940	101213.7	273.7	55.9					55.9	15.2	1.71	18.4	5.9	83.5	10.6	29.37	29.17
5	100940	101213.7	273.7	44.1					44.1	15.0	1.71	18.4	5.9	83.5	10.6	29.37	29.17
6	100940	101213.7	273.7	57.8					57.8	15.0	1.71	18.4	5.9	83.5	10.6	29.37	29.17
7	100940	101213.7	273.7	47.1					47.1	15.1	1.71	18.4	5.9	83.5	10.6	29.37	29.17
8	100940	101213.7	273.7	48.0					48.0	15.1	1.71	18.4	5.9	83.5	10.6	29.37	29.17
9	100940	101213.7	273.7	54.9					54.9	15.1	1.71	18.4	5.9	83.5	10.6	29.37	29.17
10	100940	101213.7	273.7	69.6					69.6	15.2	1.71	18.4	5.9	83.5	10.6	29.37	29.17
11	100940	101213.7	273.7	67.6					67.6	15.1	1.71	18.4	5.9	83.5	10.6	29.37	29.17
12	100940	101213.7	273.7	77.4					77.4	15.1	1.71	18.4	5.9	83.5	10.6	29.37	29.17
Mean	**100940**	**101214**	**273.7**	**58.7**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**58.7**	**15.2**	**1.7**	**18.4**	**5.9**	**90.1**	**10.6**	**28.82**	**28.70**

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

Mean density	**1.213**	**kg/m3**

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

Mean velocity	**8.17**	**m/sec**		
Standard uncertainty of velocity	**0.36**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.73**	**m/sec**	**8.9**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**50607**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4616**	**m^3/hour**	**#DIV/0!**	**m3/hour**
Volume flow rate expanded uncertainty	**9.1**	**% of value**	**#DIV/0!**	**% of value**

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

SCV 1H Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 SRM AS0450

v1.0 May-20

		Cal gas conc	15.30	**% vol**
Measured concentration	12.00	**% vol**	**Full Scale**	25.00	**% vol**

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.1	% range		≤0.2 % vol
Standard deviation of repeatability at span level	0.0	% range		≤0.2 % vol
Deviation from linearity(lack of fit)	0.6	% range		≤0.3 % vol
Zero drift	0.5	% of span value		≤±5% span value
Span drift	1.2	% of span value		≤±5% span value
Influence of sample gas flow	0.1	% vol/10l/h		≤0.2 % vol
Influence of atmospheric pressure	0.2	% vol/3kPa		≤0.2 % vol
Influence of ambient temperature	0.2	% vol/20K		≤0.5 % vol
Cross sensitivity	0.2	% vol		≤0.4 % vol
Influence of voltage	0.1	% vol/10V		≤0.2 % vol
Influence from vibration	0.0	% vol		≤0.2 % vol
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges			
	min	max	value at calib	
flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
temp	280	288	282	K
Voltage	105	115	110	V

Performance characteristic			**Uncertainty**	**Value of uncertainty quantity**			**% vol**
Standard deviation of repeatability at zero			u_{r0}				0.02
Standard deviation of repeatability at span level			u_{rs}				0.00
Lack of fit			u_{fit}				0.08
Zero drift			u_{0dr}				0.05
Span drift			u_{sdr}				0.10
Influence of sample gas flow			u_{spres}				0.000
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				0.029
Cross sensitivity			u_{interf}				0.11
Influence of voltage			u_{volt}				0.014
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.06

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%**		**3.21**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 SRM AS0450

v1.0 May-20

Emission Limit Value	N/A	**mg/m^3 (Corrected)**	**Cal gas conc.**	175.44	**mg.m^{-3}**
Measured concentration	224.98	**mg/m3 (101.3kPa, 273K)**	**Range**	250.09	**mg/m^3**
Measured concentration	449.99	**mg/m^3 (Corrected)**			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	140.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	12.00	0.0	101.3	273.0
	Uncert	0.38	0.0	0.0	0.0
Factors		2.00	1.00	1.00	1.00
Uncertainty in factor		0.09	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**2.00**	uf	**0.09**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.4	% of range		≤±1% range
Standard deviation of repeatability at span level	0.4	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.8	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	-0.3	% full scale/10l		≤±2% range
Influence of atmospheric pressure	0.1	% full scale /3kPa		≤±2% range
Influence of ambient temperature	1.5	% full scale/20K		≤±5% range
Cross sensitivity	0.1	% full scale		≤4% range
Influence of voltage	0.3	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.3	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	280	288	282	K
Voltage	105	115	110	V

Performance characteristic		**Uncertainty**	**Value of uncertainty quantity**	**mg/m3**
Standard deviation of repeatability at zero		u_{r0}		1.07
Standard deviation of repeatability at span level		u_{rs}		0.00
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		2.61
Zero drift		u_{0dr}		0.00
Span drift		u_{sdr}		0.00
Influence of sample gas flow		u_{spres}		0.00
Influence of atmospheric pressure		u_{apres}		0.02
Influence of ambient temperature		u_{temp}		0.57
Cross sensitivity		u_{interf}		0.14
Influence of voltage		u_{volt}		0.24
Influence from vibration		u_{vib}		0.00
Uncertainty of calibration gas		u_{cal}		1.12
Uncertainty in std conditions correction factor (no O_2 factor)		u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}		19.24

Measurement uncertainty				
Combined uncertainty			3.10	mg/m^3
Expanded uncertainty	k =	2	6.21	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			6.21	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**40.44**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**40.44 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**8.99 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

Uncertainty calculation for gaseous measurement of NOx according to BS EN 14792:2017 - Horiba PG250 SRM AS0450

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	154.4	mg.m^{-3}
Measured concentration	21.67	mg/m3 (101.3kPa, 273K)	**Range**	513.4	mg/m^3
Measured concentration	43.35	mg/m^3 (Corrected)			
NO/NO2 ratio	99		**Gas**	NOx	
			Full Scale	250	ppm
			Cal gas conc	75.2	ppm
			Conversion	2.05	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	12.00	0.0	101.3	273.0
	Uncert	0.38	0.0	0.0	0.0
Factors		2.00	1.00	1.00	1.00
Uncertainty in factor		0.09	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**2.00**	uf	**0.09**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.0	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	0.4	% full scale/10l		≤±2% range
Influence of atmospheric pressure	-0.2	% full scale /3kPa		≤±2% range
Influence of ambient temperature	-2.4	% full scale/20K		≤±5% range
Cross sensitivity	0.5	% full scale		≤4% range
Influence of voltage	-0.1	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.4	%		≥95%
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	280	288	282	K
Voltage	105	115	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}				0.00
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{flt}				0.00
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.00
Influence of sample gas flow		u_{spres}				0.01
Influence of atmospheric pressure		u_{apres}				-0.08
Influence of ambient temperature		u_{temp}				-1.91
Cross sensitivity		u_{interf}				1.48
Influence of voltage		u_{volt}				-0.15
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				0.57
Uncertainty of calibration gas		u_{cal}				0.11
Uncertainty in std conditions correction factor (no O_2 factor)		u_f				0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}				1.85

Measurement uncertainty				
Combined uncertainty			2.49	mg/m^3
Expanded uncertainty	k =	2	4.98	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			4.98	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**10.62**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**10.62**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**24.51**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**4.65**	**% ELV**

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	3.086	m/s
Air density meas. during calibration	1.213	kg/m^3
DP meas. during calibration	8.05	Pa
Uncertainty of velocity meas. at calibration	2.1	%
Uncertainty of air density meas. at calibration	0.075	%
Uncertainty of DP meas. at calibration	3.88	%
Pitot coefficient, K	0.833	-
Expanded uncertainty (95%, k=2) as % of value	8.8	%
Expanded uncertainty (95%, k=2)	0.07	

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	101190	101442.4	252.4	51.0					51.0	14.0	1.57	185	5	83.0	12	29.28	29.10
2	101190	101442.4	252.4	60.8					60.8	14.0	1.57	185	5	83.0	12	29.28	29.10
3	101190	101442.4	252.4	61.8					61.8	14.1	1.57	185	5	83.0	12	29.28	29.10
4	101190	101442.4	252.4	66.7					66.7	14.0	1.57	185	5	83.0	12	29.28	29.10
5	101190	101442.4	252.4	75.5					75.5	14.0	1.57	185	5	83.0	12	29.28	29.10
6	101190	101442.4	252.4	64.7					64.7	14.0	1.57	185	5	83.0	12	29.28	29.10
7	101190	101442.4	252.4	32.4					32.4	14.0	1.57	185	5	83.0	12	29.28	29.10
8	101190	101442.4	252.4	55.9					55.9	13.9	1.57	185	5	83.0	12	29.28	29.10
9	101190	101442.4	252.4	60.8					60.8	13.8	1.57	185	5	83.0	12	29.28	29.10
10	101190	101442.4	252.4	64.7					64.7	13.7	1.57	185	5	83.0	12	29.28	29.10
11	101190	101442.4	252.4	65.7					65.7	13.6	1.57	185	5	83.0	12	29.28	29.10
12	101190	101442.4	252.4	73.5					73.5	13.5	1.57	185	5	83.0	12	29.28	29.10
Mean	**101190**	**101442**	**252.4**	**61.1**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**61.1**	**13.9**	**1.6**	**185.0**	**5.0**	**89.8**	**12.0**	**28.77**	**28.66**

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

Mean density	**1.219**	**kg/m3**

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

Mean velocity	**8.30**	**m/sec**		
Standard uncertainty of velocity	**0.37**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.74**	**m/sec**	**8.9**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**51417**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4688**	**m^3/hour**	**#DIV/0!**	**m3/hour**
Volume flow rate expanded uncertainty	**9.1**	**% of value**	**#DIV/0!**	**% of value**

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

SCV 2A Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0208

v1.0 May-20

		Cal gas conc	15.30	**% vol**
Measured concentration	11.26	**% vol**	**Full Scale**	25.00	**% vol**

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% range		≤0.2 % vol
Standard deviation of repeatability at span level	0.1	% range		≤0.2 % vol
Deviation from linearity(lack of fit)	0.3	% range		≤0.3 % vol
Zero drift	0.3	% of span value		≤±5% span value
Span drift	1.4	% of span value		≤±5% span value
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	-0.1	% vol/20K		≤0.5 % vol
Cross sensitivity	0.6	% vol		≤0.4 % vol
Influence of voltage	0.0	% vol/10V		≤0.2 % vol
Influence from vibration	0.0	% vol		≤0.2 % vol
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges			
	min	max	value at calib	
flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
temp	284	288	281	K
Voltage	105	115	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}				0.02
Lack of fit			u_{fit}				0.04
Zero drift			u_{0dr}				0.03
Span drift			u_{sdr}				0.13
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.018
Cross sensitivity			u_{interf}				0.32
Influence of voltage			u_{volt}				0.000
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.06

Measurement uncertainty				
Combined uncertainty			0.36	% vol
Expanded uncertainty	k =	2	0.71	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.71**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.35**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	N/A	**mg/m^3 (Corrected)**	**Cal gas conc.**	175.44	**mg.m^{-3}**
Measured concentration	200.77	**mg/m3 (101.3kPa, 273K)**	**Range**	250.09	**mg/m^3**
Measured concentration	371.21	**mg/m^3 (Corrected)**			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	140.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	11.26	0.0	101.3	273.0
	Uncert	0.71	0.0	0.0	0.0
Factors		1.85	1.00	1.00	1.00
Uncertainty in factor		0.14	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.85**	uf	**0.14**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.1	% of range		≤±1% range
Standard deviation of repeatability at span level	0.1	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.8	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.1	% full scale/20K		≤±5% range
Cross sensitivity	2.9	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.3	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	284	288	281	K
Voltage	105	115	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}		0.26
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		2.56
Zero drift		u_{0dr}		0.00
Span drift		u_{sdr}		0.00
Influence of sample gas flow		u_{spres}		0.03
Influence of atmospheric pressure		u_{apres}		0.51
Influence of ambient temperature		u_{temp}		0.03
Cross sensitivity		u_{interf}		4.19
Influence of voltage		u_{volt}		0.00
Influence from vibration		u_{vib}		0.00
Uncertainty of calibration gas		u_{cal}		1.00
Uncertainty in std conditions correction factor (no O_2 factor)		u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}		27.26

Measurement uncertainty				
Combined uncertainty			5.04	mg/m^3
Expanded uncertainty	k =	2	10.08	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			10.08	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**57.61**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**57.61 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**15.52 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

Uncertainty calculation for gaseous measurement of NOx according to BS EN 14792:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	154.4	mg.m^{-3}
Measured concentration	30.28	mg/m3 (101.3kPa, 273K)	**Range**	513.4	mg/m^3
Measured concentration	55.98	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	250	ppm
Cal gas conc	75.2	ppm
Conversion	2.05	

NO/NO2 ratio	99

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.0	101.3	273.0
	measured	11.26	0.0	101.3	273.0
	Uncert	0.71	0.0	0.0	0.0
Factors		1.85	1.00	1.00	1.00
Uncertainty in factor		0.14	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.85**	uf	**0.14**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.5	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.2	% full scale/20K		≤±5% range
Cross sensitivity	0.7	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.0	%		≥95%
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	284	288	281	K
Voltage	105	115	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}		0.24
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{fit}		1.36
Zero drift		u_{0dr}		0.00
Span drift		u_{sdr}		0.00
Influence of sample gas flow		u_{spres}		0.06
Influence of atmospheric pressure		u_{apres}		1.05
Influence of ambient temperature		u_{temp}		0.24
Cross sensitivity		u_{interf}		2.07
Influence of voltage		u_{volt}		0.00
Influence from vibration		u_{vib}		0.00
Converter efficiency		u_{conv}		0.87
Uncertainty of calibration gas		u_{cal}		0.15
Uncertainty in std conditions correction factor (no O_2 factor)		u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}		4.11

Measurement uncertainty				
Combined uncertainty			2.85	mg/m^3
Expanded uncertainty	k =	2	5.71	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			5.71	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**13.38**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**13.38**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**23.90**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**5.34**	**% ELV**

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	3.086	m/s
Air density meas. during calibration	1.213	kg/m^3
DP meas. during calibration	8.05	Pa
Uncertainty of velocity meas. at calibration	2.1	%
Uncertainty of air density meas. at calibration	0.075	%
Uncertainty of DP meas. at calibration	3.88	%
Pitot coefficient, K	0.833	-
Expanded uncertainty (95%, k=2) as % of value	8.8	%
Expanded uncertainty (95%, k=2)	0.07	

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	102010	102251	241	38.2					38.2	11.4	1.35	150	5.7	82.9	11.4	29.37	29.21
2	102010	102251	241	54.9					54.9	11.8	1.35	150	5.7	82.9	11.4	29.37	29.21
3	102010	102251	241	54.9					54.9	12.0	1.35	150	5.7	82.9	11.4	29.37	29.21
4	102010	102251	241	70.6					70.6	12.1	1.35	150	5.7	82.9	11.4	29.37	29.21
5	102010	102251	241	70.6					70.6	11.8	1.35	150	5.7	82.9	11.4	29.37	29.21
6	102010	102251	241	77.4					77.4	11.7	1.35	150	5.7	82.9	11.4	29.37	29.21
7	102010	102251	241	32.4					32.4	11.1	1.35	150	5.7	82.9	11.4	29.37	29.21
8	102010	102251	241	52.9					52.9	11.5	1.35	150	5.7	82.9	11.4	29.37	29.21
9	102010	102251	241	56.9					56.9	11.4	1.35	150	5.7	82.9	11.4	29.37	29.21
10	102010	102251	241	69.6					69.6	11.4	1.35	150	5.7	82.9	11.4	29.37	29.21
11	102010	102251	241	75.5					75.5	11.0	1.35	150	5.7	82.9	11.4	29.37	29.21
12	102010	102251	241	69.6					69.6	10.9	1.35	150	5.7	82.9	11.4	29.37	29.21
Mean	**102010**	**102251**	**241.0**	**60.3**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**60.3**	**11.5**	**1.4**	**150.0**	**5.7**	**89.7**	**11.4**	**28.82**	**28.73**

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

Mean density	**1.242**	**kg/m3**

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

Mean velocity	**8.15**	**m/sec**		
Standard uncertainty of velocity	**0.36**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.73**	**m/sec**	**8.9**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**50456**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4605**	**m^3/hour**	**#DIV/0!**	**m3/hour**
Volume flow rate expanded uncertainty	**9.1**	**% of value**	**#DIV/0!**	**% of value**

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

SCV 2B Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0208

v1.0 May-20

		Cal gas conc	15.30	**% vol**
Measured concentration	10.93	**% vol**	**Full Scale**	25.00	**% vol**

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% range		≤0.2 % vol
Standard deviation of repeatability at span level	0.1	% range		≤0.2 % vol
Deviation from linearity(lack of fit)	0.3	% range		≤0.3 % vol
Zero drift	0.4	% of span value		≤±5% span value
Span drift	0.2	% of span value		≤±5% span value
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	-0.1	% vol/20K		≤0.5 % vol
Cross sensitivity	0.6	% vol		≤0.4 % vol
Influence of voltage	0.0	% vol/10V		≤0.2 % vol
Influence from vibration	0.0	% vol		≤0.2 % vol
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges			
	min	max	value at calib	
flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
temp	284	288	281	K
Voltage	105	115	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}				0.02
Lack of fit			u_{fit}				0.04
Zero drift			u_{0dr}				0.03
Span drift			u_{sdr}				0.02
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.018
Cross sensitivity			u_{interf}				0.32
Influence of voltage			u_{volt}				0.000
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.05

Measurement uncertainty				
Combined uncertainty			0.33	% vol
Expanded uncertainty	k =	2	0.67	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.67**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.12**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	N/A	**mg/m^3 (Corrected)**	**Cal gas conc.**	175.44	**mg.m^{-3}**
Measured concentration	148.53	**mg/m3 (101.3kPa, 273K)**	**Range**	250.09	**mg/m^3**
Measured concentration	265.57	**mg/m^3 (Corrected)**			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	140.3	**ppm**
Conversion	1.25	

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.0	101.3	273.0
	measured	10.93	0.0	101.3	273.0
	Uncert	0.67	0.0	0.0	0.0
Factors		1.79	1.00	1.00	1.00
Uncertainty in factor		0.12	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.79**	uf	**0.12**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.1	% of range		≤±1% range
Standard deviation of repeatability at span level	0.1	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.8	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.1	% full scale/20K		≤±5% range
Cross sensitivity	2.9	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.3	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	284	288	281	K
Voltage	105	115	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}		0.26
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		2.56
Zero drift		u_{0dr}		0.00
Span drift		u_{sdr}		0.00
Influence of sample gas flow		u_{spres}		0.03
Influence of atmospheric pressure		u_{apres}		0.51
Influence of ambient temperature		u_{temp}		0.03
Cross sensitivity		u_{interf}		4.19
Influence of voltage		u_{volt}		0.00
Influence from vibration		u_{vib}		0.00
Uncertainty of calibration gas		u_{cal}		0.74
Uncertainty in std conditions correction factor (no O_2 factor)		u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}		17.67

Measurement uncertainty				
Combined uncertainty			4.99	mg/m^3
Expanded uncertainty	k =	2	9.99	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.99	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**39.59**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**39.59 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**14.91 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

Uncertainty calculation for gaseous measurement of NOx according to BS EN 14792:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	154.4	mg.m^{-3}
Measured concentration	36.53	mg/m3 (101.3kPa, 273K)	**Range**	513.4	mg/m^3
Measured concentration	65.31	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	250	ppm
Cal gas conc	75.2	ppm
Conversion	2.05	

NO/NO2 ratio	99

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.0	101.3	273.0
	measured	10.93	0.0	101.3	273.0
	Uncert	0.67	0.0	0.0	0.0
Factors		1.79	1.00	1.00	1.00
Uncertainty in factor		0.12	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.79**	uf	**0.12**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.5	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.2	% full scale/20K		≤±5% range
Cross sensitivity	0.7	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.0	%		≥95%
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	284	288	281	K
Voltage	105	115	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}				0.24
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{fit}				1.36
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.00
Influence of sample gas flow		u_{spres}				0.06
Influence of atmospheric pressure		u_{apres}				1.05
Influence of ambient temperature		u_{temp}				0.24
Cross sensitivity		u_{interf}				2.07
Influence of voltage		u_{volt}				0.00
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				1.04
Uncertainty of calibration gas		u_{cal}				0.18
Uncertainty in std conditions correction factor (no O_2 factor)		u_f				0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}				4.34

Measurement uncertainty				
Combined uncertainty			2.92	mg/m^3
Expanded uncertainty	k =	2	5.83	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			5.83	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**13.57**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**13.57**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**20.78**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**5.45**	**% ELV**

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	3.086	m/s
Air density meas. during calibration	1.213	kg/m^3
DP meas. during calibration	8.05	Pa
Uncertainty of velocity meas. at calibration	2.1	%
Uncertainty of air density meas. at calibration	0.075	%
Uncertainty of DP meas. at calibration	3.88	%
Pitot coefficient, K	0.833	-
Expanded uncertainty (95%, k=2) as % of value	8.8	%
Expanded uncertainty (95%, k=2)	0.07	

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	101890	102083.1	193.1	22.5					22.5	11.8	1.4	109	6	83.1	10.9	29.40	29.24
2	101890	102083.1	193.1	42.2					42.2	12.0	1.4	109	6	83.1	10.9	29.40	29.24
3	101890	102083.1	193.1	45.1					45.1	12.1	1.4	109	6	83.1	10.9	29.40	29.24
4	101890	102083.1	193.1	53.9					53.9	12.1	1.4	109	6	83.1	10.9	29.40	29.24
5	101890	102083.1	193.1	47.1					47.1	12.0	1.4	109	6	83.1	10.9	29.40	29.24
6	101890	102083.1	193.1	42.2					42.2	11.9	1.4	109	6	83.1	10.9	29.40	29.24
7	101890	102083.1	193.1	28.4					28.4	12.0	1.4	109	6	83.1	10.9	29.40	29.24
8	101890	102083.1	193.1	34.3					34.3	12.1	1.4	109	6	83.1	10.9	29.40	29.24
9	101890	102083.1	193.1	45.1					45.1	12.1	1.4	109	6	83.1	10.9	29.40	29.24
10	101890	102083.1	193.1	51.0					51.0	12.4	1.4	109	6	83.1	10.9	29.40	29.24
11	101890	102083.1	193.1	56.9					56.9	12.3	1.4	109	6	83.1	10.9	29.40	29.24
12	101890	102083.1	193.1	66.7					66.7	12.0	1.4	109	6	83.1	10.9	29.40	29.24
Mean	**101890**	**102083**	**193.1**	**44.6**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**44.6**	**12.1**	**1.4**	**109.0**	**6.0**	**89.9**	**10.9**	**28.84**	**28.74**

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

Mean density	**1.238**	**kg/m3**

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

Mean velocity	**7.01**	**m/sec**		
Standard uncertainty of velocity	**0.32**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.64**	**m/sec**	**9.1**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**43387**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4022**	**m^3/hour**	**#DIV/0!**	**m3/hour**
Volume flow rate expanded uncertainty	**9.3**	**% of value**	**#DIV/0!**	**% of value**

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

SCV 2D Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0208

v1.0 May-20

		Cal gas conc	15.30	**% vol**
Measured concentration	10.20	**% vol**	**Full Scale**	25.00	**% vol**

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% range		≤0.2 % vol
Standard deviation of repeatability at span level	0.1	% range		≤0.2 % vol
Deviation from linearity(lack of fit)	0.3	% range		≤0.3 % vol
Zero drift	0.4	% of span value		≤±5% span value
Span drift	0.2	% of span value		≤±5% span value
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	-0.1	% vol/20K		≤0.5 % vol
Cross sensitivity	0.6	% vol		≤0.4 % vol
Influence of voltage	0.0	% vol/10V		≤0.2 % vol
Influence from vibration	0.0	% vol		≤0.2 % vol
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges			
	min	max	value at calib	
flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
temp	284	288	281	K
Voltage	105	115	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}				0.02
Lack of fit			u_{fit}				0.04
Zero drift			u_{0dr}				0.03
Span drift			u_{sdr}				0.02
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.018
Cross sensitivity			u_{interf}				0.32
Influence of voltage			u_{volt}				0.000
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.05

Measurement uncertainty				
Combined uncertainty			0.33	% vol
Expanded uncertainty	k =	2	0.67	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.67**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.56**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	N/A	**mg/m^3 (Corrected)**	**Cal gas conc.**	175.44	**mg.m^{-3}**
Measured concentration	172.38	**mg/m3 (101.3kPa, 273K)**	**Range**	250.09	**mg/m^3**
Measured concentration	287.23	**mg/m^3 (Corrected)**			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	140.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	10.20	0.0	101.3	273.0
	Uncert	0.67	0.0	0.0	0.0
Factors		1.67	1.00	1.00	1.00
Uncertainty in factor		0.10	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.67**	uf	**0.10**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.1	% of range		≤±1% range
Standard deviation of repeatability at span level	0.1	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.8	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.1	% full scale/20K		≤±5% range
Cross sensitivity	2.9	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.3	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	284	288	281	K
Voltage	105	115	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}		0.26
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		2.56
Zero drift		u_{0dr}		0.00
Span drift		u_{sdr}		0.00
Influence of sample gas flow		u_{spres}		0.03
Influence of atmospheric pressure		u_{apres}		0.51
Influence of ambient temperature		u_{temp}		0.03
Cross sensitivity		u_{interf}		4.19
Influence of voltage		u_{volt}		0.00
Influence from vibration		u_{vib}		0.00
Uncertainty of calibration gas		u_{cal}		0.86
Uncertainty in std conditions correction factor (no O_2 factor)		u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}		17.77

Measurement uncertainty				
Combined uncertainty			5.01	mg/m^3
Expanded uncertainty	k =	2	10.03	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			10.03	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**39.28**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**39.28 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**13.67 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

Uncertainty calculation for gaseous measurement of NOx according to BS EN 14792:2017 - Horiba PG250 AS0208

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	154.4	mg.m^{-3}
Measured concentration	34.42	mg/m3 (101.3kPa, 273K)	**Range**	513.4	mg/m^3
Measured concentration	57.35	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	250	ppm
Cal gas conc	75.2	ppm
Conversion	2.05	

NO/NO2 ratio	99

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.0	101.3	273.0
	measured	10.20	0.0	101.3	273.0
	Uncert	0.67	0.0	0.0	0.0
Factors		1.67	1.00	1.00	1.00
Uncertainty in factor		0.10	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.67**	uf	**0.10**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.5	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	2.0	% full scale/10l		≤±2% range
Influence of atmospheric pressure	2.0	% full scale /3kPa		≤±2% range
Influence of ambient temperature	0.2	% full scale/20K		≤±5% range
Cross sensitivity	0.7	% full scale		≤4% range
Influence of voltage	0.0	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.0	%		≥95%
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	284	288	281	K
Voltage	105	115	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}		0.24
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{fit}		1.36
Zero drift		u_{0dr}		0.00
Span drift		u_{sdr}		0.00
Influence of sample gas flow		u_{spres}		0.06
Influence of atmospheric pressure		u_{apres}		1.05
Influence of ambient temperature		u_{temp}		0.24
Cross sensitivity		u_{interf}		2.07
Influence of voltage		u_{volt}		0.00
Influence from vibration		u_{vib}		0.00
Converter efficiency		u_{conv}		0.98
Uncertainty of calibration gas		u_{cal}		0.17
Uncertainty in std conditions correction factor (no O_2 factor)		u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}		3.55

Measurement uncertainty				
Combined uncertainty			2.89	mg/m^3
Expanded uncertainty	k =	2	5.79	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			5.79	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**11.97**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**11.97**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**20.88**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**5.41**	**% ELV**

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	3.086	m/s
Air density meas. during calibration	1.213	kg/m^3
DP meas. during calibration	8.05	Pa
Uncertainty of velocity meas. at calibration	2.1	%
Uncertainty of air density meas. at calibration	0.075	%
Uncertainty of DP meas. at calibration	3.88	%
Pitot coefficient, K	0.833	-
Expanded uncertainty (95%, k=2) as % of value	8.8	%
Expanded uncertainty (95%, k=2)	0.07	

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	101890	102059.3	169.3	50.0					50.0	12.5	1.44	130	6.5	83.5	10	29.44	29.28
2	101890	102059.3	169.3	60.8					60.8	12.6	1.44	130	6.5	83.5	10	29.44	29.28
3	101890	102059.3	169.3	55.9					55.9	12.7	1.44	130	6.5	83.5	10	29.44	29.28
4	101890	102059.3	169.3	29.4					29.4	12.8	1.44	130	6.5	83.5	10	29.44	29.28
5	101890	102059.3	169.3	43.1					43.1	12.8	1.44	130	6.5	83.5	10	29.44	29.28
6	101890	102059.3	169.3	53.9					53.9	12.8	1.44	130	6.5	83.5	10	29.44	29.28
7	101890	102059.3	169.3	33.3					33.3	12.7	1.44	130	6.5	83.5	10	29.44	29.28
8	101890	102059.3	169.3	49.0					49.0	12.7	1.44	130	6.5	83.5	10	29.44	29.28
9	101890	102059.3	169.3	44.1					44.1	12.6	1.44	130	6.5	83.5	10	29.44	29.28
10	101890	102059.3	169.3	55.9					55.9	12.5	1.44	130	6.5	83.5	10	29.44	29.28
11	101890	102059.3	169.3	54.9					54.9	12.5	1.44	130	6.5	83.5	10	29.44	29.28
12	101890	102059.3	169.3	79.4					79.4	12.4	1.44	130	6.5	83.5	10	29.44	29.28
Mean	**101890**	**102059**	**169.3**	**50.8**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**50.8**	**12.6**	**1.4**	**130.0**	**6.5**	**90.1**	**10.0**	**28.86**	**28.77**

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

Mean density	**1.236**	**kg/m3**

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

Mean velocity	**7.49**	**m/sec**		
Standard uncertainty of velocity	**0.34**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.67**	**m/sec**	**9.0**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**46418**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4263**	**m^3/hour**	**#DIV/0!**	**m3/hour**
Volume flow rate expanded uncertainty	**9.2**	**% 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 ^oC

T_s the stack temperature in ^oC

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

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

Oxygen Concentration Correction C_{oxy} to Particulate concentration

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

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

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

Mass Emission Rate M_R

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

IsoKinicity

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

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)