NATIONAL PHYSICAL LABORATORY
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Test Report

UKAS TESTING
0002

MCERTS
THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

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:	**26th - 29th April 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:	**28th May 2021**
Report Author	**Matthew Ellison**

Reference: XP3538LD/INTERTEK/SHLNG/APR2021/SCV/PPC/Q2/V1

Report Approver:	Chris Dimopoulos	NPL Authorised Signatory
MCERTS Registration:	MM-07-812	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. Ten 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 26th and 29th April 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**	56.6	223	10.8	1.4
Uncertainty (95% Confidence Level)	**Reference Conditions**	9.7	36.6	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	6.6			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	26/04/2021			
Sample Period	**From hh:mm**	13:30			
	To hh:mm	14:30			
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)**	130			
Process Status	**Burner Demand (%)**	34			

1.2.2 SCV D (Phase One) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV D (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**	51.7	642	12.0	1.4
Uncertainty (95% Confidence Level)	**Reference Conditions**	10.1	108	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	6.0			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	26/04/2021			
Sample Period	**From hh:mm**	15:30			
	To hh:mm	16:30			
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)**	125			
Process Status	**Burner Demand (%)**	33			

1.2.3 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**	90.3	18.6	10.4	1.6
Uncertainty (95% Confidence Level)	**Reference Conditions**	14.3	16.3	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	7.6			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	29/04/2021			
Sample Period	**From hh:mm**	11:00			
	To hh:mm	12:00			
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)**	140			
Process Status	**Burner Demand (%)**	40			

1.2.4 SCV F (Phase One) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV F (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**	65.8	172	11.4	1.6
Uncertainty (95% Confidence Level)	**Reference Conditions**	11.8	32.0	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	5.5			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	29/04/2021			
Sample Period	**From hh:mm**	13:10			
	To hh:mm	14:10			
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 (%)**	32			

1.2.5 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**	61.8	88.3	10.7	1.6
Uncertainty (95% Confidence Level)	**Reference Conditions**	10.5	20.7	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	8.3			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	29/04/2021			
Sample Period	**From hh:mm**	15:00			
	To hh:mm	16:00			
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)**	140			
Process Status	**Burner Demand (%)**	39			

1.2.6 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**	61.4	190	11.6	1.5
Uncertainty (95% Confidence Level)	**Reference Conditions**	11.2	35.7	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	6.1			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	27/04/2021			
Sample Period	**From hh:mm**	12:00			
	To hh:mm	13:00			
Monitoring Method		BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	130			
Process Status	**Burner Demand (%)**	34.5			

1.2.7 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**	67.6	175	10.1	1.5
Uncertainty (95% Confidence Level)	**Reference Conditions**	10.6	28.8	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	9.0			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	27/04/2021			
Sample Period	**From hh:mm**	13:50			
	To hh:mm	14:50			
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)**	130			
Process Status	**Burner Demand (%)**	39			

1.2.8 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**	65.1	63.5	7.9	1.7
Uncertainty (95% Confidence Level)	**Reference Conditions**	8.7	15.1	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	7.9			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	27/04/2021			
Sample Period	**From hh:mm**	15:35			
	To hh:mm	16:35			
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)**	160			
Process Status	**Burner Demand (%)**	40			

1.2.9 SCV F (Phase Two) Monitoring Results

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

Field	Units	Oxides of Nitrogen (as NO_2)	Carbon Monoxide	Oxygen	Moisture
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	66.5	37.6	9.4	1.4
Uncertainty (95% Confidence Level)	**Reference Conditions**	10.3	16.8	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	8.0			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	28/04/2021			
Sample Period	**From hh:mm**	12:00			
	To hh:mm	13:00			
Monitoring Method		BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	130			
Process Status	**Burner Demand (%)**	35			

1.2.10 SCV G (Phase Two) Monitoring Results

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

Field	Units	Oxides of Nitrogen (as NO_2)	Carbon Monoxide	Oxygen	Moisture
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	58.4	159	9.6	1.5
Uncertainty (95% Confidence Level)	**Reference Conditions**	9.4	26.6	0.7	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	7.1			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	28/04/2021			
Sample Period	**From hh:mm**	14:15			
	To hh:mm	15:15			
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)**	130			
Process Status	**Burner Demand (%)**	42			

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	130	34		
	SCV 1D	125	33		
	SCV 1E	140	40		
	SCV 1F	125	32		
	SCV 1H	140	39		
	SCV 2A	130	34.5		
	SCV 2B	130	39		
	SCV 2D	160	40		
	SCV 2F	130	35		
	SCV 2G	130	42		
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	78.9	61.8	mg/Nm^3
	SCV 1H	Oxygen	10.4	10.7	% Vol
	SCV 2A	Oxides of Nitrogen	75.2	61.4	mg/Nm^3
	SCV 2A	Oxygen	11.8	11.6	% 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.

1.5 Conclusions

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

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

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

1.6 References

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

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

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

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

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

APPENDIX ONE

2.1.1 Emissions Testing Personnel Details

Name	Role	MCERTS Number	Certification Level & Expiry Dates					
			Level 1	Level 2	TE1	TE2	TE3	TE4
Matthew Ellison	Team Leader	MM-05-682	N/A	Sep-2023	Sep-2023	Sep-2023	Dec-2023	Sep-2023
Ann-Marie Leman	Site Assistant	MM-19-1562	N/A	N/A	N/A	N/A	N/A	N/A

2.1.2 Emissions Testing Procedures

	Instrumental Methods			Manual Methods		
Determinand	**NOx**	**CO**	**O_2**	**H_2O**	**Stack Flow**	**Temperature**
SRM Standard	BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017	BS ISO 16911:2013	BS ISO 16911:2013
Instrument	Horiba PG-250	Horiba PG-250	Horiba PG-250	N/A	Pitot	Type K Thermocouple
Instrument Serial No.	AS0218	AS0218	AS0218	N/A	AS0638	AS0638
Principle	Chemiluminescence	NDIR	Zirconia	Saturation reference chart	Differential Pressure	Temperature
Operational Range	0 - 250 ppm	0 - 200 ppm	0 - 25%	N/A	N/A	N/A
Certified Range	0 - 125 mg/m^3	0 - 95 mg/m^3	0 - 25%	N/A	N/A	N/A
Uncertainty	10%	6%	6%	20%	10%	1%
NPL Procedure	QPAS B 538	QPAS B 538	QPAS B 538	QPAS B 540	QPAS B 567	QPAS B 567
UKAS Accreditation	YES	YES	YES	YES	YES	YES

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

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

Component	Sample Location	Cylinder ID	Certified Amount	Certified Uncertainty
Carbon Monoxide	Phase 1 & 2 SCVs	195688SG	155.3 ppm	1%
Nitrogen Oxide		195688SG	79.5 ppm	1%
Oxygen		250638SG	15.04%	1%

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

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

Gaseous Components	Horiba Ranges	Calibrated Values
Carbon Monoxide	0 - 200 ppm	155.3 ppm
Oxides of Nitrogen (as NO_2)	0 - 250 ppm	79.5 ppm
Oxygen	0 - 25%	15.04%

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

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

2.1.3 Equipment Checklist Reference

See workfile INTK53APR21/Equipment Checklist.

2.1.4 Data Capture Location Reference

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

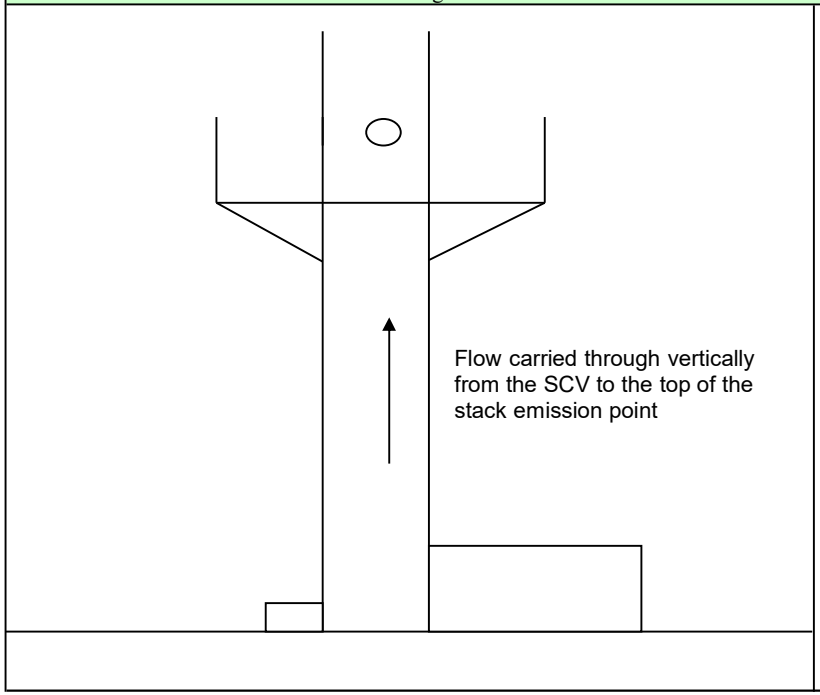
P:\Stack Emissions Team\South Hook LNG - Intertek\INTK53APR21\7. Monitoring Record Sheets

APPENDIX TWO

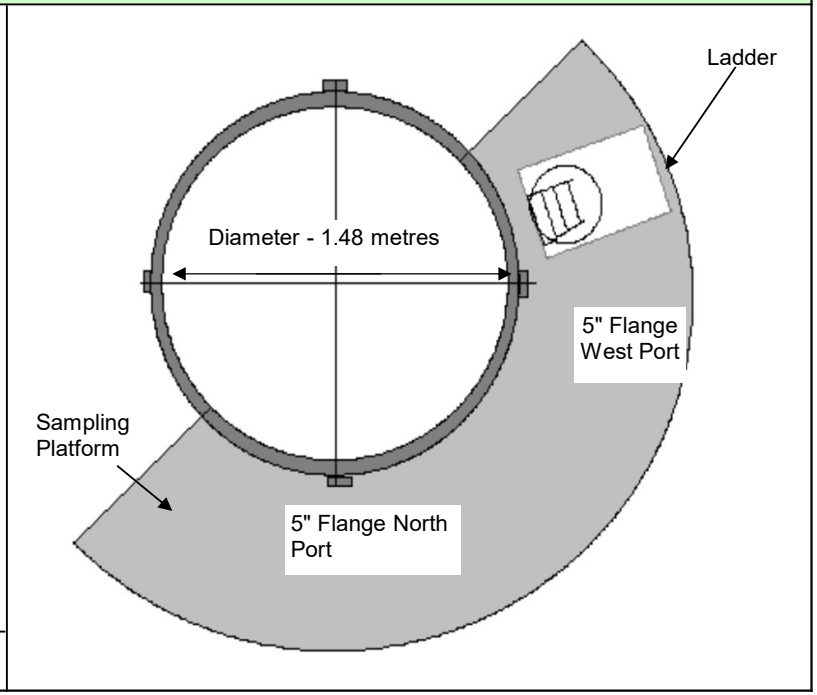
2.2.1 - Stack Diagram

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

Stack Diagram



Stack Cross-Section



Position	1	2	3	4	5	6
% of Diameter	4.1	14.9	29.7	70.3	85.1	95.9
Insertion, m	0.06	0.22	0.44	1.04	1.26	1.42
Insertion plus offset, m	0.16	0.32	0.54	1.14	1.36	1.52

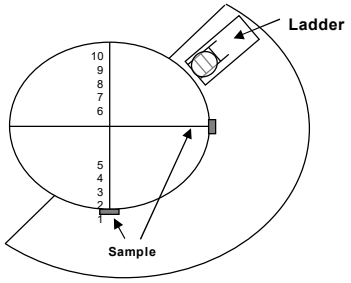
Notes - The circular stack diameter was measured as 1.48 metres, whilst the port offset (distance between the edge of the stack to the end of the port) was measured as 23 centimetres. Access to the top of the stack was by a series of three ladders. Each one had a resting platform in-between with a self 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	26/04/2021	Site Team:	MRE/AML	Time of Survey:	12:00

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	20.58
	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	760.84	mmHg
Ref O_2 Value	3	%
Moisture Content	1.41	%
CO	102	ppm
CO_2	5.9	%
N_2	83.39	%
O_2	10.70	%
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	1012.1	mbar
Pbar	759.3	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					

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	20.60	20.30
B	20.40	21.00
C		
D		

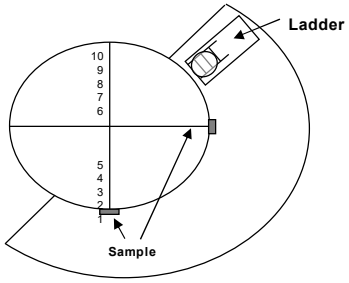
SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	4.30	4.30	4.30	4.30	42.15	12.3	6.82	6	2.07
2	1.26	5.00	5.00	5.00	5.00	49.02	12.5	7.36	7	2.24
3	1.04	5.50	5.50	5.50	5.50	53.92	12.6	7.72	8	2.35
4	0.44	5.00	5.00	5.00	5.00	49.02	12.6	7.36	8	2.24
5	0.22	4.30	4.30	4.30	4.30	42.15	12.5	6.82	7	2.07
6	0.06	4.00	4.00	4.00	4.00	39.21	12.5	6.58	8	2.00
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	4.10	4.10	4.10	4.10	40.19	12.0	6.66	6	2.02
2	1.26	4.30	4.30	4.30	4.30	42.15	11.8	6.81	7	2.07
3	1.04	4.00	4.00	4.00	4.00	39.21	11.8	6.57	8	2.00
4	0.44	4.80	4.80	4.80	4.80	47.05	12.0	7.20	8	2.19
5	0.22	5.00	5.00	5.00	5.00	49.02	12.2	7.35	7	2.24
6	0.06	6.80	6.80	6.80	6.80	66.66	12.1	8.57	8	2.61
Average values		**4.8**	**4.8**	**4.8**	**4.8**	**46.6**	**12.2**	**7.2**	**7.3**	**2.2**

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	7.15	ms^{-1}	Is the Flow Ratio 3:1 or less?	1.7 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	6.62	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	12.30	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	12.12	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	11.78	m^3s^{-1}	Minimum Δp detected > 5 Pa	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	6.71	m^3s^{-1}		

Monitoring Objective	Traverse	Site:	South Hook LNG Terminal	Stack ID:	SCV 1D
Date	26/04/2021	Site Team:	MRE/AML	Time of Survey:	15:30

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	23.73
	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	1.41	%
CO	258	ppm
CO_2	5.2	%
N_2	82.77	%
O_2	12.00	%
Dry Molecular wt	29.31	
Stack Molecular wt	29.15	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1012.1	mbar
Pbar	759.3	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					

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	23.80	23.60
B	23.80	23.70
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	4.50	4.50	4.50	4.50	44.11	12.0	6.98	6	2.12
2	1.26	5.10	5.10	5.10	5.10	50.00	12.0	7.43	6	2.26
3	1.04	5.30	5.30	5.30	5.30	51.96	11.9	7.57	6	2.30
4	0.44	5.10	5.10	5.10	5.10	50.00	11.9	7.43	7	2.26
5	0.22	4.20	4.20	4.20	4.20	41.17	12.0	6.74	7	2.05
6	0.06	6.30	6.30	6.30	6.30	61.76	12.2	8.26	7	2.51
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	4.00	4.00	4.00	4.00	39.21	12.4	6.58	6	2.00
2	1.26	3.80	3.80	3.80	3.80	37.25	12.4	6.42	7	1.95
3	1.04	4.70	4.70	4.70	4.70	46.07	12.3	7.14	6	2.17
4	0.44	5.70	5.70	5.70	5.70	55.88	12.5	7.86	6	2.39
5	0.22	6.10	6.10	6.10	6.10	59.80	12.4	8.13	5	2.47
6	0.06	7.80	7.80	7.80	7.80	76.46	12.5	9.20	6	2.79
Average values		**5.2**	**5.2**	**5.2**	**5.2**	**51.1**	**12.2**	**7.5**	**6.3**	**2.3**

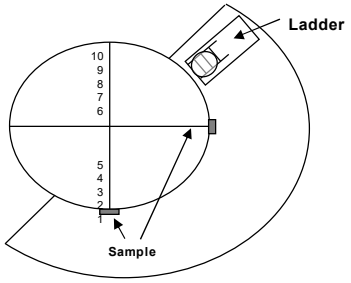
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	7.48	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	6.04	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	12.86	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	12.68	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	12.32	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	6.13	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	2.1 :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	29/04/2021	Site Team:	MRE/AML	Time of Survey:	11:00

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	24.70
	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	758.97	mmHg
Ref O_2 Value	3	%
Moisture Content	1.64	%
CO	8.6	ppm
CO_2	6.2	%
N_2	83.50	%
O_2	10.30	%
Dry Molecular wt	29.40	
Stack Molecular wt	29.22	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1009.2	mbar
Pbar	757.1	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	24.80	24.70
B	24.80	24.50
C		
D		

SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	5.00	5.00	5.00	5.00	49.02	14.5	7.39	3	2.24
2	1.26	6.10	6.10	6.10	6.10	59.80	14.6	8.16	4	2.47
3	1.04	6.40	6.40	6.40	6.40	62.74	14.8	8.37	4	2.53
4	0.44	5.90	5.90	5.90	5.90	57.84	15.0	8.03	6	2.43
5	0.22	5.50	5.50	5.50	5.50	53.92	15.1	7.76	8	2.35
6	0.06	5.80	5.80	5.80	5.80	56.86	15.2	7.97	8	2.41
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	4.60	4.60	4.60	4.60	45.09	14.3	7.09	6	2.14
2	1.26	5.20	5.20	5.20	5.20	50.98	14.2	7.53	6	2.28
3	1.04	5.00	5.00	5.00	5.00	49.02	14.1	7.38	5	2.24
4	0.44	7.00	7.00	7.00	7.00	68.62	14.0	8.74	6	2.65
5	0.22	7.10	7.10	7.10	7.10	69.60	13.9	8.80	8	2.66
6	0.06	7.50	7.50	7.50	7.50	73.52	13.9	9.04	9	2.74
Average values		**5.9**	**5.9**	**5.9**	**5.9**	**58.1**	**14.5**	**8.0**	**6.1**	**2.4**

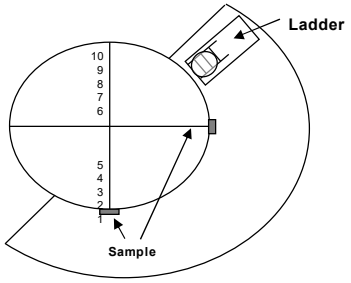
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	8.02	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	7.62	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	13.79	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	13.57	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	13.08	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	7.75	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	1.6 :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 1F
Date	29/04/2021	Site Team:	MRE/AML	Time of Survey:	12:45

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
Static Pressure	Δp (mmH20)
	19.33
	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	758.57	mmHg
Ref O_2 Value	3	%
Moisture Content	1.6	%
CO	75	ppm
CO_2	5.8	%
N_2	82.89	%
O_2	11.30	%
Dry Molecular wt	29.38	
Stack Molecular wt	29.20	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1009.2	mbar
Pbar	757.1	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	19.60	19.80
B	19.00	18.90
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	3.10	3.10	3.10	3.10	30.39	14.1	5.82	5	1.76
2	1.26	3.80	3.80	3.80	3.80	37.25	14.0	6.44	5	1.95
3	1.04	3.90	3.90	3.90	3.90	38.23	13.9	6.52	8	1.97
4	0.44	4.10	4.10	4.10	4.10	40.19	13.9	6.69	8	2.02
5	0.22	4.30	4.30	4.30	4.30	42.15	13.9	6.85	9	2.07
6	0.06	3.80	3.80	3.80	3.80	37.25	13.9	6.44	11	1.95
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	2.20	2.20	2.20	2.20	21.57	14.1	4.90	6	1.48
2	1.26	2.50	2.50	2.50	2.50	24.51	14.3	5.23	4	1.58
3	1.04	3.00	3.00	3.00	3.00	29.41	14.4	5.73	6	1.73
4	0.44	4.70	4.70	4.70	4.70	46.07	14.6	7.17	8	2.17
5	0.22	5.90	5.90	5.90	5.90	57.84	14.6	8.03	8	2.43
6	0.06	5.00	5.00	5.00	5.00	49.02	14.4	7.39	10	2.24
Average values		**3.9**	**3.9**	**3.9**	**3.9**	**37.8**	**14.2**	**6.4**	**7.3**	**1.9**

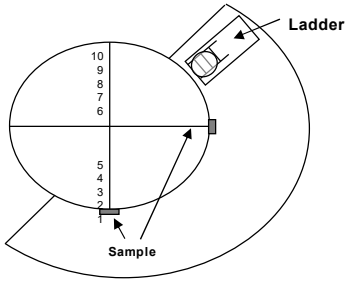
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	6.43	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	5.54	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	11.06	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	10.89	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	10.50	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	5.63	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

Monitoring Objective	Traverse	Site:	South Hook LNG Terminal	Stack ID:	SCV 1H
Date	29/04/2021	Site Team:	MRE/AML	Time of Survey:	15:30

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	22.68
	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	758.82	mmHg
Ref O_2 Value	3	%
Moisture Content	1.62	%
CO	22	ppm
CO_2	6	%
N_2	83.30	%
O_2	10.70	%
Dry Molecular wt	29.39	
Stack Molecular wt	29.20	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1009.2	mbar
Pbar	757.1	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	22.20	23.20
B	22.80	22.50
C		
D		

SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	6.00	6.00	6.00	6.00	58.82	14.3	8.10	4	2.45
2	1.26	6.50	6.50	6.50	6.50	63.72	14.4	8.43	5	2.55
3	1.04	7.80	7.80	7.80	7.80	76.46	14.4	9.23	5	2.79
4	0.44	8.50	8.50	8.50	8.50	83.33	14.3	9.64	6	2.92
5	0.22	6.90	6.90	6.90	6.90	67.64	14.3	8.68	8	2.63
6	0.06	9.60	9.60	9.60	9.60	94.11	14.0	10.23	9	3.10
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	6.60	6.60	6.60	6.60	64.70	14.2	8.49	7	2.57
2	1.26	6.00	6.00	6.00	6.00	58.82	14.4	8.10	7	2.45
3	1.04	7.70	7.70	7.70	7.70	75.48	14.6	9.18	7	2.77
4	0.44	8.40	8.40	8.40	8.40	82.35	14.5	9.58	8	2.90
5	0.22	8.10	8.10	8.10	8.10	79.41	14.4	9.41	9	2.85
6	0.06	9.40	9.40	9.40	9.40	92.15	14.4	10.13	10	3.07
Average values		**7.6**	**7.6**	**7.6**	**7.6**	**74.7**	**14.4**	**9.1**	**7.1**	**2.8**

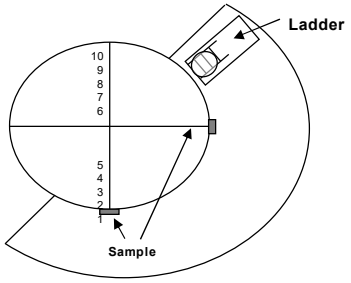
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	9.10	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	8.32	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	15.65	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	15.39	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	14.84	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	8.46	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	1.6 :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	27/04/2021	Site Team:	MRE/AML	Time of Survey:	10:15

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	AS0638
Traverse Manometer Range	255
Traverse Temp. Readout ID	AS0638
Traverse Thermocouple ID	AS0451a
	Δp (mmH20)
Static Pressure	21.15
	Pass
Swirl Test Conducted	Yes
Protractor ID	AS0626
Post-Test Blockage Test (L-Type only)	
Post Test Leak Check <2.5 mm H2O	Pass
Pitot Assembly Visual Inspection (Post)	Pass

Diagram of Sample Location:



Comments/Deviations:

None

Conditions	Value	Units
Stack pressure	758.48	mmHg
Ref O_2 Value	3	%
Moisture Content	1.47	%
CO	85	ppm
CO_2	5.4	%
N_2	82.99	%
O_2	11.60	%
Dry Molecular wt	29.33	
Stack Molecular wt	29.16	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1008.9	mbar
Pbar	756.9	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	20.80	21.50
Duct Diameter (m)	1.48		B	20.90	21.40
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	3.70	3.70	3.70	3.70	36.27	12.8	6.35	6	1.92
2	1.26	4.20	4.20	4.20	4.20	41.17	12.9	6.76	8	2.05
3	1.04	4.40	4.40	4.40	4.40	43.13	12.9	6.92	8	2.10
4	0.44	4.80	4.80	4.80	4.80	47.05	12.8	7.23	7	2.19
5	0.22	5.50	5.50	5.50	5.50	53.92	12.8	7.74	8	2.35
6	0.06	5.70	5.70	5.70	5.70	55.88	12.8	7.88	10	2.39
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	3.70	3.70	3.70	3.70	36.27	12.7	6.35	6	1.92
2	1.26	3.70	3.70	3.70	3.70	36.27	12.8	6.35	8	1.92
3	1.04	4.70	4.70	4.70	4.70	46.07	12.9	7.15	8	2.17
4	0.44	5.50	5.50	5.50	5.50	53.92	13.0	7.74	10	2.35
5	0.22	6.00	6.00	6.00	6.00	58.82	12.9	8.08	12	2.45
6	0.06	6.50	6.50	6.50	6.50	63.72	12.9	8.41	10	2.55
Average values		**4.9**	**4.9**	**4.9**	**4.9**	**47.7**	**12.9**	**7.2**	**8.4**	**2.2**

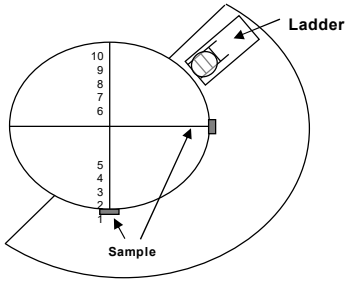
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	7.25	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	6.08	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	12.46	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	12.28	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	11.88	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	6.17	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	1.8 :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 2B
Date	27/04/2021	Site Team:	MRE/AML	Time of Survey:	13:30

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	18.38
	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	758.28	mmHg
Ref O_2 Value	3	%
Moisture Content	1.54	%
CO	44	ppm
CO_2	7.4	%
N_2	84.50	%
O_2	8.10	%
Dry Molecular wt	29.51	
Stack Molecular wt	29.33	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1008.9	mbar
Pbar	756.9	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	18.60	18.40
Duct Diameter (m)	1.48		B	18.00	18.50
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	5.30	5.30	5.30	5.30	51.96	13.5	7.58	6	2.30
2	1.26	6.10	6.10	6.10	6.10	59.80	13.8	8.14	8	2.47
3	1.04	4.30	4.30	4.30	4.30	42.15	14.0	6.84	8	2.07
4	0.44	4.80	4.80	4.80	4.80	47.05	14.0	7.22	8	2.19
5	0.22	4.80	4.80	4.80	4.80	47.05	14.0	7.22	10	2.19
6	0.06	5.30	5.30	5.30	5.30	51.96	14.0	7.59	13	2.30
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	6.50	6.50	6.50	6.50	63.72	12.4	8.38	5	2.55
2	1.26	3.70	3.70	3.70	3.70	36.27	12.8	6.33	4	1.92
3	1.04	4.60	4.60	4.60	4.60	45.09	13.3	7.06	4	2.14
4	0.44	6.00	6.00	6.00	6.00	58.82	13.5	8.07	5	2.45
5	0.22	8.60	8.60	8.60	8.60	84.31	13.6	9.66	6	2.93
6	0.06	7.90	7.90	7.90	7.90	77.44	13.7	9.26	8	2.81
Average values		**5.7**	**5.7**	**5.7**	**5.7**	**55.5**	**13.6**	**7.8**	**7.1**	**2.4**

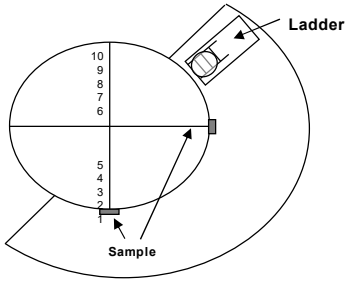
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	7.78	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	8.95	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	13.38	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	13.17	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	12.72	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	9.09	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 2D
Date	27/04/2021	Site Team:	MRE/AML	Time of Survey:	15:45

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	20.50
	Pass
Swirl Test Conducted	Yes
Protractor ID	AS0626
Post-Test Blockage Test (L-Type only)	
Post Test Leak Check <2.5 mm H2O	Pass
Pitot Assembly Visual Inspection (Post)	Pass

Diagram of Sample Location:



Comments/Deviations:

None

Conditions	Value	Units
Stack pressure	758.43	mmHg
Ref O_2 Value	3	%
Moisture Content	1.73	%
CO	50	ppm
CO_2	7.1	%
N_2	84.00	%
O_2	8.90	%
Dry Molecular wt	29.49	
Stack Molecular wt	29.29	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1008.9	mbar
Pbar	756.9	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	20.40	20.80
B	20.00	20.80
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	4.00	4.00	4.00	4.00	39.21	15.3	6.61	6	2.00
2	1.26	5.90	5.90	5.90	5.90	57.84	15.4	8.03	8	2.43
3	1.04	5.50	5.50	5.50	5.50	53.92	15.5	7.76	7	2.35
4	0.44	4.60	4.60	4.60	4.60	45.09	15.6	7.10	8	2.14
5	0.22	4.80	4.80	4.80	4.80	47.05	15.6	7.25	10	2.19
6	0.06	4.20	4.20	4.20	4.20	41.17	15.6	6.78	10	2.05
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	15.0	5.63	6	1.70
2	1.26	4.10	4.10	4.10	4.10	40.19	15.1	6.69	6	2.02
3	1.04	3.90	3.90	3.90	3.90	38.23	15.2	6.53	6	1.97
4	0.44	5.50	5.50	5.50	5.50	53.92	15.3	7.75	8	2.35
5	0.22	6.80	6.80	6.80	6.80	66.66	15.3	8.62	8	2.61
6	0.06	8.00	8.00	8.00	8.00	78.42	15.4	9.35	10	2.83
Average values		**5.0**	**5.0**	**5.0**	**5.0**	**49.2**	**15.4**	**7.3**	**7.8**	**2.2**

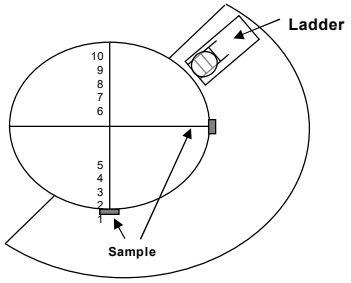
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	7.34	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	7.86	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	12.62	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	12.41	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	11.93	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	8.00	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	2.8 :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 2F
Date	28/04/2021	Site Team:	MRE/AML	Time of Survey:	11:00

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	16.68
	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	753.50	mmHg
Ref O_2 Value	3	%
Moisture Content	1.44	%
CO	30	ppm
CO_2	7.1	%
N_2	84.00	%
O_2	8.90	%
Dry Molecular wt	29.49	
Stack Molecular wt	29.33	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1002.7	mbar
Pbar	752.3	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					

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	16.80	16.60
B	16.50	16.80
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	4.00	4.00	4.00	4.00	39.21	12.8	6.60	8	2.00
2	1.26	5.10	5.10	5.10	5.10	50.00	12.7	7.45	9	2.26
3	1.04	5.30	5.30	5.30	5.30	51.96	12.7	7.60	9	2.30
4	0.44	4.80	4.80	4.80	4.80	47.05	12.8	7.23	8	2.19
5	0.22	5.00	5.00	5.00	5.00	49.02	12.3	7.37	10	2.24
6	0.06	5.00	5.00	5.00	5.00	49.02	12.1	7.37	12	2.24
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	3.80	3.80	3.80	3.80	37.25	12.4	6.43	5	1.95
2	1.26	4.10	4.10	4.10	4.10	40.19	12.5	6.68	6	2.02
3	1.04	4.60	4.60	4.60	4.60	45.09	12.8	7.08	6	2.14
4	0.44	6.00	6.00	6.00	6.00	58.82	12.9	8.09	8	2.45
5	0.22	6.80	6.80	6.80	6.80	66.66	13.0	8.61	6	2.61
6	0.06	7.10	7.10	7.10	7.10	69.60	12.7	8.79	8	2.66
Average values		**5.1**	**5.1**	**5.1**	**5.1**	**50.3**	**12.6**	**7.4**	**7.9**	**2.3**

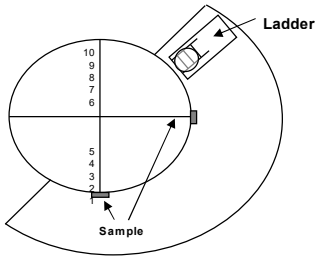
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	7.44	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	8.01	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	12.80	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	12.61	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	12.13	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	8.13	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	1.9 :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 2G
Date	28/04/2021	Site Team:	MRE/AML	Time of Survey:	13:30

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
Static Pressure	Δp (mmH20)
	20.95
	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	753.81	mmHg
Ref O_2 Value	3	%
Moisture Content	1.48	%
CO	100	ppm
CO_2	8.4	%
N_2	81.49	%
O_2	10.10	%
Dry Molecular wt	29.75	
Stack Molecular wt	29.57	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1002.7	mbar
Pbar	752.3	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					

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	21.10	21.00
B	20.90	20.80
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	3.20	3.20	3.20	3.20	31.37	13.0	5.88	6	1.79
2	1.26	4.30	4.30	4.30	4.30	42.15	12.9	6.82	7	2.07
3	1.04	5.30	5.30	5.30	5.30	51.96	12.7	7.56	7	2.30
4	0.44	5.30	5.30	5.30	5.30	51.96	12.6	7.56	9	2.30
5	0.22	4.90	4.90	4.90	4.90	48.04	12.5	7.27	9	2.21
6	0.06	5.90	5.90	5.90	5.90	57.84	12.4	7.98	10	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	3.70	3.70	3.70	3.70	36.27	13.3	6.33	4	1.92
2	1.26	4.00	4.00	4.00	4.00	39.21	13.4	6.58	6	2.00
3	1.04	4.20	4.20	4.20	4.20	41.17	13.4	6.74	5	2.05
4	0.44	5.80	5.80	5.80	5.80	56.86	13.4	7.92	6	2.41
5	0.22	6.70	6.70	6.70	6.70	65.68	13.3	8.51	7	2.59
6	0.06	6.60	6.60	6.60	6.60	64.70	13.1	8.45	9	2.57
Average values		**5.0**	**5.0**	**5.0**	**5.0**	**48.9**	**13.0**	**7.3**	**7.1**	**2.2**

Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	7.30	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	7.06	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	12.55	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	12.37	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	11.88	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	7.17	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	2.1 :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
Units	mg/m3	mg/m3	%
26/04/2021 13:30	227	56.6	10.9
26/04/2021 13:31	227	56.5	10.9
26/04/2021 13:32	233	56.8	10.9
26/04/2021 13:33	232	56.4	11.0
26/04/2021 13:34	241	56.3	11.0
26/04/2021 13:35	250	56.3	11.0
26/04/2021 13:36	238	56.5	11.0
26/04/2021 13:37	229	56.4	10.9
26/04/2021 13:38	222	56.5	10.8
26/04/2021 13:39	222	56.6	10.8
26/04/2021 13:40	229	56.4	10.9
26/04/2021 13:41	232	56.4	10.9
26/04/2021 13:42	220	56.9	10.8
26/04/2021 13:43	221	56.5	10.8
26/04/2021 13:44	222	56.6	10.8
26/04/2021 13:45	211	56.9	10.8
26/04/2021 13:46	220	56.7	10.8
26/04/2021 13:47	214	56.8	10.8
26/04/2021 13:48	223	56.6	10.9
26/04/2021 13:49	229	56.6	10.9
26/04/2021 13:50	234	56.4	10.9
26/04/2021 13:51	215	56.8	10.9
26/04/2021 13:52	218	56.7	10.8
26/04/2021 13:53	224	56.5	10.9
26/04/2021 13:54	223	56.4	10.9
26/04/2021 13:55	227	56.5	10.9
26/04/2021 13:56	225	56.5	10.9
26/04/2021 13:57	227	56.5	10.9
26/04/2021 13:58	225	56.7	10.9
26/04/2021 13:59	224	56.7	10.9
26/04/2021 14:00	215	56.8	10.9
26/04/2021 14:01	222	56.7	10.8
26/04/2021 14:02	219	56.7	10.8
26/04/2021 14:03	229	56.6	10.9
26/04/2021 14:04	227	56.4	10.8
26/04/2021 14:05	218	56.7	10.8
26/04/2021 14:06	227	56.2	10.8
26/04/2021 14:07	226	56.4	10.9
26/04/2021 14:08	223	56.5	10.8
26/04/2021 14:09	228	56.4	10.9
26/04/2021 14:10	232	56.3	10.9
26/04/2021 14:11	229	56.6	10.9
26/04/2021 14:12	223	56.3	10.8
26/04/2021 14:13	220	56.6	10.8
26/04/2021 14:14	216	56.6	10.7
26/04/2021 14:15	215	56.5	10.7
26/04/2021 14:16	214	56.6	10.7
26/04/2021 14:17	213	56.5	10.7
26/04/2021 14:18	212	56.6	10.7
26/04/2021 14:19	215	56.3	10.8
26/04/2021 14:20	214	56.4	10.8
26/04/2021 14:21	227	56.4	10.9
26/04/2021 14:22	225	56.4	10.9
26/04/2021 14:23	221	56.7	10.9
26/04/2021 14:24	223	56.5	10.9
26/04/2021 14:25	214	56.9	10.9
26/04/2021 14:26	212	56.9	10.8
26/04/2021 14:27	211	57.1	10.8
26/04/2021 14:28	207	56.9	10.7
26/04/2021 14:29	211	56.5	10.7
26/04/2021 14:30	208	56.5	10.6
Minimum	207	56.2	10.6
Maximum	250	57.1	11.0
Average	223	56.6	10.8

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 1D			
273K, 101.3 kPa, 3% Oxygen on a dry basis			
Species	Carbon Monoxide	Oxides of Nitrogen	Oxygen
Units	mg/m3	mg/m3	%
26/04/2021 15:30	645	49.6	12.2
26/04/2021 15:31	637	50.2	12.1
26/04/2021 15:32	639	50.5	12.0
26/04/2021 15:33	649	50.7	12.0
26/04/2021 15:34	661	50.7	12.0
26/04/2021 15:35	661	50.8	12.0
26/04/2021 15:36	648	51.2	12.0
26/04/2021 15:37	637	51.1	12.0
26/04/2021 15:38	650	51.1	12.0
26/04/2021 15:39	641	51.3	12.0
26/04/2021 15:40	655	51.1	12.1
26/04/2021 15:41	662	51.1	12.1
26/04/2021 15:42	662	51.0	12.1
26/04/2021 15:43	652	51.3	12.1
26/04/2021 15:44	682	51.0	12.1
26/04/2021 15:45	670	50.9	12.1
26/04/2021 15:46	637	51.6	12.0
26/04/2021 15:47	648	51.5	12.0
26/04/2021 15:48	641	51.6	12.0
26/04/2021 15:49	637	51.5	12.0
26/04/2021 15:50	617	52.2	12.0
26/04/2021 15:51	622	51.9	12.0
26/04/2021 15:52	636	52.0	12.0
26/04/2021 15:53	644	51.6	12.1
26/04/2021 15:54	648	51.6	12.1
26/04/2021 15:55	634	51.9	12.1
26/04/2021 15:56	644	51.7	12.1
26/04/2021 15:57	653	51.7	12.1
26/04/2021 15:58	652	51.8	12.1
26/04/2021 15:59	652	51.7	12.0
26/04/2021 16:00	653	51.9	12.0
26/04/2021 16:01	644	51.8	12.0
26/04/2021 16:02	606	52.5	11.9
26/04/2021 16:03	626	52.2	12.0
26/04/2021 16:04	611	52.7	12.0
26/04/2021 16:05	633	52.1	12.0
26/04/2021 16:06	632	52.1	12.0
26/04/2021 16:07	628	52.1	11.9
26/04/2021 16:08	638	52.2	11.9
26/04/2021 16:09	607	52.7	11.9
26/04/2021 16:10	624	52.3	12.0
26/04/2021 16:11	623	52.4	12.0
26/04/2021 16:12	638	52.0	12.1
26/04/2021 16:13	650	52.0	12.1
26/04/2021 16:14	639	52.1	12.0
26/04/2021 16:15	657	51.7	12.1
26/04/2021 16:16	636	52.1	12.0
26/04/2021 16:17	634	52.3	12.0
26/04/2021 16:18	622	52.6	12.0
26/04/2021 16:19	623	52.6	11.9
26/04/2021 16:20	640	52.4	11.9
26/04/2021 16:21	639	52.4	11.9
26/04/2021 16:22	620	52.4	11.9
26/04/2021 16:23	618	52.7	11.9
26/04/2021 16:24	635	52.5	12.0
26/04/2021 16:25	654	51.9	12.1
26/04/2021 16:26	655	51.8	12.2
26/04/2021 16:27	678	51.4	12.2
26/04/2021 16:28	652	51.7	12.2
26/04/2021 16:29	667	51.6	12.2
26/04/2021 16:30	670	51.6	12.1
Minimum	606	49.6	11.9
Maximum	682	52.7	12.2
Average	642	51.7	12.0

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
Units	mg/m3	mg/m3	%
29/04/2021 11:00	22.7	88.9	10.7
29/04/2021 11:01	24.0	88.9	10.8
29/04/2021 11:02	22.4	91.9	10.9
29/04/2021 11:03	26.5	90.1	11.0
29/04/2021 11:04	28.4	88.0	11.0
29/04/2021 11:05	23.4	88.8	10.8
29/04/2021 11:06	20.8	89.8	10.6
29/04/2021 11:07	19.5	89.8	10.5
29/04/2021 11:08	17.6	90.0	10.3
29/04/2021 11:09	15.7	90.2	10.1
29/04/2021 11:10	14.0	89.8	9.9
29/04/2021 11:11	14.3	89.8	9.9
29/04/2021 11:12	13.4	89.8	9.9
29/04/2021 11:13	11.4	93.7	9.9
29/04/2021 11:14	15.1	90.5	10.0
29/04/2021 11:15	16.0	90.4	10.1
29/04/2021 11:16	17.1	90.5	10.2
29/04/2021 11:17	18.4	90.1	10.3
29/04/2021 11:18	19.1	90.0	10.4
29/04/2021 11:19	20.9	89.7	10.6
29/04/2021 11:20	23.2	89.6	10.7
29/04/2021 11:21	23.2	89.5	10.8
29/04/2021 11:22	23.7	89.5	10.8
29/04/2021 11:23	23.0	89.5	10.8
29/04/2021 11:24	17.8	93.0	10.7
29/04/2021 11:25	20.0	90.1	10.6
29/04/2021 11:26	18.7	89.6	10.4
29/04/2021 11:27	16.2	89.6	10.3
29/04/2021 11:28	15.7	89.7	10.2
29/04/2021 11:29	15.2	90.6	10.1
29/04/2021 11:30	14.8	90.2	10.0
29/04/2021 11:31	14.3	90.2	10.0
29/04/2021 11:32	14.8	90.4	10.0
29/04/2021 11:33	15.3	90.2	10.1
29/04/2021 11:34	15.6	90.5	10.2
29/04/2021 11:35	13.1	94.0	10.2
29/04/2021 11:36	16.3	90.6	10.3
29/04/2021 11:37	18.2	89.9	10.4
29/04/2021 11:38	18.7	90.0	10.5
29/04/2021 11:39	20.6	89.8	10.6
29/04/2021 11:40	20.9	89.8	10.6
29/04/2021 11:41	22.6	89.4	10.7
29/04/2021 11:42	21.7	89.6	10.7
29/04/2021 11:43	21.8	89.9	10.7
29/04/2021 11:44	20.1	89.8	10.6
29/04/2021 11:45	18.1	90.3	10.5
29/04/2021 11:46	15.9	94.0	10.4
29/04/2021 11:47	16.8	90.5	10.4
29/04/2021 11:48	17.1	89.9	10.3
29/04/2021 11:49	16.4	89.7	10.3
29/04/2021 11:50	17.3	89.7	10.3
29/04/2021 11:51	18.6	90.1	10.3
29/04/2021 11:52	17.6	90.1	10.3
29/04/2021 11:53	17.5	90.3	10.4
29/04/2021 11:54	18.6	90.2	10.4
29/04/2021 11:55	20.1	90.2	10.5
29/04/2021 11:56	19.2	90.4	10.5
29/04/2021 11:57	16.5	94.3	10.5
29/04/2021 11:58	19.1	91.0	10.5
29/04/2021 11:59	20.0	90.0	10.5
29/04/2021 12:00	19.9	90.3	10.5
Minimum	11.4	88.0	9.9
Maximum	28.4	94.3	11.0
Average	18.6	90.3	10.4

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 1F			
273K, 101.3 kPa, 3% Oxygen on a dry basis			
Species	Carbon Monoxide	Oxides of Nitrogen	Oxygen
Units	mg/m3	mg/m3	%
29/04/2021 13:10	175	64.2	11.5
29/04/2021 13:11	185	64.2	11.4
29/04/2021 13:12	179	64.9	11.5
29/04/2021 13:13	140	68.6	11.4
29/04/2021 13:14	182	65.3	11.5
29/04/2021 13:15	170	66.2	11.5
29/04/2021 13:16	173	65.3	11.4
29/04/2021 13:17	182	64.8	11.4
29/04/2021 13:18	175	64.9	11.3
29/04/2021 13:19	179	64.9	11.4
29/04/2021 13:20	173	65.2	11.3
29/04/2021 13:21	165	65.5	11.3
29/04/2021 13:22	176	65.3	11.3
29/04/2021 13:23	156	66.7	11.4
29/04/2021 13:24	144	68.9	11.4
29/04/2021 13:25	183	65.4	11.4
29/04/2021 13:26	176	65.2	11.4
29/04/2021 13:27	179	65.1	11.4
29/04/2021 13:28	187	65.1	11.4
29/04/2021 13:29	175	66.2	11.4
29/04/2021 13:30	175	66.1	11.4
29/04/2021 13:31	181	65.4	11.4
29/04/2021 13:32	176	65.8	11.4
29/04/2021 13:33	182	65.4	11.4
29/04/2021 13:34	136	69.1	11.4
29/04/2021 13:35	173	66.0	11.4
29/04/2021 13:36	177	65.5	11.4
29/04/2021 13:37	171	65.2	11.3
29/04/2021 13:38	169	65.4	11.4
29/04/2021 13:39	167	65.2	11.3
29/04/2021 13:40	169	65.5	11.3
29/04/2021 13:41	176	65.1	11.4
29/04/2021 13:42	173	65.3	11.3
29/04/2021 13:43	168	65.9	11.4
29/04/2021 13:44	155	67.0	11.4
29/04/2021 13:45	142	68.8	11.4
29/04/2021 13:46	178	65.5	11.4
29/04/2021 13:47	176	65.5	11.4
29/04/2021 13:48	178	65.3	11.4
29/04/2021 13:49	188	65.0	11.5
29/04/2021 13:50	178	65.3	11.5
29/04/2021 13:51	186	65.0	11.4
29/04/2021 13:52	181	65.1	11.4
29/04/2021 13:53	184	65.1	11.4
29/04/2021 13:54	177	65.1	11.4
29/04/2021 13:55	148	67.1	11.3
29/04/2021 13:56	142	68.0	11.2
29/04/2021 13:57	156	65.8	11.3
29/04/2021 13:58	167	65.7	11.3
29/04/2021 13:59	195	63.4	11.3
29/04/2021 14:00	166	65.8	11.4
29/04/2021 14:01	177	66.1	11.4
29/04/2021 14:02	180	65.8	11.5
29/04/2021 14:03	183	65.6	11.5
29/04/2021 14:04	184	65.2	11.5
29/04/2021 14:05	189	65.6	11.6
29/04/2021 14:06	152	68.2	11.6
29/04/2021 14:07	163	67.5	11.5
29/04/2021 14:08	184	65.4	11.5
29/04/2021 14:09	171	65.8	11.4
29/04/2021 14:10	174	65.7	11.4
Minimum	136	63.4	11.2
Maximum	195	69.1	11.6
Average	172	65.8	11.4

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
Units	mg/m3	mg/m3	%
29/04/2021 15:00	104	56.7	10.5
29/04/2021 15:01	97.6	56.8	10.4
29/04/2021 15:02	94.8	56.7	10.4
29/04/2021 15:03	93.3	56.6	10.3
29/04/2021 15:04	90.0	57.0	10.3
29/04/2021 15:05	95.6	57.5	10.4
29/04/2021 15:06	76.3	60.4	10.5
29/04/2021 15:07	109	58.0	10.6
29/04/2021 15:08	123	57.4	10.7
29/04/2021 15:09	130	57.2	10.8
29/04/2021 15:10	140	57.5	11.0
29/04/2021 15:11	145	57.6	11.1
29/04/2021 15:12	147	57.5	11.1
29/04/2021 15:13	140	57.5	11.1
29/04/2021 15:14	143	57.4	11.1
29/04/2021 15:15	139	57.4	11.0
29/04/2021 15:16	129	57.3	10.8
29/04/2021 15:17	124	57.3	10.7
29/04/2021 15:18	82.3	59.9	10.5
29/04/2021 15:19	97.4	58.5	10.5
29/04/2021 15:20	103	57.5	10.5
29/04/2021 15:21	92.9	57.8	10.4
29/04/2021 15:22	84.0	58.8	10.3
29/04/2021 15:23	96.8	57.4	10.3
29/04/2021 15:24	104	57.6	10.5
29/04/2021 15:25	110	57.7	10.6
29/04/2021 15:26	120	57.6	10.7
29/04/2021 15:27	125	57.8	10.8
29/04/2021 15:28	130	58.1	10.9
29/04/2021 15:29	136	58.1	11.0
29/04/2021 15:30	142	58.1	11.0
29/04/2021 15:31	144	58.0	11.1
29/04/2021 15:32	140	58.0	11.0
29/04/2021 15:33	97.1	62.0	11.0
29/04/2021 15:34	53.3	67.2	10.8
29/04/2021 15:35	48.5	68.6	10.7
29/04/2021 15:36	45.5	67.3	10.5
29/04/2021 15:37	36.3	68.9	10.4
29/04/2021 15:38	37.7	69.2	10.4
29/04/2021 15:39	41.3	67.8	10.3
29/04/2021 15:40	41.1	67.7	10.3
29/04/2021 15:41	42.3	67.5	10.3
29/04/2021 15:42	42.2	68.0	10.4
29/04/2021 15:43	35.1	69.5	10.5
29/04/2021 15:44	40.5	69.5	10.6
29/04/2021 15:45	47.9	67.9	10.7
29/04/2021 15:46	51.9	68.0	10.8
29/04/2021 15:47	54.4	67.8	10.9
29/04/2021 15:48	56.4	67.6	11.0
29/04/2021 15:49	58.7	67.8	11.0
29/04/2021 15:50	60.7	67.9	11.1
29/04/2021 15:51	57.4	68.0	11.0
29/04/2021 15:52	54.6	68.1	10.8
29/04/2021 15:53	50.0	68.0	10.8
29/04/2021 15:54	45.8	68.1	10.6
29/04/2021 15:55	46.2	68.0	10.6
29/04/2021 15:56	40.6	68.1	10.4
29/04/2021 15:57	77.3	62.8	10.4
29/04/2021 15:58	94.2	58.7	10.4
29/04/2021 15:59	100	58.7	10.5
29/04/2021 16:00	101	58.5	10.5
Minimum	35.1	56.6	10.3
Maximum	147	69.5	11.1
Average	88.3	61.8	10.7

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
Units	mg/m3	mg/m3	%
27/04/2021 12:00	96.6	68.6	11.6
27/04/2021 12:01	75.1	70.9	11.5
27/04/2021 12:02	81.0	70.1	11.6
27/04/2021 12:03	176	61.3	11.6
27/04/2021 12:04	196	57.6	11.6
27/04/2021 12:05	171	58.6	11.4
27/04/2021 12:06	184	58.9	11.5
27/04/2021 12:07	201	59.5	11.6
27/04/2021 12:08	214	60.1	11.6
27/04/2021 12:09	217	59.7	11.7
27/04/2021 12:10	235	59.8	11.8
27/04/2021 12:11	205	62.2	11.8
27/04/2021 12:12	127	69.3	11.9
27/04/2021 12:13	132	69.1	11.9
27/04/2021 12:14	144	68.2	11.8
27/04/2021 12:15	234	58.4	11.6
27/04/2021 12:16	260	57.2	11.7
27/04/2021 12:17	278	56.2	11.7
27/04/2021 12:18	290	55.8	11.6
27/04/2021 12:19	270	55.8	11.6
27/04/2021 12:20	279	55.5	11.5
27/04/2021 12:21	272	55.4	11.6
27/04/2021 12:22	244	55.4	11.5
27/04/2021 12:23	159	60.8	11.5
27/04/2021 12:24	83.8	68.8	11.6
27/04/2021 12:25	83.4	69.5	11.6
27/04/2021 12:26	113	66.3	11.6
27/04/2021 12:27	188	58.5	11.6
27/04/2021 12:28	179	59.6	11.6
27/04/2021 12:29	196	59.4	11.6
27/04/2021 12:30	213	59.1	11.7
27/04/2021 12:31	218	59.0	11.7
27/04/2021 12:32	228	58.9	11.8
27/04/2021 12:33	232	58.4	11.9
27/04/2021 12:34	234	58.6	11.9
27/04/2021 12:35	131	67.7	11.9
27/04/2021 12:36	113	69.3	11.8
27/04/2021 12:37	96.7	69.5	11.6
27/04/2021 12:38	269	59.0	11.7
27/04/2021 12:39	272	56.4	11.6
27/04/2021 12:40	293	55.6	11.6
27/04/2021 12:41	272	55.8	11.6
27/04/2021 12:42	283	55.6	11.6
27/04/2021 12:43	256	55.7	11.5
27/04/2021 12:44	244	55.9	11.6
27/04/2021 12:45	193	56.9	11.4
27/04/2021 12:46	149	60.6	11.4
27/04/2021 12:47	72.9	69.6	11.5
27/04/2021 12:48	67.5	70.8	11.5
27/04/2021 12:49	93.1	69.2	11.6
27/04/2021 12:50	186	61.0	11.7
27/04/2021 12:51	199	60.2	11.6
27/04/2021 12:52	207	60.3	11.7
27/04/2021 12:53	212	59.9	11.7
27/04/2021 12:54	222	59.7	11.8
27/04/2021 12:55	233	59.0	11.9
27/04/2021 12:56	235	58.8	11.8
27/04/2021 12:57	245	58.4	11.8
27/04/2021 12:58	141	66.3	11.7
27/04/2021 12:59	99.4	69.8	11.6
27/04/2021 13:00	124	67.0	11.6
Minimum	67.5	55.4	11.4
Maximum	293	70.9	11.9
Average	190	61.4	11.6

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
Units	mg/m3	mg/m3	%
27/04/2021 13:50	162	67.5	10.2
27/04/2021 13:51	186	67.0	10.7
27/04/2021 13:52	243	66.1	11.2
27/04/2021 13:53	277	65.8	11.7
27/04/2021 13:54	285	65.4	11.9
27/04/2021 13:55	317	64.9	12.0
27/04/2021 13:56	356	64.4	11.8
27/04/2021 13:57	269	65.7	11.3
27/04/2021 13:58	203	66.9	10.8
27/04/2021 13:59	170	67.7	10.3
27/04/2021 14:00	136	67.7	9.8
27/04/2021 14:01	132	67.6	9.6
27/04/2021 14:02	127	67.8	9.5
27/04/2021 14:03	123	68.2	9.5
27/04/2021 14:04	126	68.2	9.6
27/04/2021 14:05	135	68.1	9.8
27/04/2021 14:06	142	68.3	10.2
27/04/2021 14:07	167	68.0	10.6
27/04/2021 14:08	225	67.0	11.0
27/04/2021 14:09	273	65.7	11.4
27/04/2021 14:10	309	65.0	11.6
27/04/2021 14:11	341	64.7	11.7
27/04/2021 14:12	360	64.4	11.7
27/04/2021 14:13	286	65.6	11.3
27/04/2021 14:14	172	69.3	10.8
27/04/2021 14:15	146	69.4	10.3
27/04/2021 14:16	134	68.7	9.9
27/04/2021 14:17	131	68.6	9.7
27/04/2021 14:18	132	68.6	9.7
27/04/2021 14:19	125	69.0	9.7
27/04/2021 14:20	127	69.2	9.8
27/04/2021 14:21	132	68.9	9.9
27/04/2021 14:22	151	68.5	10.2
27/04/2021 14:23	169	68.5	10.6
27/04/2021 14:24	180	69.7	11.0
27/04/2021 14:25	251	67.4	11.4
27/04/2021 14:26	296	66.3	11.6
27/04/2021 14:27	323	65.5	11.7
27/04/2021 14:28	343	64.9	11.7
27/04/2021 14:29	294	65.5	11.5
27/04/2021 14:30	228	67.1	11.0
27/04/2021 14:31	171	68.0	10.4
27/04/2021 14:32	133	68.3	9.8
27/04/2021 14:33	113	68.5	9.2
27/04/2021 14:34	83.3	69.9	8.9
27/04/2021 14:35	87.5	68.7	8.6
27/04/2021 14:36	84.6	68.0	8.3
27/04/2021 14:37	83.1	68.2	8.2
27/04/2021 14:38	77.7	68.1	8.1
27/04/2021 14:39	76.6	68.2	8.1
27/04/2021 14:40	78.2	68.3	8.0
27/04/2021 14:41	75.7	68.3	8.0
27/04/2021 14:42	84.1	68.1	8.1
27/04/2021 14:43	88.5	68.2	8.3
27/04/2021 14:44	76.5	70.2	8.5
27/04/2021 14:45	101	68.9	8.9
27/04/2021 14:46	111	68.8	9.1
27/04/2021 14:47	113	68.7	9.3
27/04/2021 14:48	119	68.6	9.5
27/04/2021 14:49	120	68.6	9.7
27/04/2021 14:50	130	68.7	9.7
Minimum	75.7	64.4	8.0
Maximum	360	70.2	12.0
Average	175	67.6	10.1

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
Units	mg/m3	mg/m3	%
27/04/2021 15:35	34.6	62.0	7.2
27/04/2021 15:36	38.3	62.4	7.2
27/04/2021 15:37	41.9	63.2	7.3
27/04/2021 15:38	49.0	63.7	7.6
27/04/2021 15:39	55.7	64.3	7.8
27/04/2021 15:40	68.2	64.7	8.0
27/04/2021 15:41	84.1	65.2	8.4
27/04/2021 15:42	95.9	65.5	8.5
27/04/2021 15:43	90.5	67.6	8.8
27/04/2021 15:44	107	66.7	8.9
27/04/2021 15:45	111	65.8	8.9
27/04/2021 15:46	88.4	65.3	8.5
27/04/2021 15:47	73.3	64.8	8.2
27/04/2021 15:48	61.1	64.4	7.9
27/04/2021 15:49	53.9	64.2	7.7
27/04/2021 15:50	45.6	63.7	7.5
27/04/2021 15:51	44.0	63.6	7.3
27/04/2021 15:52	42.6	63.8	7.3
27/04/2021 15:53	35.6	65.7	7.3
27/04/2021 15:54	42.5	63.9	7.3
27/04/2021 15:55	40.1	64.1	7.3
27/04/2021 15:56	42.6	64.3	7.3
27/04/2021 15:57	45.8	64.6	7.5
27/04/2021 15:58	55.0	65.0	7.7
27/04/2021 15:59	66.5	65.7	8.0
27/04/2021 16:00	75.6	66.0	8.2
27/04/2021 16:01	86.9	66.3	8.5
27/04/2021 16:02	91.6	66.6	8.5
27/04/2021 16:03	90.6	68.5	8.8
27/04/2021 16:04	111	66.7	8.9
27/04/2021 16:05	106	66.5	8.8
27/04/2021 16:06	83.7	66.1	8.4
27/04/2021 16:07	67.4	65.6	8.1
27/04/2021 16:08	54.8	65.0	7.8
27/04/2021 16:09	50.2	64.5	7.6
27/04/2021 16:10	48.7	64.4	7.5
27/04/2021 16:11	45.7	64.1	7.4
27/04/2021 16:12	42.0	64.3	7.4
27/04/2021 16:13	36.3	66.2	7.4
27/04/2021 16:14	41.8	64.3	7.4
27/04/2021 16:15	44.1	64.3	7.4
27/04/2021 16:16	47.9	64.6	7.5
27/04/2021 16:17	53.8	65.1	7.7
27/04/2021 16:18	64.9	65.6	8.0
27/04/2021 16:19	74.6	66.0	8.2
27/04/2021 16:20	75.9	66.1	8.2
27/04/2021 16:21	89.2	66.1	8.4
27/04/2021 16:22	89.3	66.8	8.5
27/04/2021 16:23	84.2	68.3	8.6
27/04/2021 16:24	98.2	66.4	8.7
27/04/2021 16:25	92.1	66.0	8.5
27/04/2021 16:26	75.3	65.3	8.2
27/04/2021 16:27	60.6	64.7	7.9
27/04/2021 16:28	52.6	64.3	7.6
27/04/2021 16:29	49.6	64.3	7.5
27/04/2021 16:30	50.0	64.2	7.5
27/04/2021 16:31	47.9	64.3	7.5
27/04/2021 16:32	44.7	64.9	7.5
27/04/2021 16:33	40.5	65.7	7.4
27/04/2021 16:34	44.2	64.4	7.3
27/04/2021 16:35	45.2	64.4	7.4
Minimum	34.6	62.0	7.2
Maximum	111	68.5	8.9
Average	63.5	65.1	7.9

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 2F			
273K, 101.3 kPa, 3% Oxygen on a dry basis			
Species	Carbon Monoxide	Oxides of Nitrogen	Oxygen
Units	mg/m3	mg/m3	%
28/04/2021 12:00	24.0	71.8	9.5
28/04/2021 12:01	21.6	71.8	9.4
28/04/2021 12:02	22.5	71.2	9.3
28/04/2021 12:03	26.7	69.4	9.3
28/04/2021 12:04	26.9	69.6	9.3
28/04/2021 12:05	22.9	70.5	9.3
28/04/2021 12:06	22.2	72.1	9.3
28/04/2021 12:07	38.0	67.5	9.4
28/04/2021 12:08	48.3	67.5	9.7
28/04/2021 12:09	51.8	67.5	9.9
28/04/2021 12:10	53.6	67.8	9.9
28/04/2021 12:11	60.9	67.7	10.1
28/04/2021 12:12	71.3	65.8	10.1
28/04/2021 12:13	73.3	66.0	10.1
28/04/2021 12:14	64.1	66.2	10.0
28/04/2021 12:15	44.9	67.9	9.7
28/04/2021 12:16	38.1	67.5	9.5
28/04/2021 12:17	39.2	65.2	9.3
28/04/2021 12:18	30.4	65.0	9.0
28/04/2021 12:19	26.8	65.0	8.9
28/04/2021 12:20	22.9	65.5	8.8
28/04/2021 12:21	22.0	65.6	8.7
28/04/2021 12:22	21.0	65.0	8.6
28/04/2021 12:23	21.0	64.8	8.6
28/04/2021 12:24	20.3	64.9	8.7
28/04/2021 12:25	18.5	68.1	8.8
28/04/2021 12:26	20.0	67.9	8.9
28/04/2021 12:27	27.5	66.3	9.1
28/04/2021 12:28	36.5	66.2	9.3
28/04/2021 12:29	37.5	66.4	9.5
28/04/2021 12:30	43.0	66.4	9.6
28/04/2021 12:31	60.0	65.7	9.8
28/04/2021 12:32	60.3	65.5	9.9
28/04/2021 12:33	57.5	65.7	9.9
28/04/2021 12:34	56.3	65.6	9.9
28/04/2021 12:35	39.9	68.4	9.7
28/04/2021 12:36	42.1	66.5	9.5
28/04/2021 12:37	39.9	65.2	9.4
28/04/2021 12:38	31.6	64.8	9.2
28/04/2021 12:39	28.6	64.8	9.0
28/04/2021 12:40	26.4	65.1	9.0
28/04/2021 12:41	26.1	65.1	8.9
28/04/2021 12:42	20.7	65.1	8.8
28/04/2021 12:43	23.5	64.9	8.7
28/04/2021 12:44	23.0	64.7	8.7
28/04/2021 12:45	16.0	68.4	8.8
28/04/2021 12:46	26.7	65.9	8.9
28/04/2021 12:47	28.6	65.0	9.0
28/04/2021 12:48	32.6	65.4	9.2
28/04/2021 12:49	40.0	65.7	9.4
28/04/2021 12:50	41.7	65.2	9.4
28/04/2021 12:51	51.6	65.3	9.6
28/04/2021 12:52	58.4	65.3	9.8
28/04/2021 12:53	63.3	65.2	9.9
28/04/2021 12:54	60.7	65.6	9.9
28/04/2021 12:55	44.0	68.4	9.9
28/04/2021 12:56	49.7	65.4	9.7
28/04/2021 12:57	42.7	65.1	9.5
28/04/2021 12:58	41.3	64.9	9.4
28/04/2021 12:59	34.6	64.6	9.1
28/04/2021 13:00	30.0	64.7	9.0
Minimum	16.0	64.6	8.6
Maximum	73.3	72.1	10.1
Average	37.6	66.5	9.4

One Minute Averaged Gaseous Emissions Results

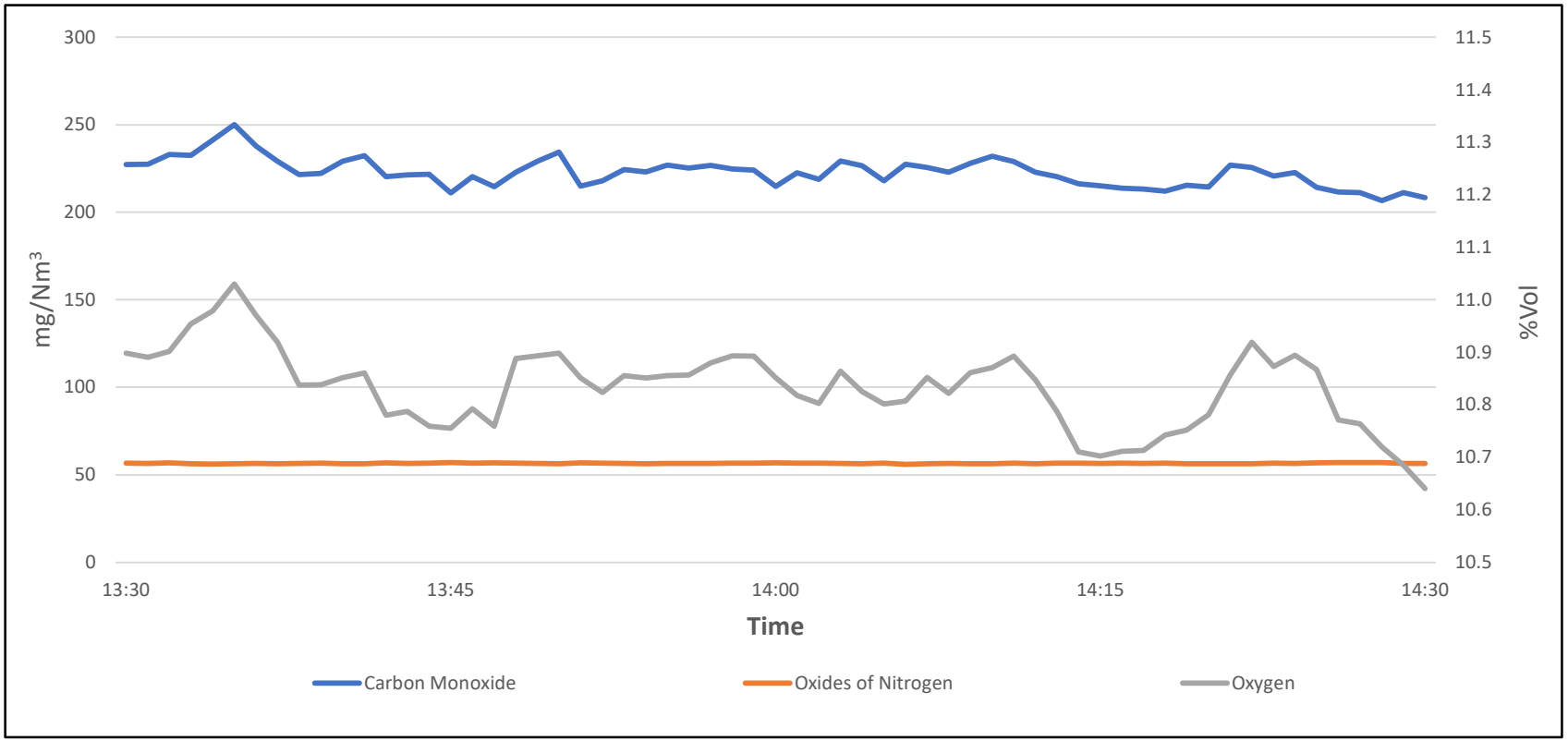
South Hook LNG - SCV 2G			
273K, 101.3 kPa, 3% Oxygen on a dry basis			
Species	Carbon Monoxide	Oxides of Nitrogen	Oxygen
Units	mg/m3	mg/m3	%
28/04/2021 14:15	204	59.9	10.5
28/04/2021 14:16	233	57.9	10.5
28/04/2021 14:17	198	57.9	10.0
28/04/2021 14:18	156	58.0	9.5
28/04/2021 14:19	131	57.6	9.2
28/04/2021 14:20	128	57.5	9.1
28/04/2021 14:21	118	57.6	9.0
28/04/2021 14:22	116	57.6	9.0
28/04/2021 14:23	124	57.6	9.1
28/04/2021 14:24	123	58.6	9.2
28/04/2021 14:25	115	60.4	9.3
28/04/2021 14:26	153	58.2	9.4
28/04/2021 14:27	179	58.2	9.8
28/04/2021 14:28	207	58.3	10.1
28/04/2021 14:29	212	58.4	10.3
28/04/2021 14:30	232	58.1	10.4
28/04/2021 14:31	243	57.7	10.5
28/04/2021 14:32	210	57.8	10.2
28/04/2021 14:33	176	58.0	9.8
28/04/2021 14:34	144	58.2	9.4
28/04/2021 14:35	105	60.9	9.2
28/04/2021 14:36	119	58.3	9.1
28/04/2021 14:37	128	57.9	9.1
28/04/2021 14:38	135	57.9	9.2
28/04/2021 14:39	142	58.0	9.3
28/04/2021 14:40	151	57.9	9.4
28/04/2021 14:41	161	57.9	9.5
28/04/2021 14:42	175	58.1	9.7
28/04/2021 14:43	197	58.1	10.0
28/04/2021 14:44	218	58.0	10.3
28/04/2021 14:45	179	60.5	10.4
28/04/2021 14:46	234	58.2	10.5
28/04/2021 14:47	222	57.9	10.4
28/04/2021 14:48	193	57.9	10.0
28/04/2021 14:49	168	57.9	9.7
28/04/2021 14:50	144	57.8	9.4
28/04/2021 14:51	135	57.7	9.2
28/04/2021 14:52	124	57.7	9.1
28/04/2021 14:53	125	58.0	9.1
28/04/2021 14:54	126	58.1	9.2
28/04/2021 14:55	103	60.9	9.2
28/04/2021 14:56	131	58.5	9.3
28/04/2021 14:57	154	58.0	9.5
28/04/2021 14:58	174	58.4	9.8
28/04/2021 14:59	192	58.1	10.0
28/04/2021 15:00	202	58.5	10.2
28/04/2021 15:01	212	58.3	10.3
28/04/2021 15:02	222	58.4	10.4
28/04/2021 15:03	194	58.6	10.2
28/04/2021 15:04	163	58.5	9.8
28/04/2021 15:05	112	61.1	9.5
28/04/2021 15:06	127	58.5	9.2
28/04/2021 15:07	112	58.1	9.0
28/04/2021 15:08	106	57.8	8.9
28/04/2021 15:09	108	58.0	8.9
28/04/2021 15:10	109	58.1	9.0
28/04/2021 15:11	121	57.9	9.1
28/04/2021 15:12	122	58.2	9.2
28/04/2021 15:13	138	58.2	9.4
28/04/2021 15:14	155	58.9	9.7
28/04/2021 15:15	133	61.5	9.9
Minimum	103	57.5	8.9
Maximum	243	61.5	10.5
Average	159	58.4	9.6

2.2.4 - Gaseous Emissions Graphical Data

South Hook LNG - SCV 1C

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

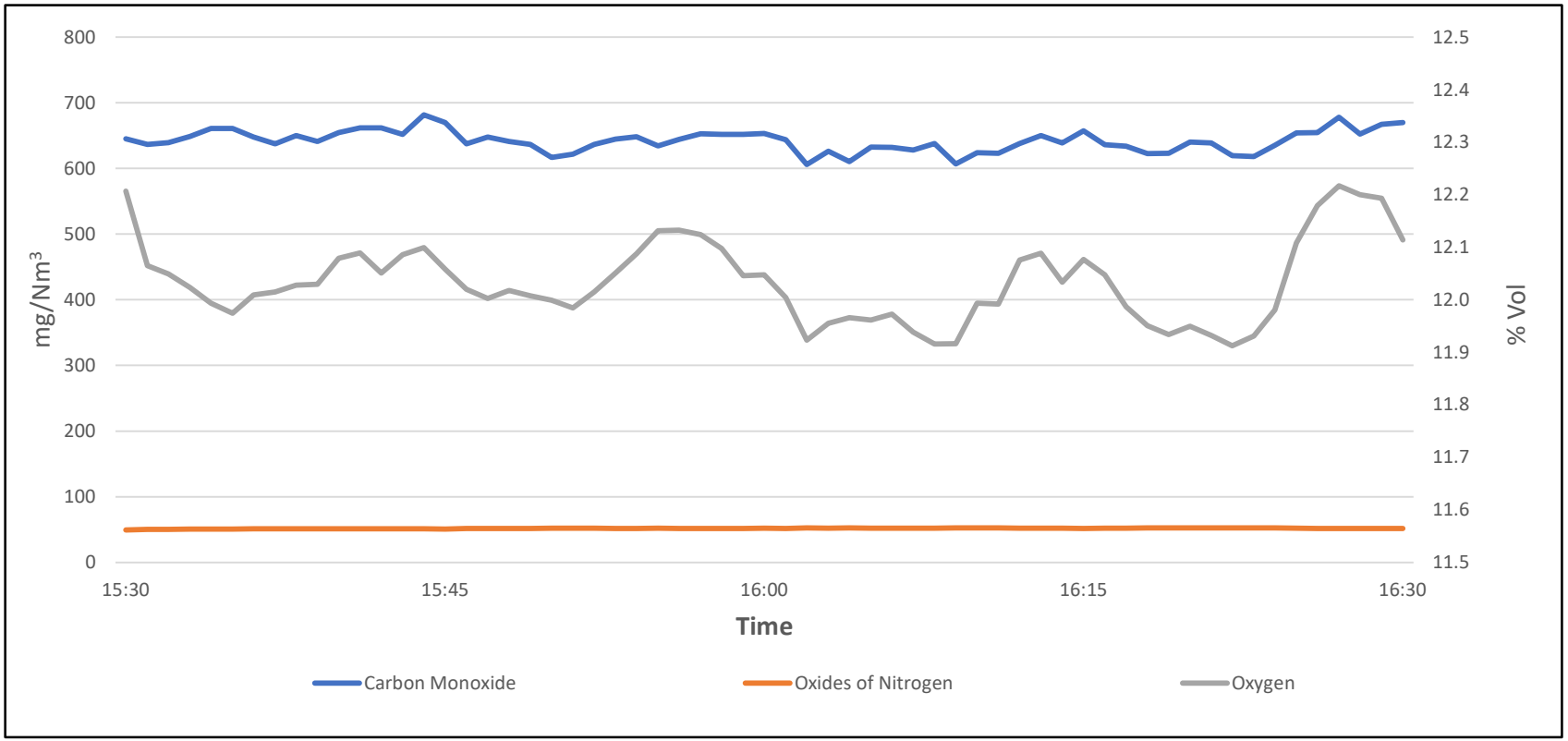
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 1D

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

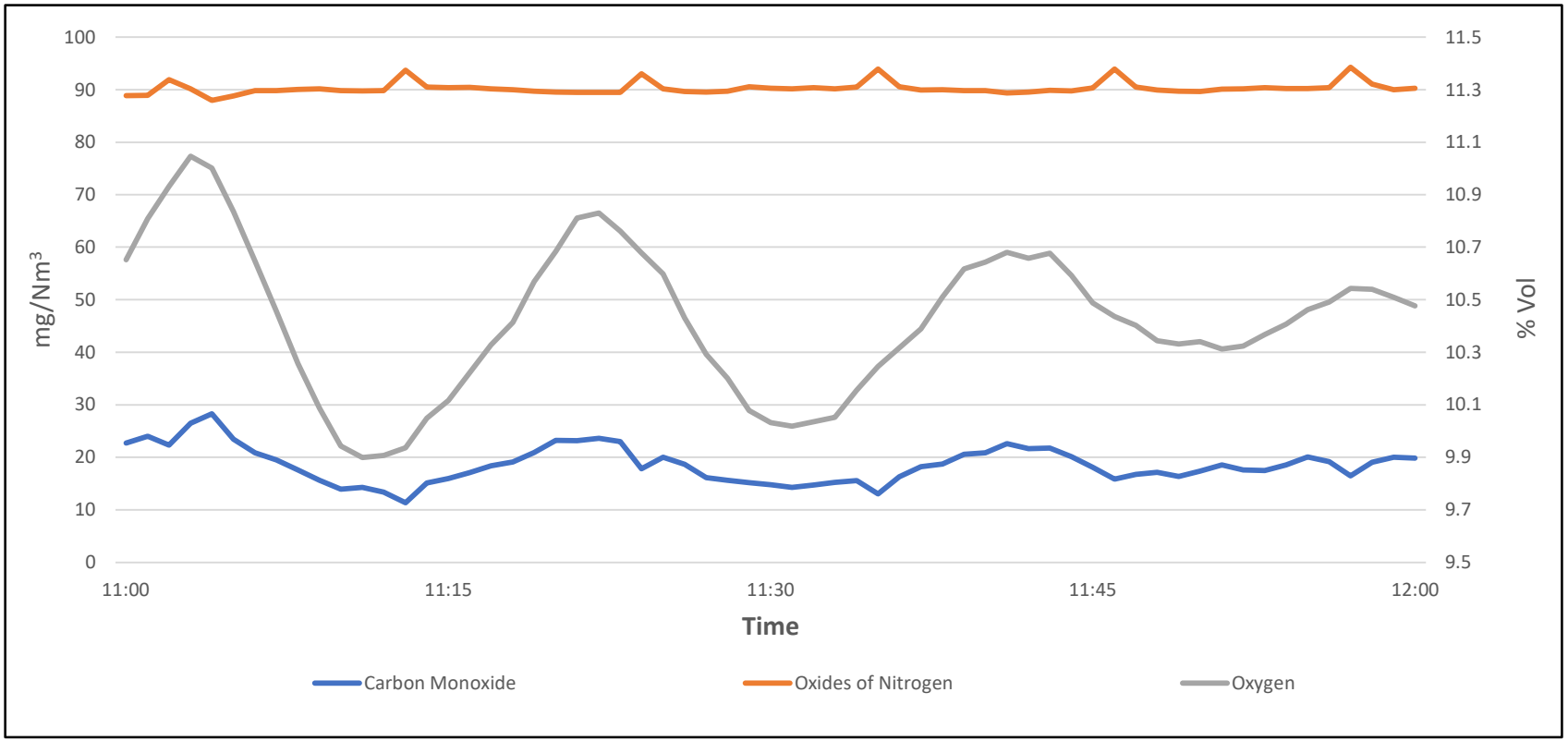
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 1E

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

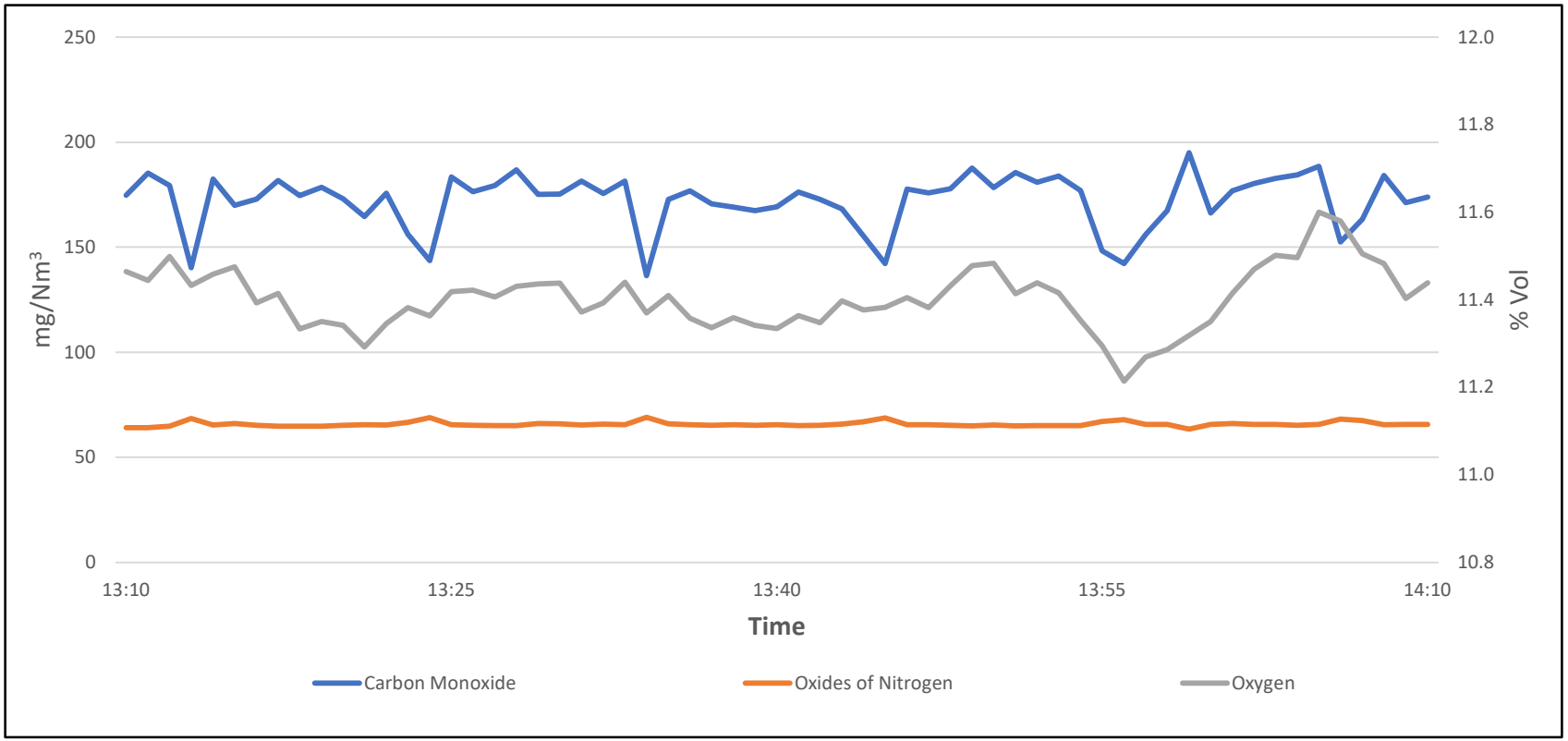
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 1F

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

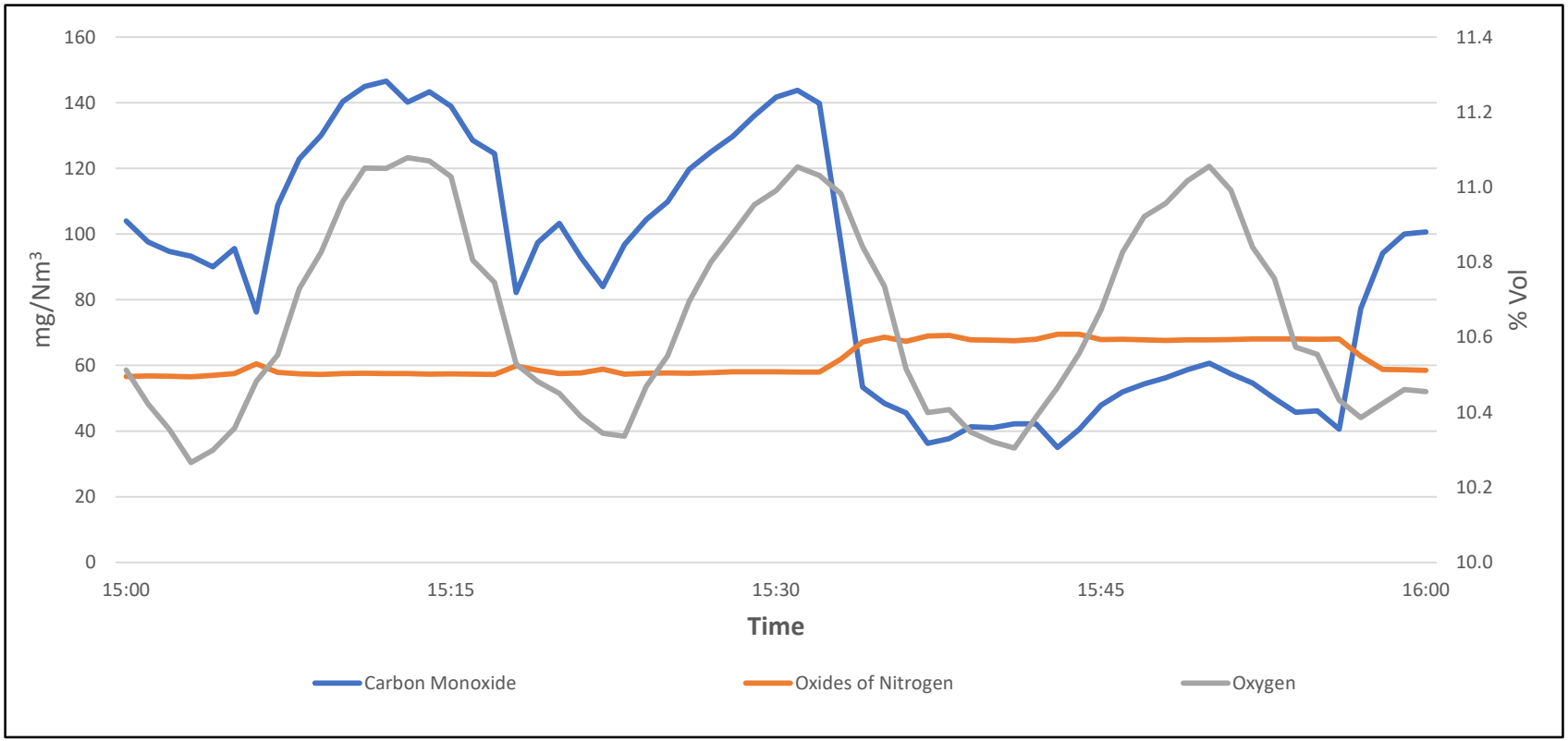
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 1H

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

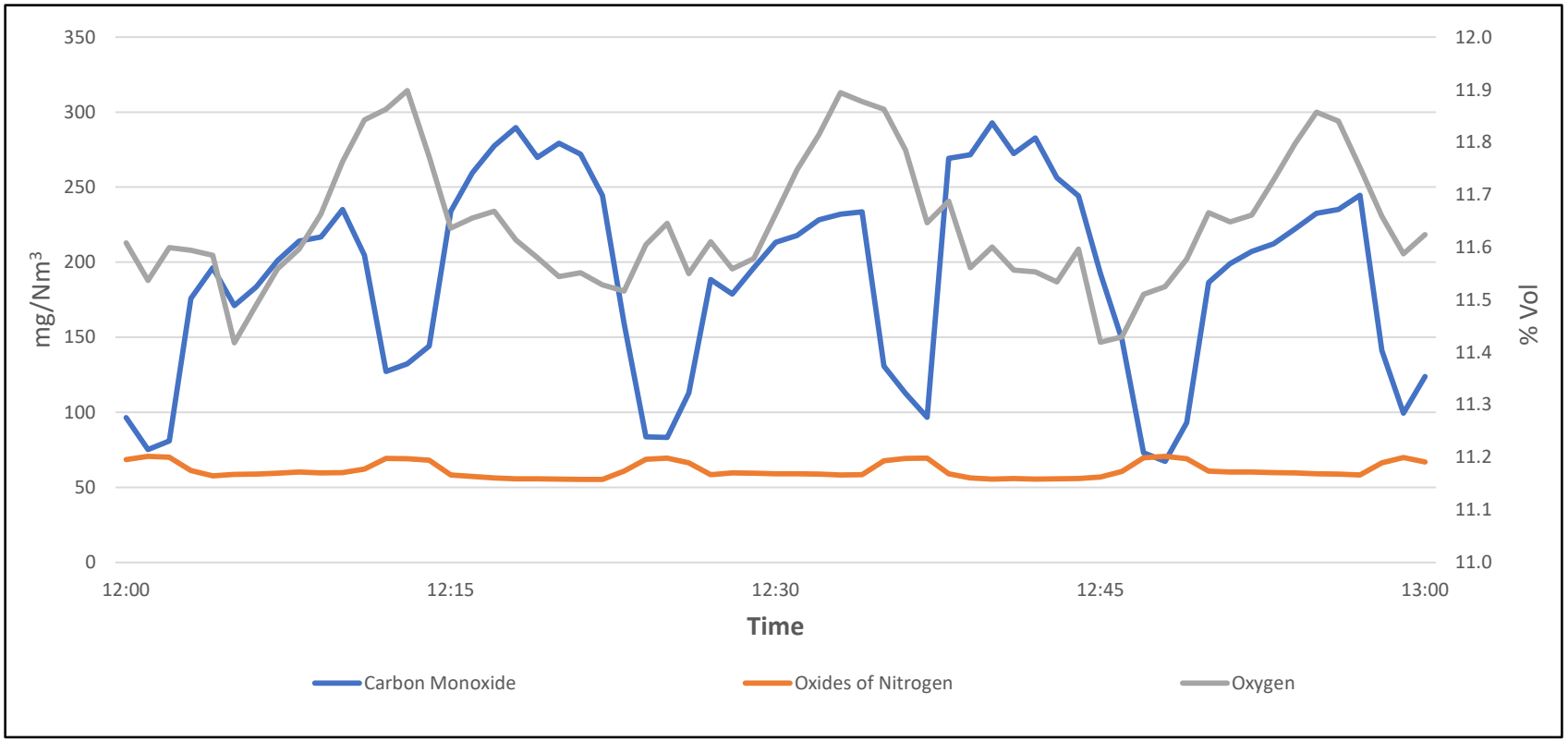
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 2A

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

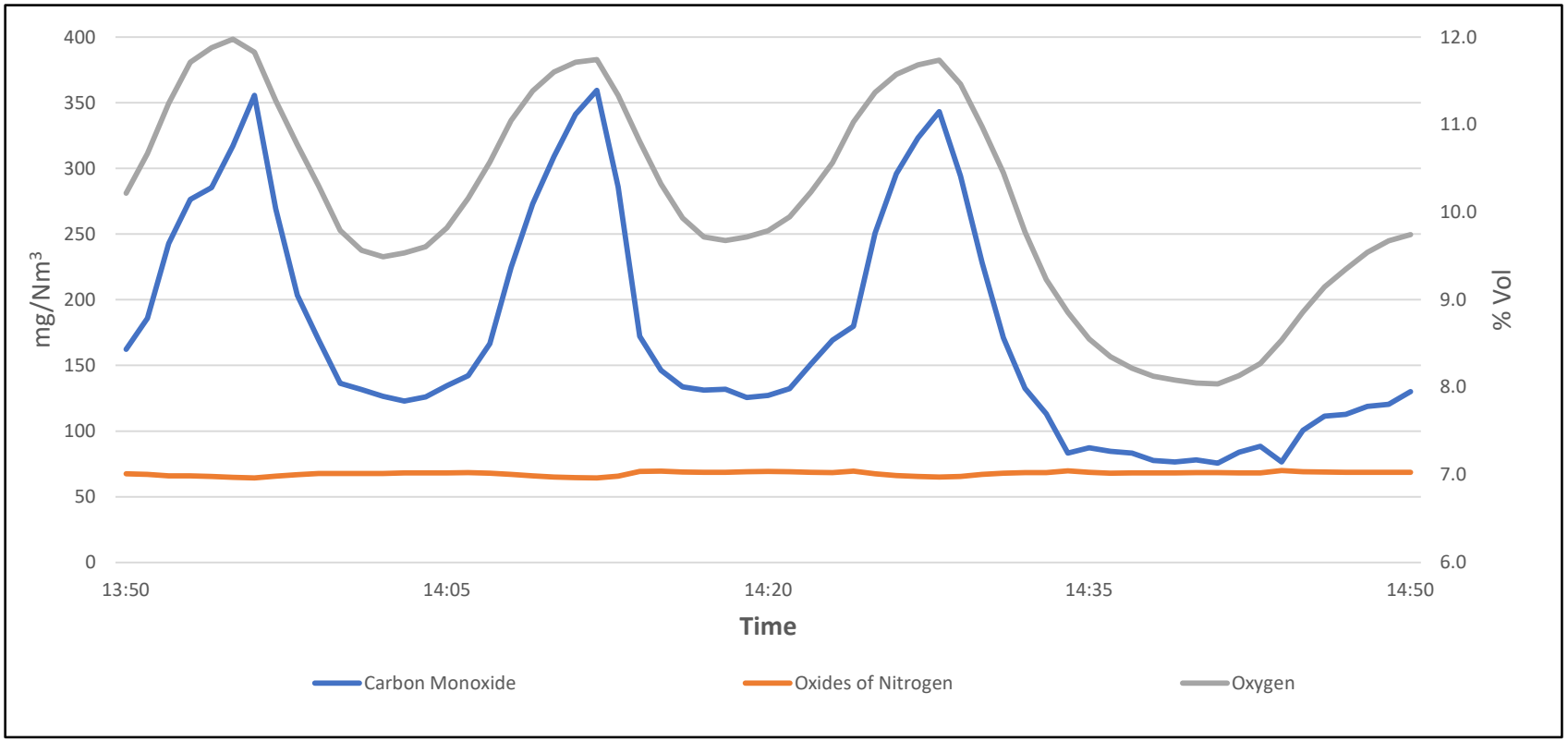
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 2B

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

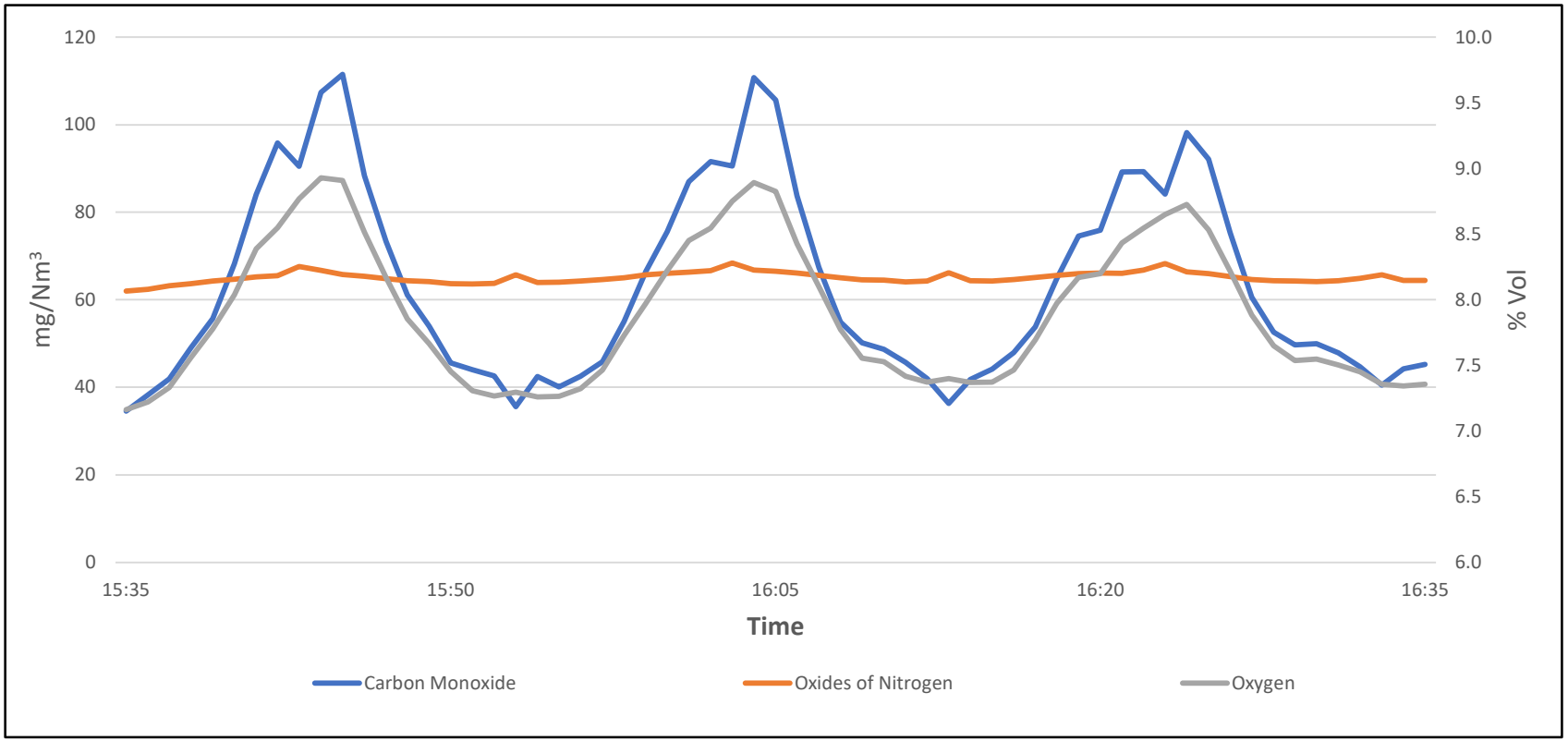
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 2D

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

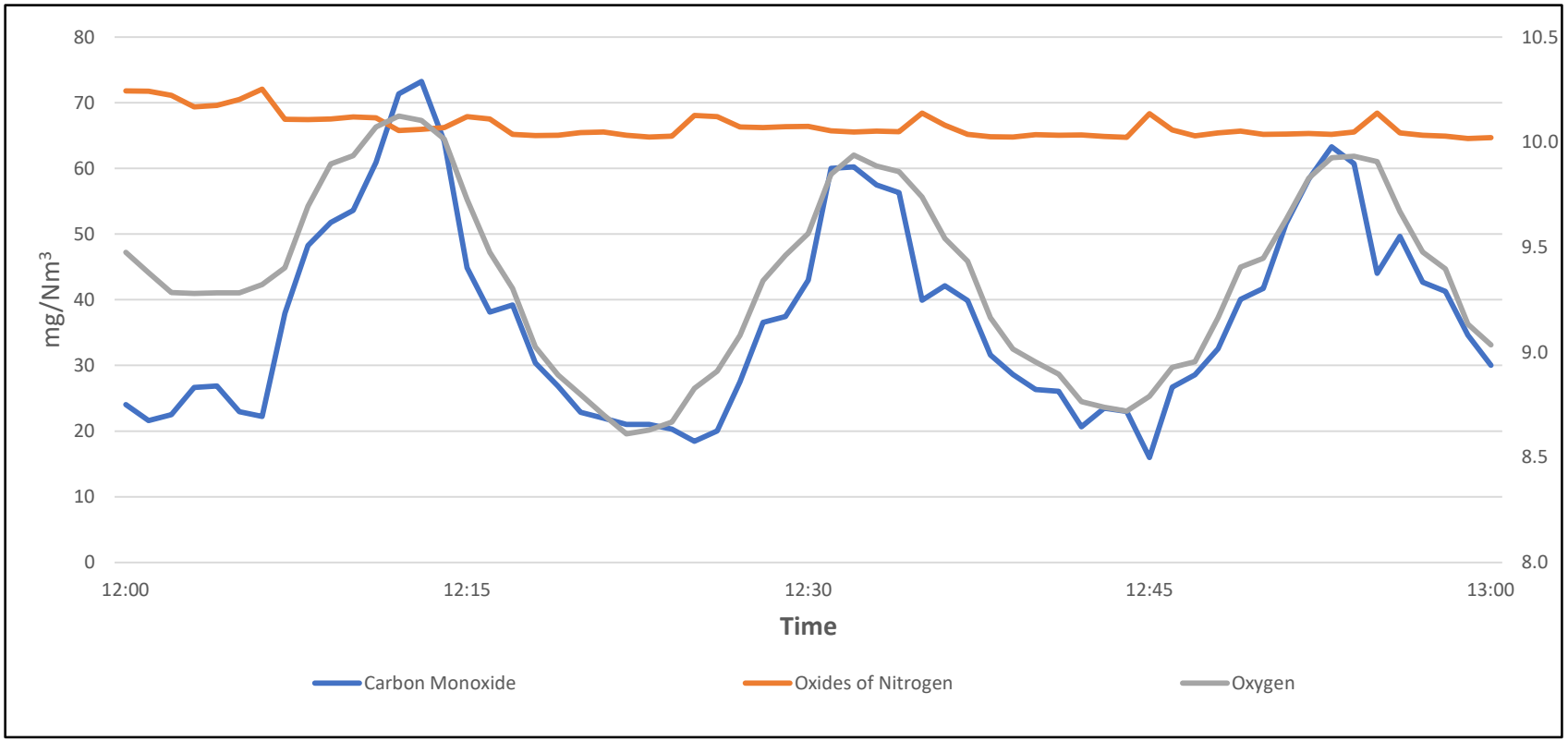
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 2F

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

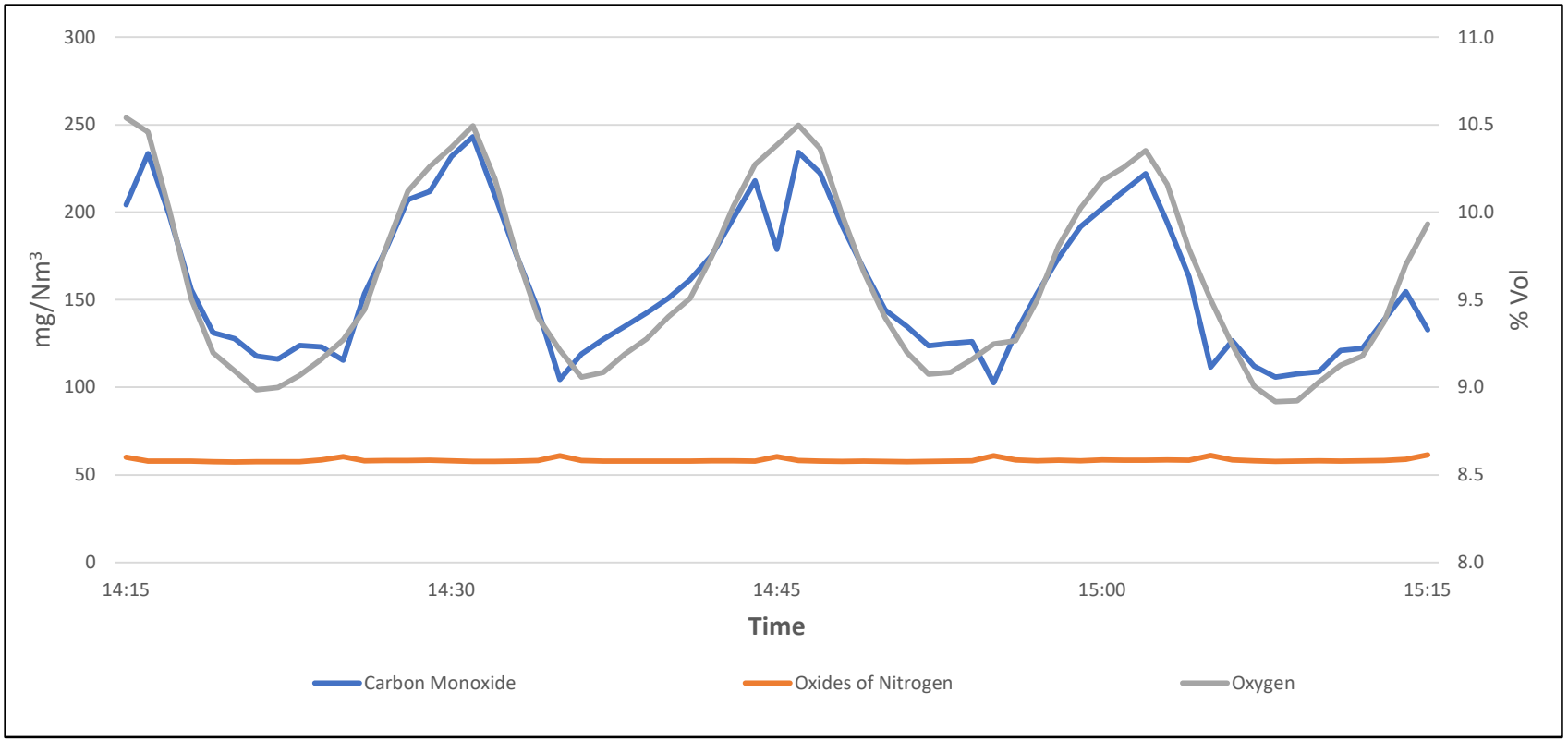
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 2G

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

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:		INTK53APR21	Calibration By:	M Ellison	Comments:	
Site:		South Hook LNG		Date:		26/04/2021	MCERTs ID:	MM-05-682		
Stack:		1C and 1D		Leak Check Method:		Flow Method	Test Team :	MRE/AML		
Species		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**				
Analyser Type/ID		Horiba PG250 AS0218		Horiba PG250 AS0218		Horiba PG250 AS0218				
Gas Cylinder ID		195688SG		195688SG		250638SG				
Gas Cylinder Concentration		155.3 ppm		79.5 ppm		15.04 % Vol				
Concentration Uncertainty		1 %		1 %		1 %				
Span Value		155.3 ppm		79.5 ppm		15.04 % Vol				
Analyser Range 0 -		200 ppm		100 ppm		25 % Vol				
ANALYSER ADJUSTMENT										
Check Zero	Time	12:50		12:50		12:50				
	Reading	1.7 ppm		0.1 ppm		0.05 % Vol				
	Gain	1		-5		2				
Adjust Zero	Time	12:51		12:51		12:51				
	Reading	0 ppm		0 ppm		0 % Vol				
	Gain	1		-4		3				
Check Span	Time	12:56		12:56		13:02				
	Reading	158.7 ppm		85.7 ppm		14.91 % Vol				
	Gain	1.392		1.075		1.018				
Adjust Span	Time	12:57		12:57		13:04				
	Reading	155.3 ppm		79.5 ppm		15.06 % Vol				
	Gain	1.367		0.996		1.026				
Check Zero	Time	13:08		13:08		13:09				
	Reading	0.7 ppm		0 ppm		-0.1 % Vol				
Zero Drift		0.70 ppm		0.00 ppm		0.10 % Vol				
Acceptance		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**				
SAMPLING SYSTEM CHECK - FLOW METHOD		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**				
Expected Flow		0.4 l/min		0.4 l/min		0.4 l/min				
Time		13:12		13:12		13:12				
Reading		0		0		0				
PASS/FAIL		**PASS**		**PASS**		**PASS**				
POST TEST DRIFT CHECK		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**				
Span Value		155.3 ppm		79.5 ppm		15.04 % Vol				
Check Zero	Time	16:51		16:51		16:51				
	Reading	1.3 ppm		-0.1 ppm		0.03 % Vol				
	Drift (%)	**0.8**		**0.1**		**0.2**				
	Acceptance	**Accept**		**Accept**		**Accept**				
Check Span	Time	16:56		16:56		17:01				
	Reading	153.8 ppm		77.9 ppm		14.92 % Vol				
	Drift (%)	**1.0**		**2.0**		**0.9**				
	Acceptance	**Accept**		**Drift Correct**		**Accept**				

GAS CALIBRATION RECORD

Client:		Intertek Ltd	Job Reference:	INTK53APR21	Calibration By:	M Ellison	Comments:			
Site:		South Hook LNG	Date:	27/04/2021	MCERTs ID:	MM-05-682				
Stack:		2A, 2B and 2D	Leak Check Method:	Flow Method	Test Team :	MRE/AML				
Species		**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**						
Analyser Type/ID		Horiba PG250 AS0218	Horiba PG250 AS0218	Horiba PG250 AS0218						
Gas Cylinder ID		195688SG	195688SG	250638SG						
Gas Cylinder Concentration		155.3 ppm	79.5 ppm	15.04 % Vol						
Concentration Uncertainty		1 %	1 %	1 %						
Span Value		155.3 ppm	79.5 ppm	15.04 % Vol						
Analyser Range 0 -		200 ppm	100 ppm	25 % Vol						
ANALYSER ADJUSTMENT										
Check Zero	Time	10:55	10:55	10:55						
	Reading	1.6 ppm	0 ppm	-0.01 % Vol						
	Gain	1	-4	3						
Adjust Zero	Time	10:56	10:56	10:57						
	Reading	0 ppm	0 ppm	0 % Vol						
	Gain	2	-4	3						
Check Span	Time	11:12	11:12	11:20						
	Reading	153.2 ppm	80.3 ppm	14.98 % Vol						
	Gain	1.367	0.996	1.026						
Adjust Span	Time	11:14	11:14	11:21						
	Reading	155.8 ppm	79.6 ppm	15.04 % Vol						
	Gain	1.387	0.986	1.03						
Check Zero	Time	11:30	11:30	11:30						
	Reading	-0.8 ppm	0 ppm	0.02 % Vol						
Zero Drift		0.80 ppm	0.00 ppm	0.02 % Vol						
Acceptance		**Accept <2% Range**	**Accept <2% Range**	**Accept <2% Range**						
SAMPLING SYSTEM CHECK - FLOW METHOD		**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**						
Expected Flow		0.4 l/min	0.4 l/min	0.4 l/min						
Time		11:30	11:30	11:30						
Reading		0	0	0						
PASS/FAIL		**PASS**	**PASS**	**PASS**						
POST TEST DRIFT CHECK		**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**						
Span Value		155.3 ppm	79.5 ppm	15.04 % Vol						
Check Zero	Time	17:08	17:08	17:08						
	Reading	0.1 ppm	0 ppm	0.09 % Vol						
	Drift (%)	**0.1**	**0.0**	**0.6**						
	Acceptance	**Accept**	**Accept**	**Accept**						
Check Span	Time	17:12	17:12	17:15						
	Reading	153.6 ppm	77.1 ppm	14.91 % Vol						
	Drift (%)	**1.4**	**3.1**	**0.9**						
	Acceptance	**Accept**	**Drift Correct**	**Accept**						

GAS CALIBRATION RECORD

Client:		Intertek Ltd		Job Reference:		INTK53APR21	Calibration By:	M Ellison	Comments:	
Site:		South Hook LNG		Date:		28/04/2021	MCERTs ID:	MM-05-682		
Stack:		2F and 2G		Leak Check Method:		Flow Method	Test Team :	MRE/AML		
Species		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**				
Analyser Type/ID		Horiba PG250 AS0218		Horiba PG250 AS0218		Horiba PG250 AS0218				
Gas Cylinder ID		195688SG		195688SG		250638SG				
Gas Cylinder Concentration		155.3 ppm		79.5 ppm		15.04 % Vol				
Concentration Uncertainty		1 %		1 %		1 %				
Span Value		155.3 ppm		79.5 ppm		15.04 % Vol				
Analyser Range 0 -		200 ppm		100 ppm		25 % Vol				
ANALYSER ADJUSTMENT										
Check Zero	Time	11:21		11:21		11:21				
	Reading	0.1 ppm		0 ppm		0.05 % Vol				
	Gain	2		-4		3				
Adjust Zero	Time	11:24		11:24		11:24				
	Reading	-0.2 ppm		0 ppm		-0.1 % Vol				
	Gain	2		-4		3				
Check Span	Time	11:29		11:29		11:37				
	Reading	153.9 ppm		79.5 ppm		21:21 % Vol				
	Gain	1.387		0.986		1.03				
Adjust Span	Time	11:33		11:33		11:38				
	Reading	155.2 ppm		79.3 ppm		15.05 % Vol				
	Gain	1.392		0.989		1.04				
Check Zero	Time	11:42		11:42		11:42				
	Reading	-1 ppm		0.1 ppm		0.09 % Vol				
Zero Drift		0.80 ppm		0.10 ppm		0.19 % Vol				
Acceptance		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**				
SAMPLING SYSTEM CHECK - FLOW METHOD		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**				
Expected Flow		0.4 l/min		0.4 l/min		0.4 l/min				
Time		11:42		11:42		11:42				
Reading		0		0		0				
PASS/FAIL		**PASS**		**PASS**		**PASS**				
POST TEST DRIFT CHECK		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**				
Span Value		155.3 ppm		79.5 ppm		15.04 % Vol				
Check Zero	Time	15:46		15:46		15:46				
	Reading	-1.6 ppm		-0.1 ppm		0.08 % Vol				
	Drift (%)	**0.9**		**0.1**		**1.2**				
	Acceptance	**Accept**		**Accept**		**Accept**				
Check Span	Time	15:50		15:50		15:52				
	Reading	152.1 ppm		78.6 ppm		15.08 % Vol				
	Drift (%)	**2.0**		**0.9**		**0.2**				
	Acceptance	**Accept**		**Accept**		**Accept**				

GAS CALIBRATION RECORD

Client:		Intertek Ltd		Job Reference:		INTK53APR21	Calibration By:	M Ellison	Comments:	
Site:		South Hook LNG		Date:		29/04/2021	MCERTs ID:	MM-05-682		
Stack:		1E, 1F and 1H		Leak Check Method:		Flow Method	Test Team :	MRE/AML		
Species		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**				
Analyser Type/ID		Horiba PG250 AS0218		Horiba PG250 AS0218		Horiba PG250 AS0218				
Gas Cylinder ID		195688SG		195688SG		250638SG				
Gas Cylinder Concentration		155.3 ppm		79.5 ppm		15.04 % Vol				
Concentration Uncertainty		1 %		1 %		1 %				
Span Value		155.3 ppm		79.5 ppm		15.04 % Vol				
Analyser Range 0 -		200 ppm		100 ppm		25 % Vol				
ANALYSER ADJUSTMENT										
Check Zero	Time	10:31		10:31		10:31				
	Reading	-1.7 ppm		0.1 ppm		-0.2 % Vol				
	Gain	2		-4		3				
Adjust Zero	Time	10:33		10:33		10:33				
	Reading	2 ppm		0 ppm		-0.1 % Vol				
	Gain	1		-4		3				
Check Span	Time	10:38		10:38		10:41				
	Reading	159.9 ppm		79.5 ppm		15.03 % Vol				
	Gain	1.392		0.989		1.04				
Adjust Span	Time	10:39		10:39		10:42				
	Reading	155.3 ppm		79.5 ppm		15.07 % Vol				
	Gain	1.353		0.987		1.038				
Check Zero	Time	10:46		10:46		10:46				
	Reading	2 ppm		0.1 ppm		0.02 % Vol				
Zero Drift		0.00 ppm		0.10 ppm		0.12 % Vol				
Acceptance		**Accept <2% Range**		**Accept <2% Range**		**Accept <2% Range**				
SAMPLING SYSTEM CHECK - FLOW METHOD		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**				
Expected Flow		0.4 l/min		0.4 l/min		0.4 l/min				
Time		10:55		10:55		10:55				
Reading		0		0		0				
PASS/FAIL		**PASS**		**PASS**		**PASS**				
POST TEST DRIFT CHECK		**Carbon Monoxide**		**Oxides of Nitrogen**		**Oxygen**				
Span Value		155.3 ppm		79.5 ppm		15.04 % Vol				
Check Zero	Time	16:30		16:30		16:30				
	Reading	2.7 ppm		0 ppm		0.06 % Vol				
	Drift (%)	**0.5**		**0.0**		**1.1**				
	Acceptance	**Accept**		**Accept**		**Accept**				
Check Span	Time	16:36		16:36		16:41				
	Reading	153.9 ppm		79 ppm		15.09 % Vol				
	Drift (%)	**0.9**		**0.6**		**0.1**				
	Acceptance	**Accept**		**Accept**		**Accept**				

2.2.6 - Uncertainty Calculations

SCV 1C Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	10.84	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	0.2	% of span value		≤±5% span value
Span drift	0.9	% 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	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}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.02
Lack of fit			u_{fit}				0.14
Zero drift			u_{0dr}				0.02
Span drift			u_{sdr}				0.08
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.011
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			0.37	% vol
Expanded uncertainty	k =	2	0.74	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.74**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.80**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	**mg/m^3 (Corrected)**	**Cal gas conc.**	194.19	**mg.m^{-3}**
Measured concentration	125.87	**mg/m3 (101.3kPa, 273K)**	**Range**	250.09	**mg/m^3**
Measured concentration	222.91	**mg/m^3 (Corrected)**			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	10.84	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.77	1.00	1.00	1.00
Uncertainty in factor		0.13	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.77**	uf	**0.13**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.8	% of span value		≤±5% span value
Span drift	1.0	% 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	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}		0.55
Standard deviation of repeatability at span level		u_{rs}		0.00
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		1.69
Zero drift		u_{0dr}		0.94
Span drift		u_{sdr}		1.08
Influence of sample gas flow		u_{spres}		0.03
Influence of atmospheric pressure		u_{apres}		0.51
Influence of ambient temperature		u_{temp}		0.02
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}		0.63
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}		16.15

Measurement uncertainty				
Combined uncertainty			4.84	mg/m^3
Expanded uncertainty	k =	2	9.68	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.68	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**36.56**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**36.56 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**16.40 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	31.94	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	56.57	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	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	10.84	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.77	1.00	1.00	1.00
Uncertainty in factor		0.13	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.77**	uf	**0.13**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% 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)	0.6	% 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	95.4	%		≥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}				0.14
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{flt}				0.70
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.00
Influence of sample gas flow		u_{spres}				0.02
Influence of atmospheric pressure		u_{apres}				0.42
Influence of ambient temperature		u_{temp}				0.06
Cross sensitivity		u_{interf}				0.83
Influence of voltage		u_{volt}				0.00
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				0.84
Uncertainty of calibration gas		u_{cal}				0.16
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}				4.10

Measurement uncertainty				
Combined uncertainty			1.45	mg/m^3
Expanded uncertainty	k =	2	2.90	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			2.90	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**9.68**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**9.68**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**17.10**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.71**	**% 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	101210	101411.8	201.8	42.2					42.2	12.3	1.41	102	5.8	83.5	10.7	29.36	29.20
2	101210	101411.8	201.8	49.0					49.0	12.5	1.41	102	5.8	83.5	10.7	29.36	29.20
3	101210	101411.8	201.8	53.9					53.9	12.6	1.41	102	5.8	83.5	10.7	29.36	29.20
4	101210	101411.8	201.8	49.0					49.0	12.6	1.41	102	5.8	83.5	10.7	29.36	29.20
5	101210	101411.8	201.8	42.2					42.2	12.5	1.41	102	5.8	83.5	10.7	29.36	29.20
6	101210	101411.8	201.8	39.2					39.2	12.5	1.41	102	5.8	83.5	10.7	29.36	29.20
7	101210	101411.8	201.8	40.2					40.2	12.0	1.41	102	5.8	83.5	10.7	29.36	29.20
8	101210	101411.8	201.8	42.2					42.2	11.8	1.41	102	5.8	83.5	10.7	29.36	29.20
9	101210	101411.8	201.8	39.2					39.2	11.8	1.41	102	5.8	83.5	10.7	29.36	29.20
10	101210	101411.8	201.8	47.1					47.1	12.0	1.41	102	5.8	83.5	10.7	29.36	29.20
11	101210	101411.8	201.8	49.0					49.0	12.2	1.41	102	5.8	83.5	10.7	29.36	29.20
12	101210	101411.8	201.8	66.7					66.7	12.1	1.41	102	5.8	83.5	10.7	29.36	29.20
Mean	**101210**	**101412**	**201.8**	**46.6**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**46.6**	**12.2**	**1.4**	**102.0**	**5.8**	**90.1**	**10.7**	**28.81**	**28.72**

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

Mean density	**1.228**	**kg/m3**

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

Mean velocity	**7.24**	**m/sec**		
Standard uncertainty of velocity	**0.33**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.65**	**m/sec**	**9.0**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**44831**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4126**	**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 1D Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	12.03	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	0.2	% of span value		≤±5% span value
Span drift	0.9	% 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	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}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.02
Lack of fit			u_{fit}				0.14
Zero drift			u_{0dr}				0.02
Span drift			u_{sdr}				0.08
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.011
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			0.37	% vol
Expanded uncertainty	k =	2	0.74	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.74**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.14**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	mg/m^3 (Corrected)	**Cal gas conc.**	194.19	mg.m^{-3}
Measured concentration	319.66	mg/m3 (101.3kPa, 273K)	**Range**	250.09	mg/m^3
Measured concentration	641.64	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	12.03	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		2.01	1.00	1.00	1.00
Uncertainty in factor		0.17	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**2.01**	uf	**0.17**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.8	% of span value		≤±5% span value
Span drift	1.0	% 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	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}		0.55
Standard deviation of repeatability at span level		u_{rs}		0.00
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		1.69
Zero drift		u_{0dr}		0.94
Span drift		u_{sdr}		1.08
Influence of sample gas flow		u_{spres}		0.03
Influence of atmospheric pressure		u_{apres}		0.51
Influence of ambient temperature		u_{temp}		0.02
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}		1.60
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}		52.82

Measurement uncertainty				
Combined uncertainty			5.06	mg/m^3
Expanded uncertainty	k =	2	10.11	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			10.11	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**107.57**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**107.57 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**16.77 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	25.76	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	51.71	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	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	12.03	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		2.01	1.00	1.00	1.00
Uncertainty in factor		0.17	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**2.01**	uf	**0.17**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% 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)	0.6	% 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	95.4	%		≥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}				0.14
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{fit}				0.70
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.00
Influence of sample gas flow		u_{spres}				0.02
Influence of atmospheric pressure		u_{apres}				0.42
Influence of ambient temperature		u_{temp}				0.06
Cross sensitivity		u_{interf}				0.83
Influence of voltage		u_{volt}				0.00
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				0.68
Uncertainty of calibration gas		u_{cal}				0.13
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}				4.26

Measurement uncertainty				
Combined uncertainty			1.36	mg/m^3
Expanded uncertainty	k =	2	2.72	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			2.72	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**10.12**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**10.12**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**19.56**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.54**	**% 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	101210	101442.7	232.7	44.1					44.1	12.0	1.41	258	5.2	82.8	12	29.31	29.15
2	101210	101442.7	232.7	50.0					50.0	12.0	1.41	258	5.2	82.8	12	29.31	29.15
3	101210	101442.7	232.7	52.0					52.0	11.9	1.41	258	5.2	82.8	12	29.31	29.15
4	101210	101442.7	232.7	50.0					50.0	11.9	1.41	258	5.2	82.8	12	29.31	29.15
5	101210	101442.7	232.7	41.2					41.2	12.0	1.41	258	5.2	82.8	12	29.31	29.15
6	101210	101442.7	232.7	61.8					61.8	12.2	1.41	258	5.2	82.8	12	29.31	29.15
7	101210	101442.7	232.7	39.2					39.2	12.4	1.41	258	5.2	82.8	12	29.31	29.15
8	101210	101442.7	232.7	37.3					37.3	12.4	1.41	258	5.2	82.8	12	29.31	29.15
9	101210	101442.7	232.7	46.1					46.1	12.3	1.41	258	5.2	82.8	12	29.31	29.15
10	101210	101442.7	232.7	55.9					55.9	12.5	1.41	258	5.2	82.8	12	29.31	29.15
11	101210	101442.7	232.7	59.8					59.8	12.4	1.41	258	5.2	82.8	12	29.31	29.15
12	101210	101442.7	232.7	76.5					76.5	12.5	1.41	258	5.2	82.8	12	29.31	29.15
Mean	**101210**	**101443**	**232.7**	**51.1**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**51.1**	**12.2**	**1.4**	**258.0**	**5.2**	**89.7**	**12.0**	**28.79**	**28.69**

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

Mean density	**1.227**	**kg/m3**

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

Mean velocity	**7.56**	**m/sec**		
Standard uncertainty of velocity	**0.34**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.68**	**m/sec**	**9.0**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**46850**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4296**	**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 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	10.42	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	1.1	% 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	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}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.02
Lack of fit			u_{fit}				0.14
Zero drift			u_{0dr}				0.09
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}				-0.011
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			0.37	% vol
Expanded uncertainty	k =	2	0.74	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.74**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**7.11**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	mg/m^3 (Corrected)	**Cal gas conc.**	194.19	mg.m^{-3}
Measured concentration	10.92	mg/m3 (101.3kPa, 273K)	**Range**	250.09	mg/m^3
Measured concentration	18.58	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	10.42	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.70	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)		**1.70**	uf	**0.12**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.5	% of span value		≤±5% span value
Span drift	0.9	% 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	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}		0.55
Standard deviation of repeatability at span level	u_{rs}		0.00
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{flt}		1.69
Zero drift	u_{0dr}		0.51
Span drift	u_{sdr}		1.01
Influence of sample gas flow	u_{spres}		0.03
Influence of atmospheric pressure	u_{apres}		0.51
Influence of ambient temperature	u_{temp}		0.02
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}		0.05
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}		1.30

Measurement uncertainty				
Combined uncertainty			4.72	mg/m^3
Expanded uncertainty	k =	2	9.43	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.43	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**16.26**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**16.26 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**87.53 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	53.04	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	90.27	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	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	10.42	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.70	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)		**1.70**	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	0.1	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.6	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.6	% 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	95.4	%		≥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}				0.14
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{flt}				0.70
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.59
Influence of sample gas flow		u_{spres}				0.02
Influence of atmospheric pressure		u_{apres}				0.42
Influence of ambient temperature		u_{temp}				0.06
Cross sensitivity		u_{interf}				0.83
Influence of voltage		u_{volt}				0.00
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				1.39
Uncertainty of calibration gas		u_{cal}				0.27
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}				6.32

Measurement uncertainty				
Combined uncertainty			1.93	mg/m^3
Expanded uncertainty	k =	2	3.87	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			3.87	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**14.26**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**14.26**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**15.79**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.62**	**% 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	100920	101162.2	242.2	49.0					49.0	14.5	1.64	8.6	6.2	83.5	10.3	29.40	29.22
2	100920	101162.2	242.2	59.8					59.8	14.6	1.64	8.6	6.2	83.5	10.3	29.40	29.22
3	100920	101162.2	242.2	62.7					62.7	14.8	1.64	8.6	6.2	83.5	10.3	29.40	29.22
4	100920	101162.2	242.2	57.8					57.8	15.0	1.64	8.6	6.2	83.5	10.3	29.40	29.22
5	100920	101162.2	242.2	53.9					53.9	15.1	1.64	8.6	6.2	83.5	10.3	29.40	29.22
6	100920	101162.2	242.2	56.9					56.9	15.2	1.64	8.6	6.2	83.5	10.3	29.40	29.22
7	100920	101162.2	242.2	45.1					45.1	14.3	1.64	8.6	6.2	83.5	10.3	29.40	29.22
8	100920	101162.2	242.2	51.0					51.0	14.2	1.64	8.6	6.2	83.5	10.3	29.40	29.22
9	100920	101162.2	242.2	49.0					49.0	14.1	1.64	8.6	6.2	83.5	10.3	29.40	29.22
10	100920	101162.2	242.2	68.6					68.6	14.0	1.64	8.6	6.2	83.5	10.3	29.40	29.22
11	100920	101162.2	242.2	69.6					69.6	13.9	1.64	8.6	6.2	83.5	10.3	29.40	29.22
12	100920	101162.2	242.2	73.5					73.5	13.9	1.64	8.6	6.2	83.5	10.3	29.40	29.22
Mean	**100920**	**101162**	**242.2**	**58.1**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**58.1**	**14.5**	**1.6**	**8.6**	**6.2**	**90.1**	**10.3**	**28.84**	**28.73**

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

Mean density	**1.216**	**kg/m3**

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

Mean velocity	**8.12**	**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	**50282**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4587**	**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 1F Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	11.40	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	1.1	% 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	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}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.02
Lack of fit			u_{fit}				0.14
Zero drift			u_{0dr}				0.09
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}				-0.011
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			0.37	% vol
Expanded uncertainty	k =	2	0.74	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.74**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.51**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	mg/m^3 (Corrected)	**Cal gas conc.**	194.19	mg.m^{-3}
Measured concentration	91.80	mg/m3 (101.3kPa, 273K)	**Range**	250.09	mg/m^3
Measured concentration	172.17	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	11.40	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.88	1.00	1.00	1.00
Uncertainty in factor		0.15	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.88**	uf	**0.15**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.5	% of span value		≤±5% span value
Span drift	0.9	% 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	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}		0.55
Standard deviation of repeatability at span level	u_{rs}		0.00
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{flt}		1.69
Zero drift	u_{0dr}		0.51
Span drift	u_{sdr}		1.01
Influence of sample gas flow	u_{spres}		0.03
Influence of atmospheric pressure	u_{apres}		0.51
Influence of ambient temperature	u_{temp}		0.02
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}		0.46
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}		13.31

Measurement uncertainty				
Combined uncertainty			4.74	mg/m^3
Expanded uncertainty	k =	2	9.47	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.47	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**32.01**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**32.01 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**18.59 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	35.08	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	65.78	mg/m^3 (Corrected)			

NO/NO2 ratio	99	

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	ppm
Conversion	2.05	

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.0	101.3	273.0
	measured	11.40	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.88	1.00	1.00	1.00
Uncertainty in factor		0.15	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.88**	uf	**0.15**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% 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)	0.6	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.6	% 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	95.4	%		≥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}				0.14
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{fit}				0.70
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.59
Influence of sample gas flow		u_{spres}				0.02
Influence of atmospheric pressure		u_{apres}				0.42
Influence of ambient temperature		u_{temp}				0.06
Cross sensitivity		u_{interf}				0.83
Influence of voltage		u_{volt}				0.00
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				0.92
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}				5.09

Measurement uncertainty				
Combined uncertainty			1.62	mg/m^3
Expanded uncertainty	k =	2	3.23	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			3.23	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**11.84**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**11.84**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**18.00**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.02**	**% 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	100920	101109.6	189.6	30.38965751					30.4	14.1	1.6	75	5.8	82.9	11.3	29.38	29.20
2	100920	101109.6	189.6	37.25183824					37.3	14.0	1.6	75	5.8	82.9	11.3	29.38	29.20
3	100920	101109.6	189.6	38.23214977					38.2	13.9	1.6	75	5.8	82.9	11.3	29.38	29.20
4	100920	101109.6	189.6	40.19277283					40.2	13.9	1.6	75	5.8	82.9	11.3	29.38	29.20
5	100920	101109.6	189.6	42.1533959					42.2	13.9	1.6	75	5.8	82.9	11.3	29.38	29.20
6	100920	101109.6	189.6	37.25183824					37.3	13.9	1.6	75	5.8	82.9	11.3	29.38	29.20
7	100920	101109.6	189.6	21.56685372					21.6	14.1	1.6	75	5.8	82.9	11.3	29.38	29.20
8	100920	101109.6	189.6	24.50778831					24.5	14.3	1.6	75	5.8	82.9	11.3	29.38	29.20
9	100920	101109.6	189.6	29.40934598					29.4	14.4	1.6	75	5.8	82.9	11.3	29.38	29.20
10	100920	101109.6	189.6	46.07464203					46.1	14.6	1.6	75	5.8	82.9	11.3	29.38	29.20
11	100920	101109.6	189.6	57.83838042					57.8	14.6	1.6	75	5.8	82.9	11.3	29.38	29.20
12	100920	101109.6	189.6	49.01557663					49.0	14.4	1.6	75	5.8	82.9	11.3	29.38	29.20
Mean	**100920**	**101110**	**189.6**	**37.8**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**37.8**	**14.2**	**1.6**	**75.0**	**5.8**	**89.7**	**11.3**	**28.83**	**28.72**

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

Mean density	**1.216 kg/m3**

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

Mean velocity	**6.51 m/sec**	
Standard uncertainty of velocity	**0.30 m/sec**	**4.6 % of value**
Expanded uncertainty in velocity	**0.60 m/sec**	**9.2 % of value**

	Circular duct		Rectangular duct	
Flow rate	**40326**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**3793**	**m^3/hour**	**#DIV/0!**	**m3/hour**
Volume flow rate expanded uncertainty	**9.4**	**% 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 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	10.66	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	1.1	% 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	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}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.02
Lack of fit			u_{fit}				0.14
Zero drift			u_{0dr}				0.09
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}				-0.011
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			0.37	% vol
Expanded uncertainty	k =	2	0.74	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.74**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.95**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	mg/m^3 (Corrected)	**Cal gas conc.**	194.19	mg.m^{-3}
Measured concentration	50.59	mg/m3 (101.3kPa, 273K)	**Range**	250.09	mg/m^3
Measured concentration	88.08	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.0	101.3	273.0
	measured	10.66	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.74	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)		**1.74**	uf	**0.12**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.5	% of span value		≤±5% span value
Span drift	0.9	% 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	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}		0.55
Standard deviation of repeatability at span level	u_{rs}		0.00
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{flt}		1.69
Zero drift	u_{0dr}		0.51
Span drift	u_{sdr}		1.01
Influence of sample gas flow	u_{spres}		0.03
Influence of atmospheric pressure	u_{apres}		0.51
Influence of ambient temperature	u_{temp}		0.02
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}		0.25
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}		6.31

Measurement uncertainty				
Combined uncertainty			4.72	mg/m^3
Expanded uncertainty	k =	2	9.44	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.44	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**20.73**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**20.73 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**23.54 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	35.54	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	61.88	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	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	10.66	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.74	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)		**1.74**	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	0.1	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.6	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.6	% 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	95.4	%		≥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}				0.14
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{flt}				0.70
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.59
Influence of sample gas flow		u_{spres}				0.02
Influence of atmospheric pressure		u_{apres}				0.42
Influence of ambient temperature		u_{temp}				0.06
Cross sensitivity		u_{interf}				0.83
Influence of voltage		u_{volt}				0.00
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				0.93
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}				4.44

Measurement uncertainty				
Combined uncertainty			1.62	mg/m^3
Expanded uncertainty	k =	2	3.24	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			3.24	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**10.52**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**10.52**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**17.00**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.03**	**% 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	100920	101142.4	222.4	58.8					58.8	14.3	1.62	22	6	83.3	10.7	29.39	29.20
2	100920	101142.4	222.4	63.7					63.7	14.4	1.62	22	6	83.3	10.7	29.39	29.20
3	100920	101142.4	222.4	76.5					76.5	14.4	1.62	22	6	83.3	10.7	29.39	29.20
4	100920	101142.4	222.4	83.3					83.3	14.3	1.62	22	6	83.3	10.7	29.39	29.20
5	100920	101142.4	222.4	67.6					67.6	14.3	1.62	22	6	83.3	10.7	29.39	29.20
6	100920	101142.4	222.4	94.1					94.1	14.0	1.62	22	6	83.3	10.7	29.39	29.20
7	100920	101142.4	222.4	64.7					64.7	14.2	1.62	22	6	83.3	10.7	29.39	29.20
8	100920	101142.4	222.4	58.8					58.8	14.4	1.62	22	6	83.3	10.7	29.39	29.20
9	100920	101142.4	222.4	75.5					75.5	14.6	1.62	22	6	83.3	10.7	29.39	29.20
10	100920	101142.4	222.4	82.3					82.3	14.5	1.62	22	6	83.3	10.7	29.39	29.20
11	100920	101142.4	222.4	79.4					79.4	14.4	1.62	22	6	83.3	10.7	29.39	29.20
12	100920	101142.4	222.4	92.1					92.1	14.4	1.62	22	6	83.3	10.7	29.39	29.20
Mean	**100920**	**101142**	**222.4**	**74.7**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**74.7**	**14.4**	**1.6**	**22.0**	**6.0**	**90.0**	**10.7**	**28.83**	**28.72**

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

Mean density	**1.216**	**kg/m3**

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

Mean velocity	**9.21**	**m/sec**		
Standard uncertainty of velocity	**0.41**	**m/sec**	**4.4**	**% of value**
Expanded uncertainty in velocity	**0.82**	**m/sec**	**8.9**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**57030**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**5176**	**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 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	11.64	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	0.6	% of span value		≤±5% span value
Span drift	0.9	% 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	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}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.02
Lack of fit			u_{fit}				0.14
Zero drift			u_{0dr}				0.05
Span drift			u_{sdr}				0.08
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.011
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			0.37	% vol
Expanded uncertainty	k =	2	0.74	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.74**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**6.37**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	mg/m^3 (Corrected)	**Cal gas conc.**	194.19	mg.m^{-3}
Measured concentration	99.56	mg/m3 (101.3kPa, 273K)	**Range**	250.09	mg/m^3
Measured concentration	191.55	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	11.64	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.92	1.00	1.00	1.00
Uncertainty in factor		0.15	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.92**	uf	**0.15**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.1	% of span value		≤±5% span value
Span drift	1.4	% 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	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}		0.55
Standard deviation of repeatability at span level	u_{rs}		0.00
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{flt}		1.69
Zero drift	u_{0dr}		0.07
Span drift	u_{sdr}		1.59
Influence of sample gas flow	u_{spres}		0.03
Influence of atmospheric pressure	u_{apres}		0.51
Influence of ambient temperature	u_{temp}		0.02
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}		0.50
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}		15.19

Measurement uncertainty				
Combined uncertainty			4.87	mg/m^3
Expanded uncertainty	k =	2	9.74	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.74	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**35.69**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**35.69 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**18.63 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	31.89	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	61.36	mg/m^3 (Corrected)			

NO/NO2 ratio	99

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	ppm
Conversion	2.05	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	11.64	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.92	1.00	1.00	1.00
Uncertainty in factor		0.15	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.92**	uf	**0.15**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% 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)	0.6	% 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	95.4	%		≥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}				0.14
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{flt}				0.70
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.00
Influence of sample gas flow		u_{spres}				0.02
Influence of atmospheric pressure		u_{apres}				0.42
Influence of ambient temperature		u_{temp}				0.06
Cross sensitivity		u_{interf}				0.83
Influence of voltage		u_{volt}				0.00
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				0.84
Uncertainty of calibration gas		u_{cal}				0.16
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}				4.86

Measurement uncertainty				
Combined uncertainty			1.45	mg/m^3
Expanded uncertainty	k =	2	2.90	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			2.90	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**11.22**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**11.22 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**18.28 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.71 % 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	100890	100890		36.3					36.3	12.8	1.47	85	5.4	83.0	11.6	29.33	29.16
2	100890	100890		41.2					41.2	12.9	1.47	85	5.4	83.0	11.6	29.33	29.16
3	100890	100890		43.1					43.1	12.9	1.47	85	5.4	83.0	11.6	29.33	29.16
4	100890	100890		47.1					47.1	12.8	1.47	85	5.4	83.0	11.6	29.33	29.16
5	100890	100890		53.9					53.9	12.8	1.47	85	5.4	83.0	11.6	29.33	29.16
6	100890	100890		55.9					55.9	12.8	1.47	85	5.4	83.0	11.6	29.33	29.16
7	100890	100890		36.3					36.3	12.7	1.47	85	5.4	83.0	11.6	29.33	29.16
8	100890	100890		36.3					36.3	12.8	1.47	85	5.4	83.0	11.6	29.33	29.16
9	100890	100890		46.1					46.1	12.9	1.47	85	5.4	83.0	11.6	29.33	29.16
10	100890	100890		53.9					53.9	13.0	1.47	85	5.4	83.0	11.6	29.33	29.16
11	100890	100890		58.8					58.8	12.9	1.47	85	5.4	83.0	11.6	29.33	29.16
12	100890	100890		63.7					63.7	12.9	1.47	85	5.4	83.0	11.6	29.33	29.16
Mean	**100890**	**100890**	**#DIV/0!**	**47.7**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**47.7**	**12.9**	**1.5**	**85.0**	**5.4**	**89.8**	**11.6**	**28.80**	**28.70**

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

Mean density	**1.218**	**kg/m3**

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

Mean velocity	**7.34**	**m/sec**		
Standard uncertainty of velocity	**0.33**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.66**	**m/sec**	**9.0**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**45451**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4181**	**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 2B Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	10.12	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	0.6	% of span value		≤±5% span value
Span drift	0.9	% 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	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}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.02
Lack of fit			u_{fit}				0.14
Zero drift			u_{0dr}				0.05
Span drift			u_{sdr}				0.08
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.011
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			0.37	% vol
Expanded uncertainty	k =	2	0.74	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.74**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**7.31**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	mg/m^3 (Corrected)	**Cal gas conc.**	194.19	mg.m^{-3}
Measured concentration	106.42	mg/m3 (101.3kPa, 273K)	**Range**	250.09	mg/m^3
Measured concentration	176.02	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	10.12	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.65	1.00	1.00	1.00
Uncertainty in factor		0.11	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.65**	uf	**0.11**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.1	% of span value		≤±5% span value
Span drift	1.4	% 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	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}		0.55
Standard deviation of repeatability at span level		u_{rs}		0.00
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		1.69
Zero drift		u_{0dr}		0.07
Span drift		u_{sdr}		1.59
Influence of sample gas flow		u_{spres}		0.03
Influence of atmospheric pressure		u_{apres}		0.51
Influence of ambient temperature		u_{temp}		0.02
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}		11.96

Measurement uncertainty				
Combined uncertainty			4.87	mg/m^3
Expanded uncertainty	k =	2	9.75	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.75	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**28.85**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**28.85 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**16.39 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	40.87	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	67.59	mg/m^3 (Corrected)			

NO/NO2 ratio	99	

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	ppm
Conversion	2.05	

Correction for reference conditions

		O2, %	Moisture, %	Pressure, KPa	Temperature, K
	ref	3.00	0.0	101.3	273.0
	measured	10.12	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.65	1.00	1.00	1.00
Uncertainty in factor		0.11	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.65**	uf	**0.11**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% 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)	0.6	% 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	95.4	%		≥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}		0.14
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{fit}		0.70
Zero drift	u_{0dr}		0.00
Span drift	u_{sdr}		0.00
Influence of sample gas flow	u_{spres}		0.02
Influence of atmospheric pressure	u_{apres}		0.42
Influence of ambient temperature	u_{temp}		0.06
Cross sensitivity	u_{interf}		0.83
Influence of voltage	u_{volt}		0.00
Influence from vibration	u_{vib}		0.00
Converter efficiency	u_{conv}		1.07
Uncertainty of calibration gas	u_{cal}		0.20
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}		4.59

Measurement uncertainty				
Combined uncertainty			1.60	mg/m^3
Expanded uncertainty	k =	2	3.21	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			3.21	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**10.61**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**10.61**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**15.69**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.00**	**% 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	100890	101070.25	180.25	52.0					52.0	13.5	1.54	44	7.4	84.5	8.1	29.51	29.33
2	100890	101070.25	180.25	59.8					59.8	13.8	1.54	44	7.4	84.5	8.1	29.51	29.33
3	100890	101070.25	180.25	42.2					42.2	14.0	1.54	44	7.4	84.5	8.1	29.51	29.33
4	100890	101070.25	180.25	47.1					47.1	14.0	1.54	44	7.4	84.5	8.1	29.51	29.33
5	100890	101070.25	180.25	47.1					47.1	14.0	1.54	44	7.4	84.5	8.1	29.51	29.33
6	100890	101070.25	180.25	52.0					52.0	14.0	1.54	44	7.4	84.5	8.1	29.51	29.33
7	100890	101070.25	180.25	63.7					63.7	12.4	1.54	44	7.4	84.5	8.1	29.51	29.33
8	100890	101070.25	180.25	36.3					36.3	12.8	1.54	44	7.4	84.5	8.1	29.51	29.33
9	100890	101070.25	180.25	45.1					45.1	13.3	1.54	44	7.4	84.5	8.1	29.51	29.33
10	100890	101070.25	180.25	58.8					58.8	13.5	1.54	44	7.4	84.5	8.1	29.51	29.33
11	100890	101070.25	180.25	84.3					84.3	13.6	1.54	44	7.4	84.5	8.1	29.51	29.33
12	100890	101070.25	180.25	77.4					77.4	13.7	1.54	44	7.4	84.5	8.1	29.51	29.33
Mean	**100890**	**101070**	**180.3**	**55.5**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**55.5**	**13.6**	**1.5**	**44.0**	**7.4**	**90.7**	**8.1**	**28.90**	**28.80**

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

Mean density	**1.222**	**kg/m3**

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

Mean velocity	**7.88**	**m/sec**		
Standard uncertainty of velocity	**0.35**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.71**	**m/sec**	**9.0**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**48808**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4464**	**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 2D Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	7.90	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	0.6	% of span value		≤±5% span value
Span drift	0.9	% 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	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}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.02
Lack of fit			u_{fit}				0.14
Zero drift			u_{0dr}				0.05
Span drift			u_{sdr}				0.08
Influence of sample gas flow			u_{spres}				0.001
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				-0.011
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}				0.04

Measurement uncertainty				
Combined uncertainty			0.37	% vol
Expanded uncertainty	k =	2	0.74	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.74**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**9.32**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	mg/m^3 (Corrected)	**Cal gas conc.**	194.19	mg.m^{-3}
Measured concentration	46.40	mg/m3 (101.3kPa, 273K)	**Range**	250.09	mg/m^3
Measured concentration	63.76	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	7.90	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.37	1.00	1.00	1.00
Uncertainty in factor		0.08	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.37**	uf	**0.08**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.1	% of span value		≤±5% span value
Span drift	1.4	% 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	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}		0.55
Standard deviation of repeatability at span level	u_{rs}		0.00
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{flt}		1.69
Zero drift	u_{0dr}		0.07
Span drift	u_{sdr}		1.59
Influence of sample gas flow	u_{spres}		0.03
Influence of atmospheric pressure	u_{apres}		0.51
Influence of ambient temperature	u_{temp}		0.02
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}		0.23
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}		3.59

Measurement uncertainty				
Combined uncertainty			4.85	mg/m^3
Expanded uncertainty	k =	2	9.70	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			9.70	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**15.14**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**15.14 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**23.74 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	47.38	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	65.11	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	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	7.90	0.0	101.3	273.0
	Uncert	0.74	0.0	0.0	0.0
Factors		1.37	1.00	1.00	1.00
Uncertainty in factor		0.08	0.00	0.00	0.00
Correction Factor (no O_2 factor)		**1.00**		**0.00**	
Correction Factor (inl. O_2 factor)		**1.37**	uf	**0.08**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.0	% 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)	0.6	% 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	95.4	%		≥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}				0.14
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{flt}				0.70
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.00
Influence of sample gas flow		u_{spres}				0.02
Influence of atmospheric pressure		u_{apres}				0.42
Influence of ambient temperature		u_{temp}				0.06
Cross sensitivity		u_{interf}				0.83
Influence of voltage		u_{volt}				0.00
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				1.25
Uncertainty of calibration gas		u_{cal}				0.24
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}				3.66

Measurement uncertainty				
Combined uncertainty			1.73	mg/m^3
Expanded uncertainty	k =	2	3.45	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			3.45	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**8.73**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**8.73**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**13.40**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.23**	**% 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	100890	101091.04	201.04	39.2					39.2	15.3	1.73	50	7.1	84.0	8.9	29.49	29.29
2	100890	101091.04	201.04	57.8					57.8	15.4	1.73	50	7.1	84.0	8.9	29.49	29.29
3	100890	101091.04	201.04	53.9					53.9	15.5	1.73	50	7.1	84.0	8.9	29.49	29.29
4	100890	101091.04	201.04	45.1					45.1	15.6	1.73	50	7.1	84.0	8.9	29.49	29.29
5	100890	101091.04	201.04	47.1					47.1	15.6	1.73	50	7.1	84.0	8.9	29.49	29.29
6	100890	101091.04	201.04	41.2					41.2	15.6	1.73	50	7.1	84.0	8.9	29.49	29.29
7	100890	101091.04	201.04	28.4					28.4	15.0	1.73	50	7.1	84.0	8.9	29.49	29.29
8	100890	101091.04	201.04	40.2					40.2	15.1	1.73	50	7.1	84.0	8.9	29.49	29.29
9	100890	101091.04	201.04	38.2					38.2	15.2	1.73	50	7.1	84.0	8.9	29.49	29.29
10	100890	101091.04	201.04	53.9					53.9	15.3	1.73	50	7.1	84.0	8.9	29.49	29.29
11	100890	101091.04	201.04	66.7					66.7	15.3	1.73	50	7.1	84.0	8.9	29.49	29.29
12	100890	101091.04	201.04	78.4					78.4	15.4	1.73	50	7.1	84.0	8.9	29.49	29.29
Mean	**100890**	**101091**	**201.0**	**49.2**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**49.2**	**15.4**	**1.7**	**50.0**	**7.1**	**90.4**	**8.9**	**28.90**	**28.78**

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

Mean density	**1.213 kg/m3**

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

Mean velocity	**7.43 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	**46043 m^3/hour**	**0 m3/hour**
Volume flow rate expanded uncertainty	**4237 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 2F Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	9.36	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	1.2	% 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	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}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.02
Lack of fit			u_{fit}				0.14
Zero drift			u_{0dr}				0.10
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}				-0.011
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			0.37	% vol
Expanded uncertainty	k =	2	0.75	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.75**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**7.97**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	mg/m^3 (Corrected)	**Cal gas conc.**	194.19	mg.m^{-3}
Measured concentration	24.41	mg/m3 (101.3kPa, 273K)	**Range**	250.09	mg/m^3
Measured concentration	37.76	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	9.36	0.0	101.3	273.0
	Uncert	0.75	0.0	0.0	0.0
Factors		1.55	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)		**1.55**	uf	**0.10**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.9	% of span value		≤±5% span value
Span drift	2.0	% 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	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}		0.55
Standard deviation of repeatability at span level		u_{rs}		0.00
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		1.69
Zero drift		u_{0dr}		1.01
Span drift		u_{sdr}		2.24
Influence of sample gas flow		u_{spres}		0.03
Influence of atmospheric pressure		u_{apres}		0.51
Influence of ambient temperature		u_{temp}		0.02
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}		0.12
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}		2.42

Measurement uncertainty				
Combined uncertainty			5.20	mg/m^3
Expanded uncertainty	k =	2	10.39	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			10.39	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**16.78**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**16.78 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**44.45 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	43.02	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	66.54	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	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	9.36	0.0	101.3	273.0
	Uncert	0.75	0.0	0.0	0.0
Factors		1.55	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)		**1.55**	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	0.1	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.6	% of range		≤±2 % range
Zero drift	0.1	% of span value		≤±5% span value
Span drift	0.9	% 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	95.4	%		≥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}		0.14
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		0.70
Zero drift		u_{0dr}		0.12
Span drift		u_{sdr}		0.83
Influence of sample gas flow		u_{spres}		0.02
Influence of atmospheric pressure		u_{apres}		0.42
Influence of ambient temperature		u_{temp}		0.06
Cross sensitivity		u_{interf}		0.83
Influence of voltage		u_{volt}		0.00
Influence from vibration		u_{vib}		0.00
Converter efficiency		u_{conv}		1.13
Uncertainty of calibration gas		u_{cal}		0.22
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}		4.26

Measurement uncertainty				
Combined uncertainty			1.85	mg/m^3
Expanded uncertainty	k =	2	3.69	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			3.69	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**10.26**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**10.26**	**mg.m^{-3}**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**15.42**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.45**	**% 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	100270	100433.6	163.6	39.2					39.2	12.8	1.44	30	7.1	84.0	8.9	29.49	29.33
2	100270	100433.6	163.6	50.0					50.0	12.7	1.44	30	7.1	84.0	8.9	29.49	29.33
3	100270	100433.6	163.6	52.0					52.0	12.7	1.44	30	7.1	84.0	8.9	29.49	29.33
4	100270	100433.6	163.6	47.1					47.1	12.8	1.44	30	7.1	84.0	8.9	29.49	29.33
5	100270	100433.6	163.6	49.0					49.0	12.3	1.44	30	7.1	84.0	8.9	29.49	29.33
6	100270	100433.6	163.6	49.0					49.0	12.1	1.44	30	7.1	84.0	8.9	29.49	29.33
7	100270	100433.6	163.6	37.3					37.3	12.4	1.44	30	7.1	84.0	8.9	29.49	29.33
8	100270	100433.6	163.6	40.2					40.2	12.5	1.44	30	7.1	84.0	8.9	29.49	29.33
9	100270	100433.6	163.6	45.1					45.1	12.8	1.44	30	7.1	84.0	8.9	29.49	29.33
10	100270	100433.6	163.6	58.8					58.8	12.9	1.44	30	7.1	84.0	8.9	29.49	29.33
11	100270	100433.6	163.6	66.7					66.7	13.0	1.44	30	7.1	84.0	8.9	29.49	29.33
12	100270	100433.6	163.6	69.6					69.6	12.7	1.44	30	7.1	84.0	8.9	29.49	29.33
Mean	**100270**	**100434**	**163.6**	**50.3**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**50.3**	**12.6**	**1.4**	**30.0**	**7.1**	**90.4**	**8.9**	**28.90**	**28.80**

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

Mean density	**1.218**	**kg/m3**

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

Mean velocity	**7.54**	**m/sec**		
Standard uncertainty of velocity	**0.34**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.68**	**m/sec**	**9.0**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**46686**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4284**	**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 2G Uncertainty Calculations

Uncertainty calculation for gaseous measurement of O2 according to BS EN 14789:2017 - Horiba PG250 AS0218

v1.0 May-20

		Cal gas conc	15.04	**% vol**
Measured concentration	9.61	**% 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)	1.0	% range		≤0.3 % vol
Zero drift	1.2	% 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	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}				0.00
Standard deviation of repeatability at span level		u_{rs}				0.02
Lack of fit		u_{fit}				0.14
Zero drift		u_{0dr}				0.10
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}				-0.011
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			0.37	% vol
Expanded uncertainty	k =	2	0.75	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.75**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**7.77**	**% value**

Uncertainty calculation for gaseous measurement of CO according to BS EN 15058:2017 - Horiba PG250 AS0218

v1.0 May-20

Emission Limit Value	N/A	mg/m^3 (Corrected)	**Cal gas conc.**	194.19	mg.m^{-3}
Measured concentration	100.64	mg/m3 (101.3kPa, 273K)	**Range**	250.09	mg/m^3
Measured concentration	158.98	mg/m^3 (Corrected)			

Gas	CO	
Full Scale	200.0	**ppm**
Cal gas conc	155.3	**ppm**
Conversion	1.25	

Correction for reference conditions					
		O2, %	**Moisture, %**	**Pressure, KPa**	**Temperature, K**
	ref	3.00	0.0	101.3	273.0
	measured	9.61	0.0	101.3	273.0
	Uncert	0.75	0.0	0.0	0.0
Factors		1.58	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)		**1.58**	uf	**0.10**	

Performance characteristics	**Value**			**specification**
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.2	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	1.2	% of range		≤±2 % range
Zero drift	0.9	% of span value		≤±5% span value
Span drift	2.0	% 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	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}		0.55
Standard deviation of repeatability at span level	u_{rs}		0.00
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{flt}		1.69
Zero drift	u_{0dr}		1.01
Span drift	u_{sdr}		2.24
Influence of sample gas flow	u_{spres}		0.03
Influence of atmospheric pressure	u_{apres}		0.51
Influence of ambient temperature	u_{temp}		0.02
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}		0.50
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}		10.41

Measurement uncertainty				
Combined uncertainty			5.22	mg/m^3
Expanded uncertainty	k =	2	10.44	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			10.44	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**26.56**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**26.56 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**16.71 % 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 AS0218

v1.0 May-20

Emission Limit Value	107	mg/m^3 (Corrected)	**Cal gas conc.**	163.3	mg.m^{-3}
Measured concentration	36.92	mg/m3 (101.3kPa, 273K)	**Range**	205.4	mg/m^3
Measured concentration	58.32	mg/m^3 (Corrected)			

Gas	NOx	
Full Scale	100	ppm
Cal gas conc	79.5	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	9.61	0.0	101.3	273.0
	Uncert	0.75	0.0	0.0	0.0
Factors		1.58	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)		**1.58**	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	0.1	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	0.6	% of range		≤±2 % range
Zero drift	0.1	% of span value		≤±5% span value
Span drift	0.9	% 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	95.4	%		≥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}		0.14
Standard deviation of reproducibility	u_{rp}		0.00
Lack of fit	u_{fit}		0.70
Zero drift	u_{0dr}		0.12
Span drift	u_{sdr}		0.83
Influence of sample gas flow	u_{spres}		0.02
Influence of atmospheric pressure	u_{apres}		0.42
Influence of ambient temperature	u_{temp}		0.06
Cross sensitivity	u_{interf}		0.83
Influence of voltage	u_{volt}		0.00
Influence from vibration	u_{vib}		0.00
Converter efficiency	u_{conv}		0.97
Uncertainty of calibration gas	u_{cal}		0.18
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}		3.82

Measurement uncertainty				
Combined uncertainty			1.75	mg/m^3
Expanded uncertainty	k =	2	3.50	mg/m^3
Uncertainty corrected to std conditions (no O_2 factor)			3.50	mg/m^3
Uncertainty corrected to std conditions (including O_2 factor)			**9.42**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**9.42 mg.m^{-3}**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**16.16 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**3.27 % 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	100270	100475.45	205.45	31.4					31.4	13.0	1.48	100	8.4	81.5	10.1	29.75	29.57
2	100270	100475.45	205.45	42.2					42.2	12.9	1.48	100	8.4	81.5	10.1	29.75	29.57
3	100270	100475.45	205.45	52.0					52.0	12.7	1.48	100	8.4	81.5	10.1	29.75	29.57
4	100270	100475.45	205.45	52.0					52.0	12.6	1.48	100	8.4	81.5	10.1	29.75	29.57
5	100270	100475.45	205.45	48.0					48.0	12.5	1.48	100	8.4	81.5	10.1	29.75	29.57
6	100270	100475.45	205.45	57.8					57.8	12.4	1.48	100	8.4	81.5	10.1	29.75	29.57
7	100270	100475.45	205.45	36.3					36.3	13.3	1.48	100	8.4	81.5	10.1	29.75	29.57
8	100270	100475.45	205.45	39.2					39.2	13.4	1.48	100	8.4	81.5	10.1	29.75	29.57
9	100270	100475.45	205.45	41.2					41.2	13.4	1.48	100	8.4	81.5	10.1	29.75	29.57
10	100270	100475.45	205.45	56.9					56.9	13.4	1.48	100	8.4	81.5	10.1	29.75	29.57
11	100270	100475.45	205.45	65.7					65.7	13.3	1.48	100	8.4	81.5	10.1	29.75	29.57
12	100270	100475.45	205.45	64.7					64.7	13.1	1.48	100	8.4	81.5	10.1	29.75	29.57
Mean	**100270**	**100475**	**205.5**	**48.9**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**48.9**	**13.0**	**1.5**	**100.0**	**8.4**	**88.9**	**10.1**	**29.05**	**28.94**

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

Mean density	**1.223**	**kg/m3**

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

Mean velocity	**7.41**	**m/sec**		
Standard uncertainty of velocity	**0.33**	**m/sec**	**4.5**	**% of value**
Expanded uncertainty in velocity	**0.67**	**m/sec**	**9.0**	**% of value**

	Circular duct		Rectangular duct	
Flow rate	**45869**	**m^3/hour**	**0**	**m3/hour**
Volume flow rate expanded uncertainty	**4218**	**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)