NATIONAL PHYSICAL LABORATORY
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Test Report

UKAS TESTING
0002

mCERTS

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

Permit Number:	**XP3538LD**
Operator Name:	**South Hook LNG (on behalf of Intertek Limited)**
Installation Name:	**South Hook LNG Terminal**
Dates of Monitoring Visit:	**19th - 22nd October 2020**
Contract Reference:	**E08040221**
Client Contact:	**Adrian Walsh**
Client Organisation:	**Intertek Limited**
Address:	**Unit 14 - Waterston Trading Estate Main Road, Waterston Milford Haven SA73 3SL**
Monitoring Organisation:	**National Physical Laboratory**
Address:	**Hampton Road Teddington Middlesex TW11 0LW**
Date of Report:	**1st December 2020**
Report Author	**Jonny Guy**

Reference: XP3538LD/INTERTEK/SHLNG/OCT2020/SCV/PPC/Q4/V1

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

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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. Four 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 19th and 22nd October 2020. The report documents the results obtained.

1.2.1 SCV A (Phase One) Monitoring Results

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

Field	Units	Oxides of Nitrogen (as NO_2)	Carbon Monoxide	Oxygen	Moisture
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	50.2	512	11.8	1.4
Uncertainty (95% Confidence Level)	**Reference Conditions**	9.3	40.2	0.3	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	4.6			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	22/10/2020			
Sample Period	**From hh:mm**	12:00			
	To hh:mm	13:00			
Monitoring Method		BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	90			
Burner Demand	**Burner Demand (%)**	20			

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**	54.5	152	8.2	1.1
Uncertainty (95% Confidence Level)	**Reference Conditions**	7.9	13.8	0.4	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	8.8			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	19/10/2020			
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)**	169			
Process Status	**Burner Demand (%)**	52.4			

1.2.3 SCV H (Phase One) Monitoring Results

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

Field	Units	Oxides of Nitrogen (as NO_2)	Carbon Monoxide	Oxygen	Moisture
Emission Limit Value	**mg/m^3, Reference Conditions**	107	N/A	N/A	N/A
Periodic Monitoring Result	**Reference Conditions**	47.8	457	12.8	1.5
Uncertainty (95% Confidence Level)	**Reference Conditions**	11.8	40.2	0.3	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	5.1			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	21/10/2020			
Sample Period	**From hh:mm**	12:00			
	To hh:mm	13:00			
Monitoring Method		BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017
Accreditation		UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS	UKAS & MCERTS
Process Status	**Load (Tonnes/Hour)**	120			
Process Status	**Burner Demand (%)**	33.19			

1.2.4 SCV E (Phase Two) Monitoring Results

Client: Intertek
Site: South Hook LNG
Emission Point: SCV E (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**	51.3	448	12.3	1.4
Uncertainty (95% Confidence Level)	**Reference Conditions**	9.8	35.1	0.3	N/A
	Units	mg/m^3	mg/m^3	%Vol/Vol	%Vol/Vol
Average Stack Flow	**m^3/s at Reference Conditions**	5.1			
Reference Conditions		273K, 101.3 kPa, 3% Oxygen on a dry gas basis			
Date	**dd/mm/yyyy**	21/10/2020			
Sample Period	**From hh:mm**	14:40			
	To hh:mm	15:40			
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 (%)**	36.64			

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 1A	90	20
SCV 1D	169	52.4
SCV 1H	120	33.19
SCV 2E	125	36.64

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	Unknown	47.8	mg/Nm^3
SCV 1H	Oxygen	Unknown	12.8	% 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. Four SCVs were monitored for the required determinands.

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

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

1.6 References

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

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

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

4. Environmental Agency - Online Guidance – Monitoring stack emissions: Techniques and standards for periodic monitoring.

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

6. 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	Jul-2023	Sep-2023	Sep-2023	Dec-2023	Sep-2023
Jonny Guy	Site Assistant	MM-16-1388	Jul-2022	N/A	N/A	N/A	N/A	N/A

2.1.2 Emissions Testing Procedures

	Instrumental Methods			Manual Methods		
Determinand	**NOx**	**CO**	**O_2**	**H_2O**	**Stack Flow**	**Temperature**
SRM Standard	BS EN 14792:2017	BS EN 15058:2017	BS EN 14789:2017	BS EN 14790:2017	BS EN ISO 16911:2013	BS ISO 16911:2013
Instrument	Horiba PG-250 SRM	Horiba PG-250 SRM	Horiba PG-250 SRM	N/A	Pitot	Type K Thermocouple
Instrument Serial No.	AS0450	AS0450	AS0450	N/A	AS0638	AS0638
Principle	Chemiluminescence	NDIR	Paramagnetic Cell	Saturation Chart	Flow	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°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	155.5 ppm	1%
Nitrogen Oxide		195688SG	79.5 ppm	1%
Oxygen		146312SG	15.30%	1%

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

The ranges of the Horiba PG-250 SRM analyser 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	155.5 ppm
Oxides of Nitrogen (as NO_2)	0-250 ppm	79.5 ppm
Oxygen	0-25%	15.30%

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 INTK51OCT20/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:

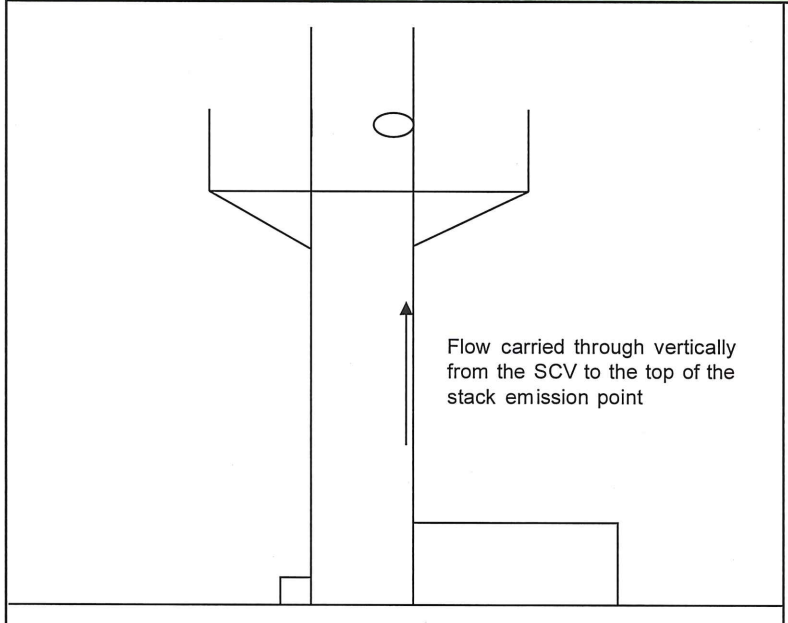
P:\Stack Emissions Team\South Hook LNG - Intertek\INTK51OCT20\7. Monitoring Record Sheets

APPENDIX TWO

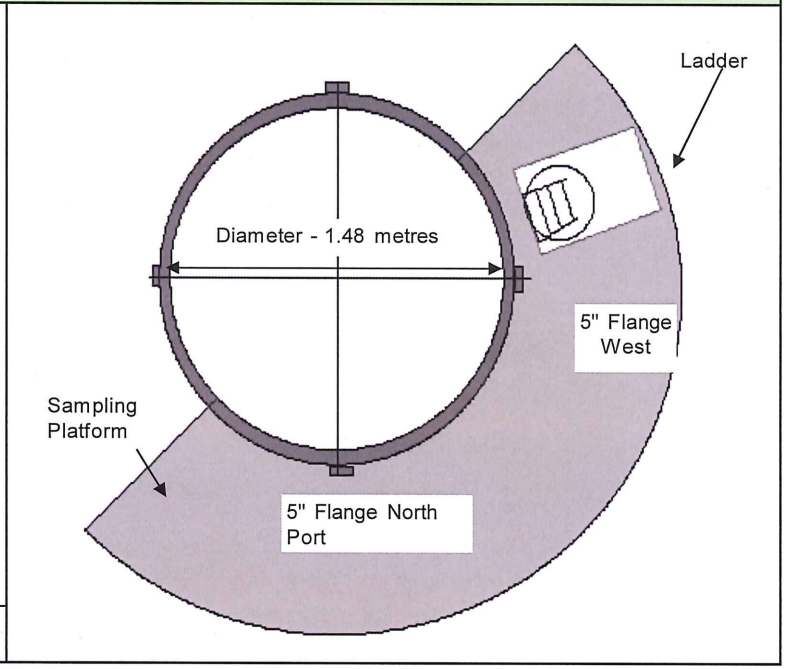
2.2.1 - Stack Diagram

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

Stack Diagram



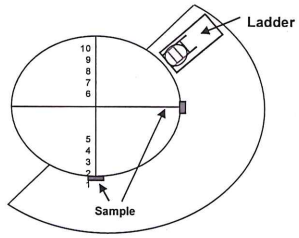
Stack Cross-Section



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 1A
Date	22/10/2020		Site Team:	MRE/JG	Time of Survey:	10:00
Tape Measure ID	AS0589		Diagram of Sample Location:			
Barometer ID	AS0500					
Traverse Pitot Type	S-Type					
Traverse Pitot Tube ID	AS0687					
Pitot Assembly Visual Inspection (Pre)	Pass					
Pre Test Leak Check <2.5 mm H2O	Pass					
Traverse Manometer Type	Digital					
Traverse Manometer ID	AS0638					
Traverse Manometer Range	255					
Traverse Temp. Readout ID	AS0638					
Traverse Thermocouple ID	AS0451a					
Static Pressure	Δp (mmH20)					
	12.35					
	Pass		Comments/Deviations:			
Swirl Test Conducted	Yes					
Protractor ID	AS0626		None			
Post-Test Blockage Test (L-Type only)						
Post Test Leak Check <2.5 mm H2O	Pass					
Pitot Assembly Visual Inspection (Post)	Pass					

Conditions	Value	Units
Stack pressure	760.31	mmHg
Ref O_2 Value	3	%
Moisture Content	1.4	%
CO	206	ppm
CO_2	4.4	%
N_2	83.78	%
O_2	11.80	%
Dry Molecular wt	29.18	
Stack Molecular wt	29.02	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1012.2	mbar
Pbar	759.4	mmHg
Pitot tube coeft	0.838	
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					

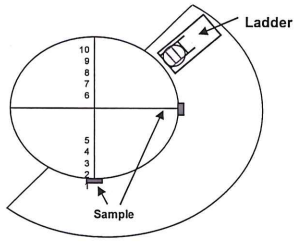
	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Width
Outside Side Division					

			Static Measurement	Δp (mmH20)	
			Measurement Line	Reading 1	Reading 2(180°)
Enter manually from previous visit	Circular Duct	Rectangular Duct	A	12.30	12.40
Duct Diameter (m)	1.48		B	12.60	12.10
Duct Depth (m)			C		
Duct Width (m)			D		

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

SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	2.30	2.30	2.30	2.30	22.55	13.8	5.07	4	1.52
2	1.26	3.00	3.00	3.00	3.00	29.41	13.8	5.79	4	1.73
3	1.04	2.90	2.90	2.90	2.90	28.43	13.7	5.69	4	1.70
4	0.44	2.90	2.90	2.90	2.90	28.43	13.6	5.69	6	1.70
5	0.22	2.70	2.70	2.70	2.70	26.47	13.6	5.49	5	1.64
6	0.06	2.50	2.50	2.50	2.50	24.51	13.7	5.28	5	1.58
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	2.50	2.50	2.50	2.50	24.51	13.6	5.28	7	1.58
2	1.26	2.50	2.50	2.50	2.50	24.51	13.6	5.28	7	1.58
3	1.04	2.60	2.60	2.60	2.60	25.49	13.7	5.39	6	1.61
4	0.44	3.00	3.00	3.00	3.00	29.41	13.6	5.78	5	1.73
5	0.22	3.10	3.10	3.10	3.10	30.39	13.8	5.88	6	1.76
6	0.06	3.10	3.10	3.10	3.10	30.39	13.7	5.88	4	1.76
Average values		**2.8**	**2.8**	**2.8**	**2.8**	**27.0**	**13.7**	**5.5**	**5.3**	**1.7**

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	5.54	ms^{-1}	Is the Flow Ratio 3:1 or less?	1.3 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	4.55	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	9.53	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	9.39	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	9.08	m^3s^{-1}	Minimum Δp detected > 5 Pa	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	4.61	m^3s^{-1}		

Monitoring Objective	Traverse		Site:	South Hook LNG Terminal	Stack ID:	SCV 1D
Date	19/10/2020		Site Team:	MRE/JG	Time of Survey:	15:30
Tape Measure ID	AS0589		Diagram of Sample Location:			
Barometer ID	AS0500					
Traverse Pitot Type	S-Type					
Traverse Pitot Tube ID	AS0687					
Pitot Assembly Visual Inspection (Pre)	Pass					
Pre Test Leak Check <2.5 mm H2O	Pass					
Traverse Manometer Type	Digital					
Traverse Manometer ID	AS0638					
Traverse Manometer Range	255					
Traverse Temp. Readout ID	AS0638					
Traverse Thermocouple ID	AS0451a					
Static Pressure	Δp (mmH20)					
	23.88					
	Pass		Comments/Deviations:			
Swirl Test Conducted	Yes					
Protractor ID	AS0626		None			
Post-Test Blockage Test (L-Type only)						
Post Test Leak Check <2.5 mm H2O	Pass					
Pitot Assembly Visual Inspection (Post)	Pass		Duct Dimensions			

Conditions	Value	Units
Stack pressure	760.56	mmHg
Ref O_2 Value	3	%
Moisture Content	1.1	%
CO	85.13	ppm
CO_2	5	%
N_2	86.79	%
O_2	8.20	%
Dry Molecular wt	29.13	
Stack Molecular wt	29.01	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1011.4	mbar
Pbar	758.8	mmHg
Pitot tube coeft	0.838	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature		° C

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					

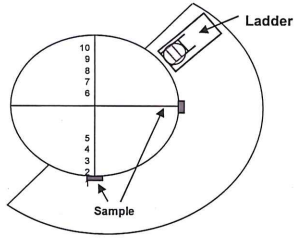
	Reading 1 (m)	Reading 2 (m)	Reading 3 (m)	Average	Duct Width
Outside Side Division					

		Static Measurement	Δp (mmH20)	
		Measurement Line	Reading 1	Reading 2(180°)
Enter manually from previous visit	Circular Duct	Rectangular Duct	A	24.30	24.00
Duct Diameter (m)	1.48		B	23.40	23.80
Duct Depth (m)			C		
Duct Width (m)			D		

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

SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	5.40	5.40	5.40	5.40	52.94	12.9	7.75	4	2.32
2	1.26	5.60	5.60	5.60	5.60	54.90	12.8	7.89	5	2.37
3	1.04	5.20	5.20	5.20	5.20	50.98	12.8	7.61	5	2.28
4	0.44	5.60	5.60	5.60	5.60	54.90	12.9	7.89	6	2.37
5	0.22	5.10	5.10	5.10	5.10	50.00	12.9	7.53	6	2.26
6	0.06	5.30	5.30	5.30	5.30	51.96	12.8	7.68	5	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	4.80	4.80	4.80	4.80	47.05	12.9	7.31	7	2.19
2	1.26	5.10	5.10	5.10	5.10	50.00	12.8	7.53	8	2.26
3	1.04	5.20	5.20	5.20	5.20	50.98	12.8	7.61	8	2.28
4	0.44	5.30	5.30	5.30	5.30	51.96	12.9	7.68	6	2.30
5	0.22	5.50	5.50	5.50	5.50	53.92	12.9	7.82	7	2.35
6	0.06	5.10	5.10	5.10	5.10	50.00	12.8	7.53	9	2.26
Average values		**5.3**	**5.3**	**5.3**	**5.3**	**51.6**	**12.9**	**7.7**	**6.3**	**2.3**

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	7.65	ms^{-1}	Is the Flow Ratio 3:1 or less?	1.2 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	8.83	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	13.16	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	13.02	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	12.58	m^3s^{-1}	Minimum Δp detected > 5 Pa	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	8.92	m^3s^{-1}		

Monitoring Objective	Traverse		Site:	South Hook LNG Terminal	Stack ID:	SCV 1H
Date	21/10/2020		Site Team:	MRE/JG	Time of Survey:	11:00
Tape Measure ID	AS0589		Diagram of Sample Location:			
Barometer ID	AS0500					
Traverse Pitot Type	S-Type					
Traverse Pitot Tube ID	AS0687					
Pitot Assembly Visual Inspection (Pre)	Pass					
Pre Test Leak Check <2.5 mm H2O	Pass					
Traverse Manometer Type	Digital					
Traverse Manometer ID	AS0638					
Traverse Manometer Range	255					
Traverse Temp. Readout ID	AS0638					
Traverse Thermocouple ID	AS0451a					
Static Pressure	Δp (mmH20)					
	26.65					
	Pass		Comments/Deviations:			
Swirl Test Conducted	Yes					
Protractor ID	AS0626		None			
Post-Test Blockage Test (L-Type only)						
Post Test Leak Check <2.5 mm H2O	Pass					
Pitot Assembly Visual Inspection (Post)	Pass					

Conditions	Value	Units
Stack pressure	745.53	mmHg
Ref O_2 Value	3	%
Moisture Content	1.5	%
CO	163	ppm
CO_2	4.4	%
N_2	82.79	%
O_2	12.80	%
Dry Molecular wt	29.22	
Stack Molecular wt	29.05	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	991.1	mbar
Pbar	743.6	mmHg
Pitot tube coeft	0.838	
Reference Temp	273	K
Reference Pressure	760	mmHg
Ambient Temperature		° C

Duct Dimensions

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

Circular Duct

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

Rectangular Duct

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

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

			Static Measurement	Δp (mmH20)	
			Measurement Line	Reading 1	Reading 2(180°)
Enter manually from previous visit		Circular Duct	Rectangular Duct	A	26.80	26.80
Duct Diameter (m)		1.48		B	26.30	26.70
Duct Depth (m)				C		
Duct Width (m)				D		

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

SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	4.10	4.10	4.10	4.10	40.19	14.8	6.84	6	2.02
2	1.26	4.80	4.80	4.80	4.80	47.05	14.7	7.40	6	2.19
3	1.04	4.90	4.90	4.90	4.90	48.04	14.7	7.48	7	2.21
4	0.44	3.90	3.90	3.90	3.90	38.23	14.7	6.67	7	1.97
5	0.22	5.00	5.00	5.00	5.00	49.02	14.8	7.55	6	2.24
6	0.06	5.30	5.30	5.30	5.30	51.96	15.0	7.78	8	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	3.80	3.80	3.80	3.80	37.25	14.6	6.58	7	1.95
2	1.26	3.40	3.40	3.40	3.40	33.33	14.5	6.23	8	1.84
3	1.04	4.50	4.50	4.50	4.50	44.11	14.5	7.16	8	2.12
4	0.44	3.70	3.70	3.70	3.70	36.27	14.6	6.50	8	1.92
5	0.22	5.60	5.60	5.60	5.60	54.90	14.6	7.99	7	2.37
6	0.06	5.80	5.80	5.80	5.80	56.86	14.7	8.13	8	2.41
Average values		**4.6**	**4.6**	**4.6**	**4.6**	**44.8**	**14.7**	**7.2**	**7.2**	**2.1**

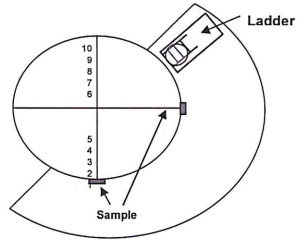
Duct / Stack Flow Characteristics:	Average	Units
Stack Velocity at stack gas T & P and a wet gas basis	7.19	ms^{-1}
Stack flow @ STP, O_2 (ref) and on a dry gas basis	5.14	m^3s^{-1}
Stack flow @ stack gas T & P and on a wet gas basis	12.37	m^3s^{-1}
Stack flow @ stack gas T & P and on a dry gas basis	12.19	m^3s^{-1}
Stack flow @ STP and on a wet gas basis	11.51	m^3s^{-1}
Stack flow @ STP, O_2 (ref) and on a wet gas basis	5.21	m^3s^{-1}

Flow Criteria Measurements	
Is the Flow Ratio 3:1 or less?	1.7 :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 2E
Date	21/10/2020	Site Team:	MRE/JG	Time of Survey:	15:00

Tape Measure ID	AS0589
Barometer ID	AS0500
Traverse Pitot Type	S-Type
Traverse Pitot Tube ID	AS0687
Pitot Assembly Visual Inspection (Pre)	Pass
Pre Test Leak Check <2.5 mm H2O	Pass
Traverse Manometer Type	Digital
Traverse Manometer ID	AS0638
Traverse Manometer Range	255
Traverse Temp. Readout ID	AS0638
Traverse Thermocouple ID	AS0451a
Static Pressure	Δp (mmH20)
	23.90
	Pass
Swirl Test Conducted	Yes
Protractor ID	AS0626
Post-Test Blockage Test (L-Type only)	
Post Test Leak Check <2.5 mm H2O	Pass
Pitot Assembly Visual Inspection (Post)	Pass

Diagram of Sample Location:



Comments/Deviations:

None

Conditions	Value	Units
Stack pressure	761.31	mmHg
Ref O_2 Value	3	%
Moisture Content	1.4	%
CO	177	ppm
CO_2	4.4	%
N_2	83.32	%
O_2	12.3	%
Dry Molecular wt	29.19	
Stack Molecular wt	29.04	
Duct Diameter	1.48	m
Duct Depth		m
Duct Width		m
Area of stack	1.72	m^2
Pbar	1012.4	mbar
Pbar	759.5	mmHg
Pitot tube coeft	0.838	
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	24.00	23.80
Duct Diameter (m)	1.48		B	24.00	23.80
Duct Depth (m)			C		
Duct Width (m)			D		

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

SAMPLING LINE: North										
Traverse Point	Distance into duct (m)	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Spot Reading mm H2O	Δp Average mm H_2O	Δp Pa	Stack Temp Ts °C	Velocity @ stack gas T&P on wet gas basis m/s	Angle of Swirl °	√Δp
1	1.42	4.20	4.20	4.20	4.20	41.17	14.8	6.85	8	2.05
2	1.26	4.50	4.50	4.50	4.50	44.11	14.6	7.09	7	2.12
3	1.04	4.30	4.30	4.30	4.30	42.15	14.4	6.93	8	2.07
4	0.44	4.00	4.00	4.00	4.00	39.21	14.8	6.69	6	2.00
5	0.22	3.70	3.70	3.70	3.70	36.27	14.6	6.43	8	1.92
6	0.06	3.60	3.60	3.60	3.60	35.29	14.6	6.34	9	1.90
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	2.80	2.80	2.80	2.80	27.45	14.8	5.60	8	1.67
2	1.26	3.50	3.50	3.50	3.50	34.31	14.5	6.25	6	1.87
3	1.04	3.60	3.60	3.60	3.60	35.29	14.6	6.34	9	1.90
4	0.44	4.00	4.00	4.00	4.00	39.21	14.8	6.69	4	2.00
5	0.22	4.20	4.20	4.20	4.20	41.17	14.8	6.85	7	2.05
6	0.06	4.10	4.10	4.10	4.10	40.19	15.0	6.77	5	2.02
Average values		3.9	3.9	3.9	3.9	38.0	14.7	6.6	7.1	2.0

Duct / Stack Flow Characteristics:	Average	Units	Flow Criteria Measurements	
Stack Velocity at stack gas T & P and a wet gas basis	6.57	ms^{-1}	Is the Flow Ratio 3:1 or less?	1.6 :1
Stack flow @ STP, O_2 (ref) and on a dry gas basis	5.11	m^3s^{-1}		
Stack flow @ stack gas T & P and on a wet gas basis	11.30	m^3s^{-1}	Any local negative flow?	NO
Stack flow @ stack gas T & P and on a dry gas basis	11.14	m^3s^{-1}	Flow <15° of duct axis?	YES
Stack flow @ STP and on a wet gas basis	10.74	m^3s^{-1}	Minimum Δp detected > 5 Pa	YES
Stack flow @ STP, O_2 (ref) and on a wet gas basis	5.18	m^3s^{-1}		

2.2.3 - One Minute Averaged Gaseous Emissions Data

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 1A			
273K, 101.3 kPa, 3% Oxygen on a dry basis			
Species	Carbon Monoxide	Oxides of Nitrogen	Oxygen
Units	mg/m3	mg/m3	%
22/10/2020 12:00	610.4	49.0	12.3
22/10/2020 12:01	595.3	48.6	12.3
22/10/2020 12:02	544.8	49.7	12.0
22/10/2020 12:03	529.0	50.2	11.8
22/10/2020 12:04	513.5	50.9	11.7
22/10/2020 12:05	516.8	50.5	11.7
22/10/2020 12:06	524.1	50.4	11.7
22/10/2020 12:07	505.2	50.6	11.7
22/10/2020 12:08	504.2	50.2	11.7
22/10/2020 12:09	517.4	50.2	11.7
22/10/2020 12:10	517.7	50.0	11.7
22/10/2020 12:11	505.1	50.1	11.7
22/10/2020 12:12	502.4	50.3	11.8
22/10/2020 12:13	506.1	50.2	11.7
22/10/2020 12:14	499.6	50.4	11.7
22/10/2020 12:15	519.3	49.7	11.7
22/10/2020 12:16	524.2	49.3	11.8
22/10/2020 12:17	529.2	49.4	11.8
22/10/2020 12:18	466.2	53.0	11.7
22/10/2020 12:19	486.2	51.0	11.7
22/10/2020 12:20	493.0	50.5	11.7
22/10/2020 12:21	498.5	50.8	11.7
22/10/2020 12:22	514.1	50.1	11.7
22/10/2020 12:23	485.7	50.4	11.6
22/10/2020 12:24	480.1	50.9	11.6
22/10/2020 12:25	493.3	50.7	11.7
22/10/2020 12:26	497.7	50.5	11.6
22/10/2020 12:27	484.0	50.5	11.6
22/10/2020 12:28	485.0	50.6	11.6
22/10/2020 12:29	507.2	49.9	11.7
22/10/2020 12:30	507.6	49.8	11.7
22/10/2020 12:31	514.9	49.2	11.7
22/10/2020 12:32	497.7	49.8	11.7
22/10/2020 12:33	512.3	49.7	11.8
22/10/2020 12:34	496.1	50.1	11.8
22/10/2020 12:35	497.1	50.0	11.8
22/10/2020 12:36	500.3	50.1	11.7
22/10/2020 12:37	491.6	50.8	11.6
22/10/2020 12:38	476.1	51.5	11.6
22/10/2020 12:39	494.3	50.3	11.6
22/10/2020 12:40	492.0	50.2	11.6
22/10/2020 12:41	492.2	50.3	11.6
22/10/2020 12:42	489.8	50.5	11.6
22/10/2020 12:43	505.1	49.9	11.7
22/10/2020 12:44	492.2	49.9	11.8
22/10/2020 12:45	482.8	50.2	11.6
22/10/2020 12:46	506.0	49.7	11.7
22/10/2020 12:47	501.0	49.6	11.7
22/10/2020 12:48	499.5	49.9	11.7
22/10/2020 12:49	486.2	50.4	11.6
22/10/2020 12:50	471.1	50.7	11.5
22/10/2020 12:51	473.3	50.8	11.4
22/10/2020 12:52	546.6	49.5	11.9
22/10/2020 12:53	549.2	50.0	12.0
22/10/2020 12:54	553.9	49.8	12.0
22/10/2020 12:55	504.9	52.7	11.9
22/10/2020 12:56	552.0	50.3	12.1
22/10/2020 12:57	560.0	49.6	12.1
22/10/2020 12:58	577.5	49.5	12.1
22/10/2020 12:59	573.6	49.6	12.1
22/10/2020 13:00	567.7	49.6	12.1
Minimum	466.2	48.6	11.4
Maximum	610.4	53.0	12.3
Average	511.8	50.2	11.8

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	%
19/10/2020 15:00	69.5	58.7	7.4
19/10/2020 15:01	71.7	57.9	7.3
19/10/2020 15:02	72.7	57.7	7.3
19/10/2020 15:03	69.2	57.6	7.3
19/10/2020 15:04	69.7	57.6	7.3
19/10/2020 15:05	72.6	57.4	7.4
19/10/2020 15:06	77.5	57.0	7.5
19/10/2020 15:07	91.1	56.5	7.7
19/10/2020 15:08	111.0	56.0	7.9
19/10/2020 15:09	143.0	55.2	8.2
19/10/2020 15:10	177.6	54.2	8.5
19/10/2020 15:11	203.7	53.4	8.8
19/10/2020 15:12	250.4	52.4	9.1
19/10/2020 15:13	268.4	52.4	9.2
19/10/2020 15:14	259.4	52.5	9.2
19/10/2020 15:15	223.5	53.1	8.9
19/10/2020 15:16	192.2	54.0	8.6
19/10/2020 15:17	162.6	54.4	8.4
19/10/2020 15:18	141.9	55.0	8.2
19/10/2020 15:19	132.2	55.1	8.1
19/10/2020 15:20	119.5	55.2	8.0
19/10/2020 15:21	118.6	55.1	7.9
19/10/2020 15:22	105.2	57.2	7.9
19/10/2020 15:23	110.0	55.6	7.9
19/10/2020 15:24	121.7	55.1	8.0
19/10/2020 15:25	124.6	55.2	8.0
19/10/2020 15:26	129.3	54.9	8.1
19/10/2020 15:27	147.8	54.5	8.2
19/10/2020 15:28	165.3	54.1	8.4
19/10/2020 15:29	181.5	53.5	8.5
19/10/2020 15:30	190.6	53.0	8.6
19/10/2020 15:31	206.4	53.0	8.7
19/10/2020 15:32	210.0	52.9	8.7
19/10/2020 15:33	208.5	53.0	8.7
19/10/2020 15:34	197.9	53.1	8.7
19/10/2020 15:35	182.8	53.5	8.6
19/10/2020 15:36	172.9	54.0	8.4
19/10/2020 15:37	161.0	53.9	8.3
19/10/2020 15:38	152.0	54.0	8.2
19/10/2020 15:39	147.3	54.1	8.2
19/10/2020 15:40	138.3	54.4	8.1
19/10/2020 15:41	138.3	54.2	8.1
19/10/2020 15:42	136.7	54.1	8.1
19/10/2020 15:43	137.1	54.2	8.1
19/10/2020 15:44	132.7	54.8	8.1
19/10/2020 15:45	123.3	55.7	8.2
19/10/2020 15:46	144.5	54.1	8.2
19/10/2020 15:47	160.3	53.8	8.3
19/10/2020 15:48	164.4	53.6	8.3
19/10/2020 15:49	172.7	53.4	8.5
19/10/2020 15:50	182.2	53.0	8.5
19/10/2020 15:51	177.3	53.3	8.5
19/10/2020 15:52	187.3	53.0	8.5
19/10/2020 15:53	172.9	53.4	8.4
19/10/2020 15:54	165.6	53.5	8.3
19/10/2020 15:55	165.5	53.4	8.4
19/10/2020 15:56	157.1	53.8	8.3
19/10/2020 15:57	153.6	53.8	8.3
19/10/2020 15:58	156.2	54.0	8.2
19/10/2020 15:59	151.2	53.8	8.3
19/10/2020 16:00	159.3	53.5	8.3
Minimum	69.2	52.4	7.3
Maximum	268.4	58.7	9.2
Average	152.3	54.5	8.2

One Minute Averaged Gaseous Emissions Results

South Hook LNG - SCV 1H			
273K, 101.3 kPa, 3% Oxygen on a dry basis			
Species	Carbon Monoxide	Oxides of Nitrogen	Oxygen
Units	mg/m3	mg/m3	%
21/10/2020 12:00	479.1	47.5	12.5
21/10/2020 12:01	487.4	47.4	12.6
21/10/2020 12:02	481.1	47.7	12.6
21/10/2020 12:03	450.3	47.6	12.7
21/10/2020 12:04	435.7	47.9	12.8
21/10/2020 12:05	397.3	48.1	12.9
21/10/2020 12:06	390.4	48.1	12.9
21/10/2020 12:07	390.4	48.2	12.9
21/10/2020 12:08	406.4	48.1	12.9
21/10/2020 12:09	445.2	47.2	13.0
21/10/2020 12:10	450.5	47.3	13.0
21/10/2020 12:11	466.0	47.4	12.9
21/10/2020 12:12	488.6	47.1	12.8
21/10/2020 12:13	519.5	46.7	12.6
21/10/2020 12:14	506.4	46.8	12.5
21/10/2020 12:15	501.1	47.0	12.4
21/10/2020 12:16	497.8	47.2	12.4
21/10/2020 12:17	495.0	47.3	12.4
21/10/2020 12:18	446.5	48.3	12.5
21/10/2020 12:19	456.9	47.5	12.6
21/10/2020 12:20	425.1	48.0	12.8
21/10/2020 12:21	411.3	48.5	12.9
21/10/2020 12:22	388.9	49.4	12.9
21/10/2020 12:23	402.7	48.5	12.8
21/10/2020 12:24	404.1	48.2	12.9
21/10/2020 12:25	405.3	48.0	12.9
21/10/2020 12:26	426.7	47.8	13.0
21/10/2020 12:27	474.7	47.4	12.9
21/10/2020 12:28	475.8	47.0	12.9
21/10/2020 12:29	486.7	47.1	12.9
21/10/2020 12:30	511.1	46.9	12.8
21/10/2020 12:31	549.2	46.6	12.7
21/10/2020 12:32	541.3	46.5	12.7
21/10/2020 12:33	537.3	46.9	12.6
21/10/2020 12:34	509.0	47.1	12.6
21/10/2020 12:35	508.0	47.4	12.6
21/10/2020 12:36	482.9	47.5	12.6
21/10/2020 12:37	449.0	47.8	12.8
21/10/2020 12:38	414.3	48.4	12.9
21/10/2020 12:39	412.0	48.5	13.1
21/10/2020 12:40	421.7	48.0	13.1
21/10/2020 12:41	406.3	48.6	13.1
21/10/2020 12:42	413.8	48.6	13.1
21/10/2020 12:43	407.6	48.9	13.1
21/10/2020 12:44	402.8	49.5	13.0
21/10/2020 12:45	463.5	47.9	12.8
21/10/2020 12:46	494.0	47.7	12.7
21/10/2020 12:47	497.2	47.7	12.7
21/10/2020 12:48	514.3	47.4	12.6
21/10/2020 12:49	537.4	47.0	12.7
21/10/2020 12:50	521.9	47.5	12.6
21/10/2020 12:51	510.9	47.3	12.6
21/10/2020 12:52	472.0	47.8	12.7
21/10/2020 12:53	454.5	48.4	12.8
21/10/2020 12:54	450.5	48.5	12.9
21/10/2020 12:55	447.7	48.4	12.9
21/10/2020 12:56	414.9	48.9	13.0
21/10/2020 12:57	395.0	49.2	13.1
21/10/2020 12:58	393.0	49.3	13.1
21/10/2020 12:59	401.5	48.9	13.1
21/10/2020 13:00	435.8	48.3	13.0
Minimum	388.9	46.5	12.4
Maximum	549.2	49.5	13.1
Average	456.8	47.8	12.8

One Minute Averaged Gaseous Emissions Results

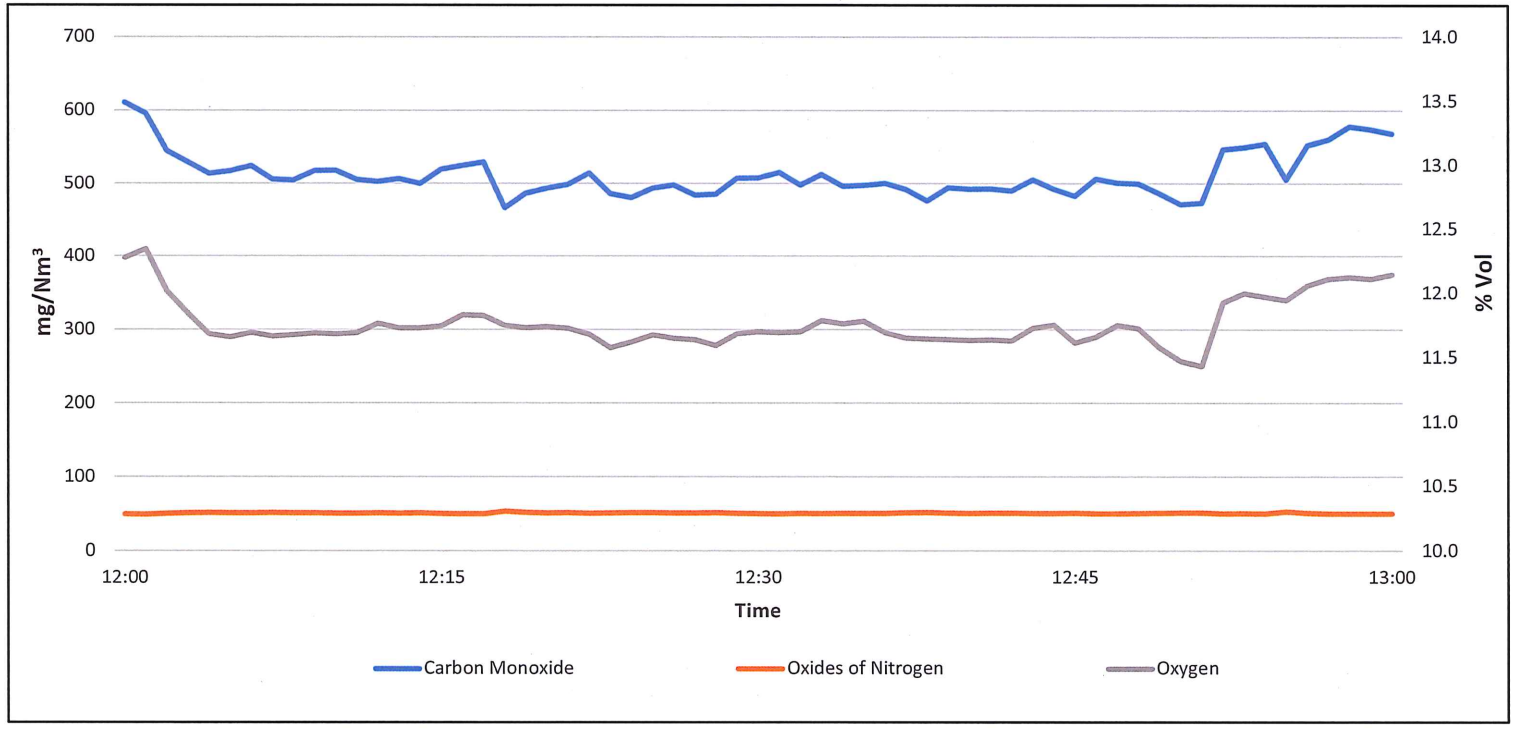
South Hook LNG - SCV 2E			
273K, 101.3 kPa, 3% Oxygen on a dry basis			
Species	Carbon Monoxide	Oxides of Nitrogen	Oxygen
Units	mg/m3	mg/m3	%
21/10/2020 14:40	419.6	51.7	12.4
21/10/2020 14:41	398.5	51.7	12.6
21/10/2020 14:42	393.5	52.3	12.6
21/10/2020 14:43	396.7	52.4	12.6
21/10/2020 14:44	379.0	52.8	12.6
21/10/2020 14:45	384.9	52.1	12.7
21/10/2020 14:46	403.6	51.8	12.7
21/10/2020 14:47	413.9	51.3	12.7
21/10/2020 14:48	454.4	50.6	12.7
21/10/2020 14:49	494.5	50.3	12.4
21/10/2020 14:50	550.6	49.9	12.2
21/10/2020 14:51	575.6	49.4	12.0
21/10/2020 14:52	590.6	49.6	11.9
21/10/2020 14:53	575.1	50.0	11.8
21/10/2020 14:54	456.8	52.6	11.7
21/10/2020 14:55	508.1	50.8	11.6
21/10/2020 14:56	497.3	50.7	11.7
21/10/2020 14:57	451.6	50.9	12.0
21/10/2020 14:58	430.8	51.5	12.3
21/10/2020 14:59	402.1	52.3	12.4
21/10/2020 15:00	397.4	52.8	12.5
21/10/2020 15:01	375.6	52.9	12.6
21/10/2020 15:02	374.4	53.1	12.6
21/10/2020 15:03	376.1	52.9	12.6
21/10/2020 15:04	372.4	53.0	12.7
21/10/2020 15:05	378.4	52.7	12.7
21/10/2020 15:06	383.9	52.0	12.7
21/10/2020 15:07	415.1	51.3	12.7
21/10/2020 15:08	472.2	50.4	12.6
21/10/2020 15:09	506.2	50.5	12.3
21/10/2020 15:10	533.8	50.3	12.0
21/10/2020 15:11	541.4	50.3	11.8
21/10/2020 15:12	534.5	50.1	11.7
21/10/2020 15:13	525.5	50.3	11.7
21/10/2020 15:14	473.4	51.8	11.7
21/10/2020 15:15	454.7	51.5	11.6
21/10/2020 15:16	473.4	50.4	11.8
21/10/2020 15:17	441.5	51.3	12.0
21/10/2020 15:18	412.0	51.7	12.3
21/10/2020 15:19	401.0	52.3	12.4
21/10/2020 15:20	386.9	52.3	12.5
21/10/2020 15:21	391.3	52.2	12.6
21/10/2020 15:22	387.9	52.2	12.6
21/10/2020 15:23	377.4	52.5	12.6
21/10/2020 15:24	383.9	51.7	12.7
21/10/2020 15:25	405.4	51.1	12.7
21/10/2020 15:26	426.8	50.7	12.7
21/10/2020 15:27	466.1	50.1	12.6
21/10/2020 15:28	526.6	49.8	12.3
21/10/2020 15:29	546.5	49.6	12.0
21/10/2020 15:30	545.2	49.8	11.8
21/10/2020 15:31	553.3	49.5	11.7
21/10/2020 15:32	523.7	50.0	11.6
21/10/2020 15:33	515.8	49.9	11.6
21/10/2020 15:34	451.7	51.8	11.6
21/10/2020 15:35	424.6	51.8	11.8
21/10/2020 15:36	425.4	51.3	12.1
21/10/2020 15:37	410.2	51.6	12.4
21/10/2020 15:38	395.8	52.2	12.5
21/10/2020 15:39	390.3	52.4	12.6
21/10/2020 15:40	376.6	52.2	12.6
Minimum	372.4	49.4	11.6
Maximum	590.6	53.1	12.7
Average	448.1	51.3	12.3

2.2.4 - Gaseous Emissions Graphical Data

South Hook LNG - SCV 1A

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

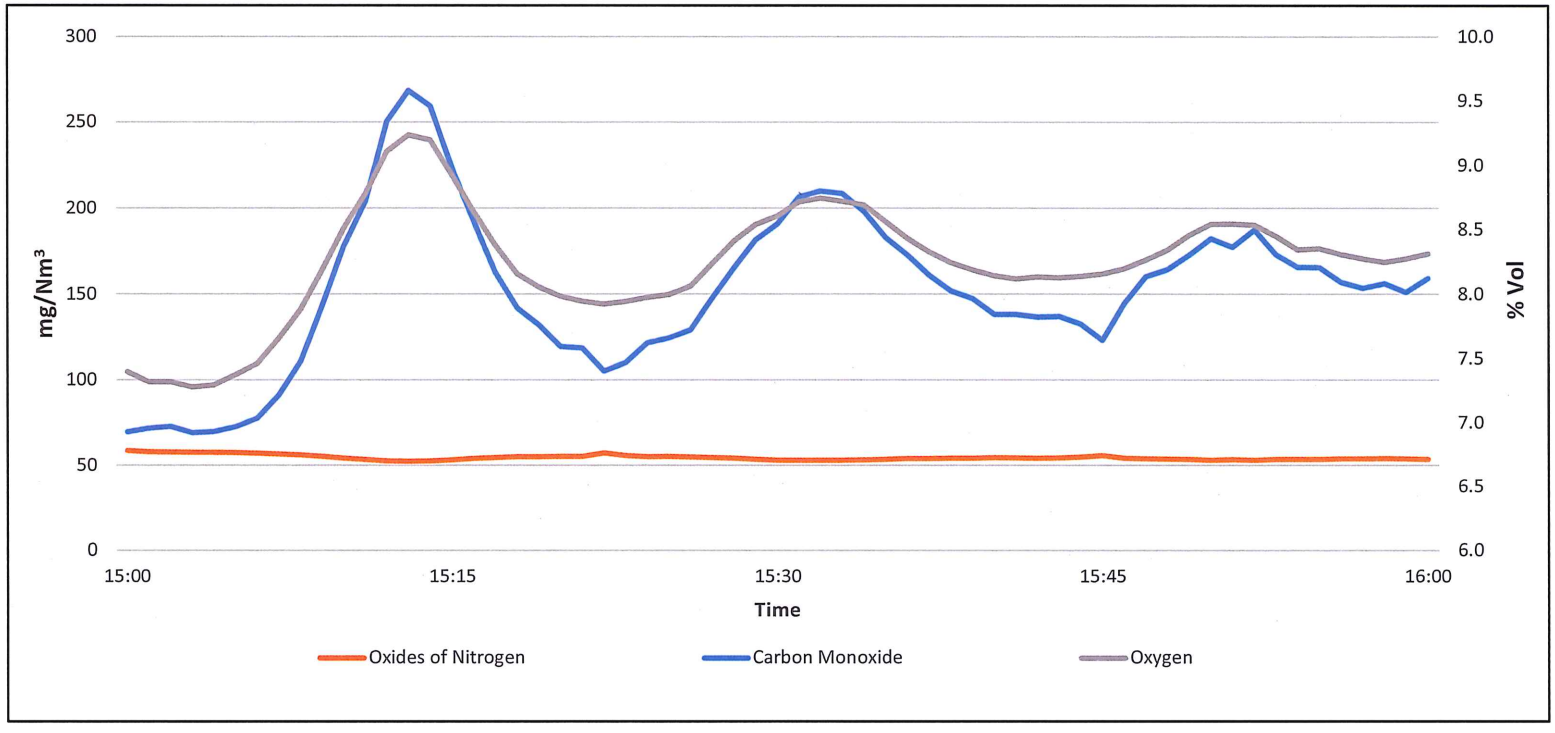
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 1D

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

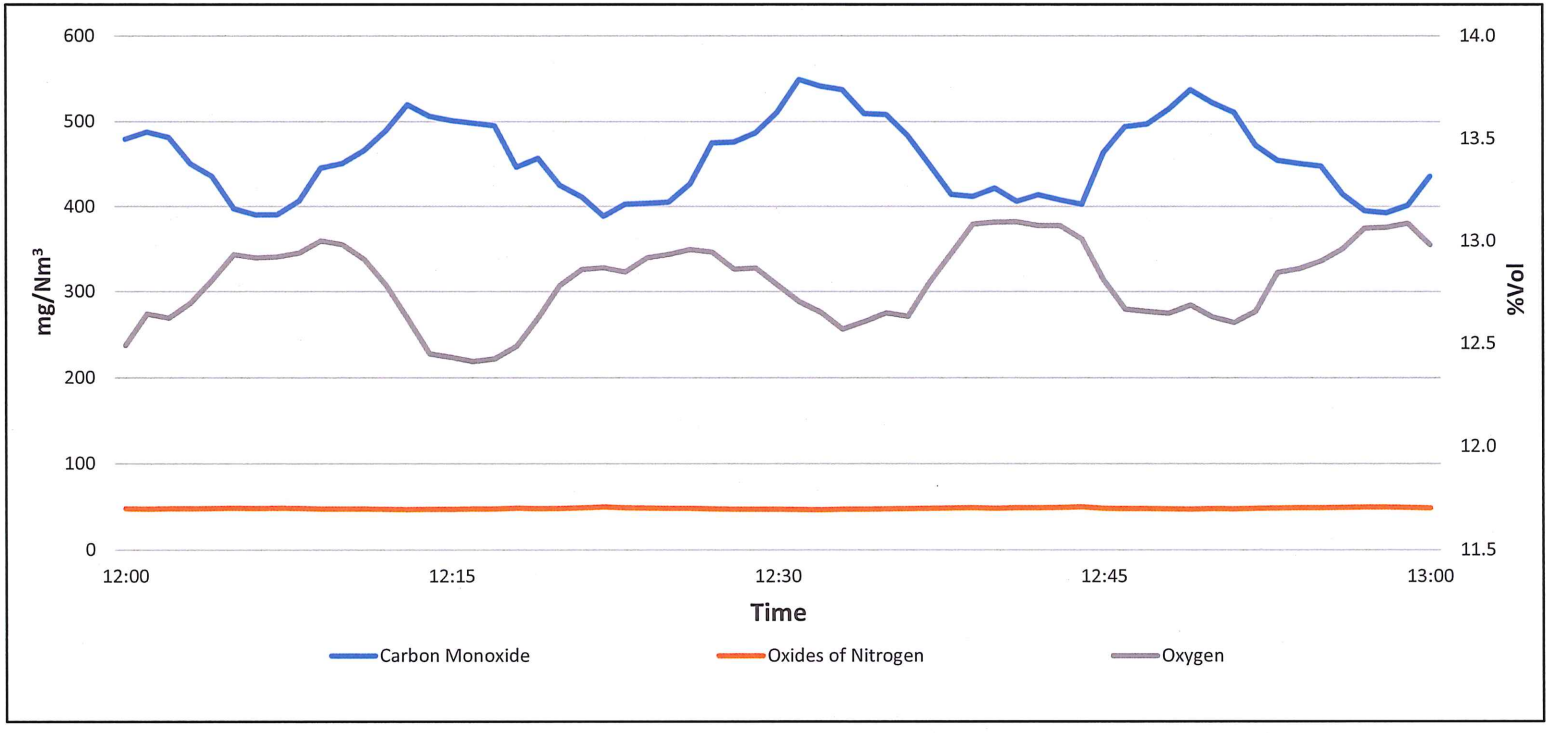
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 1H

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

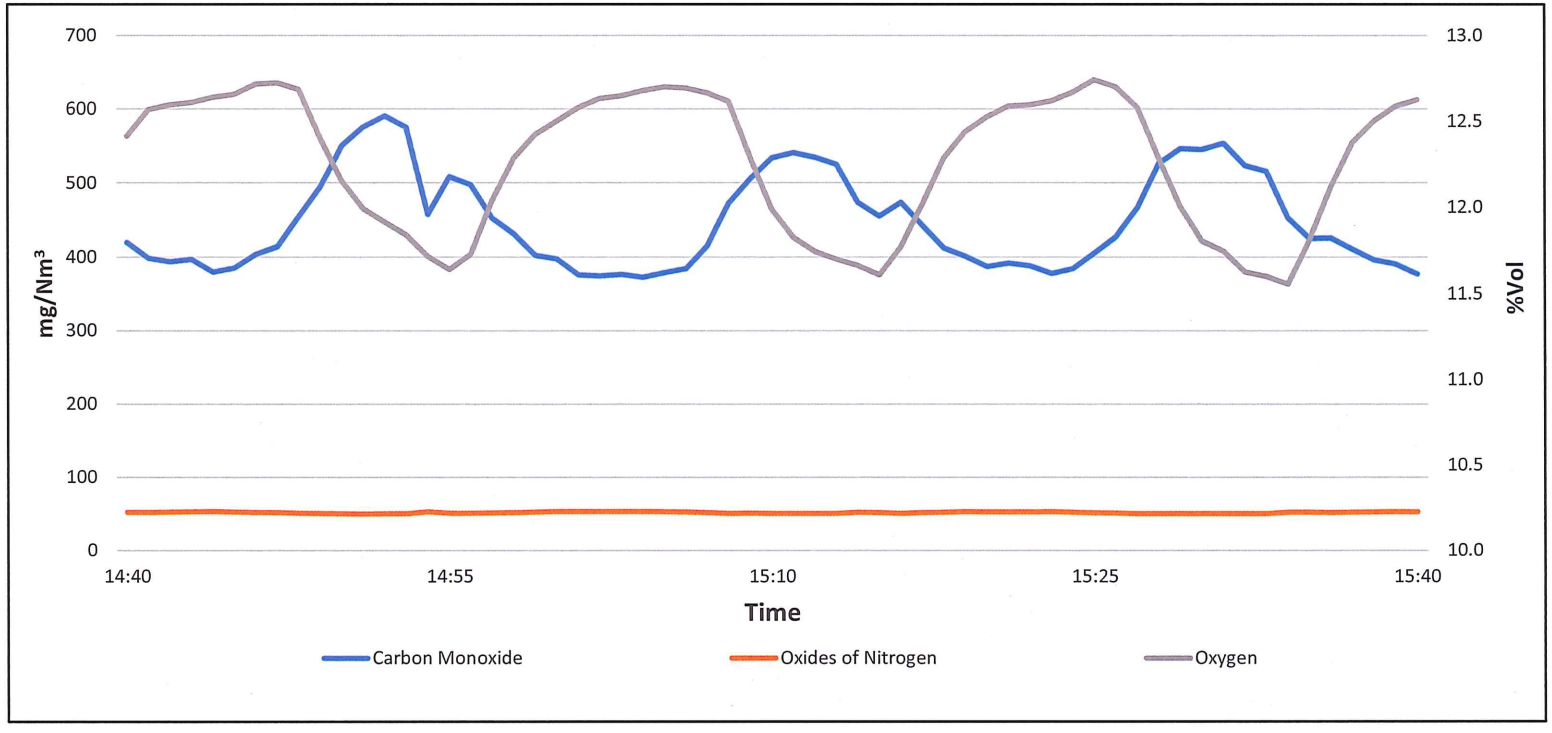
Reference Conditions - 273.15K, 101.3 kPa, 3% Oxygen on a dry gas basis



South Hook LNG - SCV 2E

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:	INTK51OCT20	Calibration By:	M Ellison	Comments:			
Site:		South Hook LNG	Date:	22/10/2020	MCERTs ID:	MM-05-682				
Stack:		SCV 1A	Leak Check Method:	Flow Method	Test Team :	MRE/JG				
Species		**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**						
Analyser Type/ID		Horiba PG250 SRM AS0450	Horiba PG250 SRM AS0450	Horiba PG250 SRM AS0450						
Gas Cylinder ID		195688SG	195688SG	158247SG						
Gas Cylinder Concentration		155.3 ppm	79.5 ppm	15.13 % Vol						
Concentration Uncertainty		1 %	1 %	1 %						
Span Value		155.3 ppm	79.5 ppm	15.13 % Vol						
Analyser Range 0 -		200 ppm	100 ppm	25 % Vol						
ANALYSER ADJUSTMENT										
Check Zero	Time	11:28	11:28	11:28						
	Reading	0 ppm	0 ppm	0.22 % Vol						
	Gain	2	0	-6						
Adjust Zero	Time	11:29	11:29	11:29						
	Reading	0 ppm	0 ppm	0 % Vol						
	Gain	2	0	-1						
Check Span	Time	11:35	11:35	11:45						
	Reading	174.4 ppm	79.1 ppm	15.4 % Vol						
	Gain	1.454	1.08	0.905						
Adjust Span	Time	11:36	11:36	11:46						
	Reading	155.6 ppm	79.6 ppm	15.13 % Vol						
	Gain	1.288	1.086	0.889						
Check Zero	Time	11:50	11:50	11:50						
	Reading	2 ppm	0.2 ppm	-0.09 % Vol						
Zero Drift		2.00 ppm	0.20 ppm	0.09 % 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		12:00	12:00	12:00						
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	15.13 % Vol						
Check Zero	Time	13:14	13:14	13:14						
	Reading	-2.7 ppm	0.2 ppm	-0.11 % Vol						
	Drift (%)	**1.7**	**0.3**	**0.7**						
	Acceptance	**Accept**	**Accept**	**Accept**						
Check Span	Time	13:21	13:21	13:26						
	Reading	148.4 ppm	79.5 ppm	15.03 % Vol						
	Drift (%)	**4.6**	**0.1**	**0.7**						
	Acceptance	**Drift Correct**	**Accept**	**Accept**						

GAS CALIBRATION RECORD

Client:		Intertek Ltd	Job Reference:	INTK51OCT20	Calibration By:	M Ellison	Comments: 1010.7			
Site:		South Hook LNG	Date:	19/10/2020	MCERTs ID:	MM-05-682				
Stack:		SCV 1D	Leak Check Method:	Flow Method	Test Team :	MRE/JG				
Species		**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**						
Analyser Type/ID		Horiba PG250 SRM AS0450	Horiba PG250 SRM AS0450	Horiba PG250 SRM AS0450						
Gas Cylinder ID		195688SG	195688SG	158247SG						
Gas Cylinder Concentration		155.3 ppm	79.5 ppm	15.13 % Vol						
Concentration Uncertainty		1 %	1 %	1 %						
Span Value		155.3 ppm	79.5 ppm	15.13 % Vol						
Analyser Range 0 -		200 ppm	100 ppm	25 % Vol						
ANALYSER ADJUSTMENT										
Check Zero	Time	09:57	09:58	09:58						
	Reading	1.7 ppm	0 ppm	0.37 % Vol						
	Gain	-1	1	-12						
Adjust Zero	Time	09:59	09:59	09:59						
	Reading	0 ppm	0 ppm	0 % Vol						
	Gain	1	1	-4						
Check Span	Time	10:09	10:09	10:18						
	Reading	150.6 ppm	79.4 ppm	15.41 % Vol						
	Gain	1.345	1.09	0.901						
Adjust Span	Time	10:11	10:11	10:19						
	Reading	155.5 ppm	79.5 ppm	15.13 % Vol						
	Gain	1.388	1.087	0.884						
Check Zero	Time	10:22	10:22	10:22						
	Reading	0.1 ppm	0.1 ppm	0.08 % Vol						
Zero Drift		0.10 ppm	0.10 ppm	0.08 % 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		10:25	10:25	10:25						
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	15.13 % Vol						
Check Zero	Time	16:30	16:30	16:30						
	Reading	1 ppm	0 ppm	-0.07 % Vol						
	Drift (%)	**0.6**	**0.0**	**0.5**						
	Acceptance	**Accept**	**Accept**	**Accept**						
Check Span	Time	16:35	16:35	16:40						
	Reading	153 ppm	78.6 ppm	14.94 % Vol						
	Drift (%)	**1.6**	**1.1**	**1.3**						
	Acceptance	**Accept**	**Accept**	**Accept**						

GAS CALIBRATION RECORD

Client:		Intertek Ltd	Job Reference:	INTK51OCT20	Calibration By:	M Ellison	Comments: 991.1			
Site:		South Hook LNG	Date:	21/10/2020	MCERTs ID:	MM-05-682				
Stack:		SCV 1H	Leak Check Method:	Flow Method	Test Team :	MRE/JG				
Species		**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**						
Analyser Type/ID		Horiba PG250 SRM AS0450	Horiba PG250 SRM AS0450	Horiba PG250 SRM AS0450						
Gas Cylinder ID		195688SG	195688SG	158247SG						
Gas Cylinder Concentration		155.3 ppm	79.5 ppm	15.13 % Vol						
Concentration Uncertainty		1 %	1 %	1 %						
Span Value		155.3 ppm	79.5 ppm	15.13 % Vol						
Analyser Range 0 -		200 ppm	100 ppm	25 % Vol						
ANALYSER ADJUSTMENT										
Check Zero	Time	10:50	10:50	10:50						
	Reading	1 ppm	0 ppm	-0.24 % Vol						
	Gain	1	0	2						
Adjust Zero	Time	10:51	10:51	10:51						
	Reading	0 ppm	0 ppm	0 % Vol						
	Gain	3	0	-4						
Check Span	Time	10:59	10:59	11:07						
	Reading	151.3 ppm	79.4 ppm	15.12 % Vol						
	Gain	1.353	1.099	0.906						
Adjust Span	Time	11:00	11:00	11:08						
	Reading	155.2 ppm	79.4 ppm	15.13 % Vol						
	Gain	1.378	1.1	0.907						
Check Zero	Time	11:12	11:12	11:12						
	Reading	-0.3 ppm	0.2 ppm	-0.02 % Vol						
Zero Drift		0.30 ppm	0.20 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		11:14	11:14	11:14						
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	15.13 % Vol						
Check Zero	Time	13:31								
	Reading	0.3 ppm	0.3 ppm	-0.08 % Vol						
	Drift (%)	**0.2**	**0.4**	**0.5**						
	Acceptance	**Accept**	**Accept**	**Accept**						
Check Span	Time	13:37	13:37	13:41						
	Reading	148.5 ppm	80.5 ppm	15.03 % Vol						
	Drift (%)	**4.3**	**1.4**	**0.7**						
	Acceptance	**Drift Correct**	**Accept**	**Accept**						

GAS CALIBRATION RECORD

Client:		Intertek Ltd	Job Reference:	INTK51OCT20	Calibration By:	M Ellison	Comments:			
Site:		South Hook LNG	Date:	21/10/2020	MCERTs ID:	MM-05-682				
Stack:		SCV 2E	Leak Check Method:	Flow Method	Test Team :	MRE/JG				
Species		**Carbon Monoxide**	**Oxides of Nitrogen**	**Oxygen**						
Analyser Type/ID		Horiba PG250 SRM AS0450	Horiba PG250 SRM AS0450	Horiba PG250 SRM AS0450						
Gas Cylinder ID		195688SG	195688SG	158247SG						
Gas Cylinder Concentration		155.3 ppm	79.5 ppm	15.13 % Vol						
Concentration Uncertainty		1 %	1 %	1 %						
Span Value		155.3 ppm	79.5 ppm	15.13 % Vol						
Analyser Range 0 -		200 ppm	100 ppm	25 % Vol						
ANALYSER ADJUSTMENT										
Check Zero	Time	14:09	14:09	14:09						
	Reading	-0.5 ppm	0 ppm	-0.08 % Vol						
	Gain	3	0	-4						
Adjust Zero	Time	14:10	14:10	14:10						
	Reading	0 ppm	0 ppm	0 % Vol						
	Gain									
Check Span	Time	14:18	14:18	14:25						
	Reading	146.1 ppm	80.9 ppm	15.16 % Vol						
	Gain	1.378	1.1	0.907						
Adjust Span	Time	14:19	14:19	14:26						
	Reading	154.3 ppm	79.5 ppm	15.13 % Vol						
	Gain	1.454	1.08	0.905						
Check Zero	Time	14:28	14:28	14:28						
	Reading	-0.12 ppm	0.2 ppm	-0.02 % Vol						
Zero Drift		0.12 ppm	0.20 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		1.2 l/min	1.2 l/min	1.2 l/min						
Time		14:40	14:40	14:40						
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	15.13 % Vol						
Check Zero	Time	15:49	15:49	15:49						
	Reading	0.2 ppm	0.5 ppm	-0.02 % Vol						
	Drift (%)	**0.1**	**0.6**	**0.1**						
	Acceptance	**Accept**	**Accept**	**Accept**						
Check Span	Time	15:55	15:55	16:02						
	Reading	159.4 ppm	79.2 ppm	15.22 % Vol						
	Drift (%)	**3.3**	**0.4**	**0.6**						
	Acceptance	**Drift Correct**	**Accept**	**Accept**						

2.2.6 - Uncertainty Calculations

SCV 1A Uncertainty Calculations

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

v1.0 May-20

		Cal gas conc	15.13	% vol
Measured concentration	11.76 % 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	0.0	% range		≤0.2 % vol
Deviation from linearity(lack of fit)	-0.5	% range		≤0.3 % vol
Zero drift	0.7	% of span value		≤±5% span value
Span drift	0.7	% of span value		≤±5% span value
Influence of sample gas flow	0.1	% vol/10l/h		≤0.2 % vol
Influence of atmospheric pressure	0.2	% vol/3kPa		≤0.2 % vol
Influence of ambient temperature	0.2	% vol/20K		≤0.5 % vol
Cross sensitivity	0.2	% vol		≤0.4 % vol
Influence of voltage	0.1	% vol/10V		≤0.2 % vol
Influence from vibration	0.0	% vol		≤0.2 % vol
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

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

Performance characteristic			Uncertainty	Value of uncertainty quantity			% vol
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.01
Lack of fit			u_{fit}				-0.07
Zero drift			u_{0dr}				0.06
Span drift			u_{sdr}				0.06
Influence of sample gas flow			u_{spres}				0.000
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				0.029
Cross sensitivity			u_{interf}				0.11
Influence of voltage			u_{volt}				0.014
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.06

Measurement uncertainty				
Combined uncertainty			0.17	% vol
Expanded uncertainty	k =	2	0.34	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.34**	**% vol**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.91**	**% value**

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

v1.0 May-20

Emission Limit Value	N/A	mg/m³ (Corrected)	Cal gas conc.	194.19	mg.m⁻³
Measured concentration	262.35	mg/m3 (101.3kPa, 273K)	Range	250.09	mg/m³
Measured concentration	510.87	mg/m³ (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	11.76	0.0	101.3	273.0
	Uncert	0.34	0.0	0.0	0.0
Factors		1.95	1.00	1.00	1.00
Uncertainty in factor		0.07	0.00	0.00	0.00
Correction Factor (no O_2 factor)		1.00		0.00	
Correction Factor (inl. O_2 factor)		1.95	uf	0.07	

Performance characteristics	Value			specification
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.3	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	2.1	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	-0.3	% full scale/10l		≤±2% range
Influence of atmospheric pressure	0.1	% full scale /3kPa		≤±2% range
Influence of ambient temperature	1.5	% full scale/20K		≤±5% range
Cross sensitivity	0.1	% full scale		≤4% range
Influence of voltage	0.3	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

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

Performance characteristic		Uncertainty	Value of uncertainty quantity			mg/m3
Standard deviation of repeatability at zero		u_{r0}				0.00
Standard deviation of repeatability at span level		u_{rs}				0.72
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{fit}				3.06
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				0.00
Influence of sample gas flow		u_{spres}				0.00
Influence of atmospheric pressure		u_{apres}				0.02
Influence of ambient temperature		u_{temp}				0.57
Cross sensitivity		u_{interf}				0.14
Influence of voltage		u_{volt}				0.24
Influence from vibration		u_{vib}				0.00
Uncertainty of calibration gas		u_{cal}				1.31
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}				18.94

Measurement uncertainty				
Combined uncertainty			3.47	mg/m³
Expanded uncertainty	k =	2	6.93	mg/m³
Uncertainty corrected to std conditions (no O_2 factor)			6.93	mg/m³
Uncertainty corrected to std conditions (including O_2 factor)			**40.21**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**40.21 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**7.87 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

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

v1.0 May-20

Emission Limit Value	107	mg/m³ (Corrected)	Cal gas conc.	163.3	mg.m⁻³
Measured concentration	25.79	mg/m3 (101.3kPa, 273K)	Range	205.4	mg/m³
Measured concentration	50.21	mg/m³ (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	11.76	0.0	101.3	273.0
	Uncert	0.34	0.0	0.0	0.0
Factors		1.95	1.00	1.00	1.00
Uncertainty in factor		0.07	0.00	0.00	0.00
Correction Factor (no O_2 factor)		1.00		0.00	
Correction Factor (inl. O_2 factor)		1.95	uf	0.07	

Performance characteristics	Value			specification
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	-1.5	% of range		≤±2 % range
Zero drift	0.3	% of span value		≤±5% span value
Span drift	0.1	% of span value		≤±5% span value
Influence of sample gas flow	0.4	% full scale/10l		≤±2% range
Influence of atmospheric pressure	-0.2	% full scale /3kPa		≤±2% range
Influence of ambient temperature	-2.4	% full scale/20K		≤±5% range
Cross sensitivity	0.5	% full scale		≤4% range
Influence of voltage	-0.1	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.2	%		≥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}		0.09
Standard deviation of repeatability at span level		u_{rs}		0.00
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{fit}		-1.81
Zero drift		u_{0dr}		0.24
Span drift		u_{sdr}		0.12
Influence of sample gas flow		u_{spres}		0.00
Influence of atmospheric pressure		u_{apres}		-0.03
Influence of ambient temperature		u_{temp}		-0.76
Cross sensitivity		u_{interf}		0.59
Influence of voltage		u_{volt}		-0.06
Influence from vibration		u_{vib}		0.00
Converter efficiency		u_{conv}		0.71
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}		1.86

Measurement uncertainty				
Combined uncertainty			2.20	mg/m³
Expanded uncertainty	k =	2	4.39	mg/m³
Uncertainty corrected to std conditions (no O_2 factor)			4.39	mg/m³
Uncertainty corrected to std conditions (including O_2 factor)			**9.33**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**9.33 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**18.58 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**4.10 % 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 uncertaintes 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	1.72 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	101200	101320.663	120.663	22.55	22.55	22.55			23	13.8	1.4	206	5.2	83.0	11.8	29.30	29.15
2	101200	101320.663	120.663	29.41	29.41	29.41			29	13.8	1.4	206	5.2	83.0	11.8	29.30	29.15
3	101200	101320.663	120.663	28.43	28.43	28.43			28	13.7	1.4	206	5.2	83.0	11.8	29.30	29.15
4	101200	101320.663	120.663	28.43	28.43	28.43			28	13.6	1.4	206	5.2	83.0	11.8	29.30	29.15
5	101200	101320.663	120.663	26.47	26.47	26.47			26	13.6	1.4	206	5.2	83.0	11.8	29.30	29.15
6	101200	101320.663	120.663	24.51	24.51	24.51			25	13.7	1.4	206	5.2	83.0	11.8	29.30	29.15
7	101200	101320.663	120.663	24.51	24.51	24.51			25	13.8	1.4	206	5.2	83.0	11.8	29.30	29.15
8	101200	101320.663	120.663	24.51	24.51	24.51			25	13.8	1.4	206	5.2	83.0	11.8	29.30	29.15
9	101200	101320.663	120.663	25.49	25.49	25.49			25	13.7	1.4	206	5.2	83.0	11.8	29.30	29.15
10	101200	101320.663	120.663	29.41	29.41	29.41			29	13.6	1.4	206	5.2	83.0	11.8	29.30	29.15
11	101200	101320.663	120.663	30.39	30.39	30.39			30	13.6	1.4	206	5.2	83.0	11.8	29.30	29.15
12	101200	101320.663	120.663	30.39	30.39	30.39			30	13.7	1.4	206	5.2	83.0	11.8	29.30	29.15
Mean	60760	60833	120.7	27.0	27.0	27.0	#DIV/0!	#DIV/0!	27.0	13.7	1.4	206.0	5.2	83.0	11.8	29.30	29.15

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

Mean density	0.744 kg/m3

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

Mean velocity	7.09 m/sec	
Standard uncertainty of velocity	0.34 m/sec	4.8 % of value
Expanded uncertainty in velocity	0.69 m/sec	9.7 % of value

	Circular duct	Rectangular duct
Flow rate	43938 m^3/hour	0 m3/hour
Volume flow rate expanded uncertainty	4326 m^3/hour	#DIV/0! m3/hour
Volume flow rate expanded uncertainty	9.8 % 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 SRM AS0450
v1.0 May-20

		Cal gas conc	15.13 % vol
Measured concentration	8.24 % 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	0.0	% range		≤0.2 % vol
Deviation from linearity(lack of fit)	-0.5	% range		≤0.3 % vol
Zero drift	0.5	% of span value		≤±5% span value
Span drift	1.3	% of span value		≤±5% span value
Influence of sample gas flow	0.1	% vol/10l/h		≤0.2 % vol
Influence of atmospheric pressure	0.2	% vol/3kPa		≤0.2 % vol
Influence of ambient temperature	0.2	% vol/20K		≤0.5 % vol
Cross sensitivity	0.2	% vol		≤0.4 % vol
Influence of voltage	0.1	% vol/10V		≤0.2 % vol
Influence from vibration	0.0	% vol		≤0.2 % vol
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

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

Performance characteristic			Uncertainty	Value of uncertainty quantity			% vol
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.01
Lack of fit			u_{fit}				-0.07
Zero drift			u_{0dr}				0.04
Span drift			u_{sdr}				0.11
Influence of sample gas flow			u_{spres}				0.000
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				0.029
Cross sensitivity			u_{interf}				0.11
Influence of voltage			u_{volt}				0.014
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.04

Measurement uncertainty				
Combined uncertainty			0.18	% vol
Expanded uncertainty	k =	2	0.37	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.37 % vol**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**4.47 % value**	

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

v1.0 May-20

Emission Limit Value	N/A	mg/m³ (Corrected)	Cal gas conc.	194.19	mg.m⁻³
Measured concentration	107.88	mg/m3 (101.3kPa, 273K)	Range	250.09	mg/m³
Measured concentration	152.17	mg/m³ (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	8.24	0.0	101.3	273.0
	Uncert	0.37	0.0	0.0	0.0
Factors		1.41	1.00	1.00	1.00
Uncertainty in factor		0.04	0.00	0.00	0.00
Correction Factor (no O_2 factor)		1.00		0.00	
Correction Factor (inl. O_2 factor)		1.41	uf	0.04	

Performance characteristics	Value			specification
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.3	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	2.1	% of range		≤±2 % range
Zero drift	0.6	% of span value		≤±5% span value
Span drift	1.6	% of span value		≤±5% span value
Influence of sample gas flow	-0.3	% full scale/10l		≤±2% range
Influence of atmospheric pressure	0.1	% full scale /3kPa		≤±2% range
Influence of ambient temperature	1.5	% full scale/20K		≤±5% range
Cross sensitivity	0.1	% full scale		≤4% range
Influence of voltage	0.3	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

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

Performance characteristic			Uncertainty	Value of uncertainty quantity			mg/m3
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.72
Standard deviation of reproducibility			u_{rp}				0.00
Lack of fit			u_{fit}				3.06
Zero drift			u_{0dr}				0.72
Span drift			u_{sdr}				1.80
Influence of sample gas flow			u_{spres}				0.00
Influence of atmospheric pressure			u_{apres}				0.02
Influence of ambient temperature			u_{temp}				0.57
Cross sensitivity			u_{interf}				0.14
Influence of voltage			u_{volt}				0.24
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.54
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}				4.39

Measurement uncertainty				
Combined uncertainty			3.79	mg/m³
Expanded uncertainty	k =	2	7.58	mg/m³
Uncertainty corrected to std conditions (no O_2 factor)			7.58	mg/m³
Uncertainty corrected to std conditions (including O_2 factor)			**13.83**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**13.83 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**9.09 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

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

v1.0 May-20

Emission Limit Value	107	mg/m³ (Corrected)	Cal gas conc.	163.3	mg.m⁻³
Measured concentration	38.64	mg/m3 (101.3kPa, 273K)	Range	205.4	mg/m³
Measured concentration	54.50	mg/m³ (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	8.24	0.0	101.3	273.0
	Uncert	0.37	0.0	0.0	0.0
Factors		1.41	1.00	1.00	1.00
Uncertainty in factor		0.04	0.00	0.00	0.00
Correction Factor (no O_2 factor)		1.00		0.00	
Correction Factor (inl. O_2 factor)		1.41	uf	0.04	

Performance characteristics	Value			specification
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	-1.5	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	1.1	% of span value		≤±5% span value
Influence of sample gas flow	0.4	% full scale/10l		≤±2% range
Influence of atmospheric pressure	-0.2	% full scale /3kPa		≤±2% range
Influence of ambient temperature	-2.4	% full scale/20K		≤±5% range
Cross sensitivity	0.5	% full scale		≤4% range
Influence of voltage	-0.1	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.2	%		≥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}				0.09
Standard deviation of repeatability at span level		u_{rs}				0.00
Standard deviation of reproducibility		u_{rp}				0.00
Lack of fit		u_{flt}				-1.81
Zero drift		u_{0dr}				0.00
Span drift		u_{sdr}				1.07
Influence of sample gas flow		u_{spres}				0.00
Influence of atmospheric pressure		u_{apres}				-0.03
Influence of ambient temperature		u_{temp}				-0.76
Cross sensitivity		u_{interf}				0.59
Influence of voltage		u_{volt}				-0.06
Influence from vibration		u_{vib}				0.00
Converter efficiency		u_{conv}				1.06
Uncertainty of calibration gas		u_{cal}				0.19
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}				1.57

Measurement uncertainty				
Combined uncertainty			2.56	mg/m³
Expanded uncertainty	k =	2	5.11	mg/m³
Uncertainty corrected to std conditions (no O_2 factor)			5.11	mg/m³
Uncertainty corrected to std conditions (including O_2 factor)			**7.87**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**7.87 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**14.44 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**4.78 % 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/m³
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	101400	101633.9685	233.9685	52.94	52.94	52.94			53	12.9	1.1	85	5	86.8	8.2	29.13	29.01
2	101400	101633.9685	233.9685	54.90	54.90	54.90			55	12.8	1.1	85	5	86.8	8.2	29.13	29.01
3	101400	101633.9685	233.9685	50.98	50.98	50.98			51	12.8	1.1	85	5	86.8	8.2	29.13	29.01
4	101400	101633.9685	233.9685	54.90	54.90	54.90			55	12.9	1.1	85	5	86.8	8.2	29.13	29.01
5	101400	101633.9685	233.9685	50.00	50.00	50.00			50	12.9	1.1	85	5	86.8	8.2	29.13	29.01
6	101400	101633.9685	233.9685	51.96	51.96	51.96			52	12.8	1.1	85	5	86.8	8.2	29.13	29.01
7	101400	101633.9685	233.9685	47.05	47.05	47.05			47	12.9	1.1	85	5	86.8	8.2	29.13	29.01
8	101400	101633.9685	233.9685	50.00	50.00	50.00			50	12.8	1.1	85	5	86.8	8.2	29.13	29.01
9	101400	101633.9685	233.9685	50.98	50.98	50.98			51	12.8	1.1	85	5	86.8	8.2	29.13	29.01
10	101400	101633.9685	233.9685	51.96	51.96	51.96			52	12.9	1.1	85	5	86.8	8.2	29.13	29.01
11	101400	101633.9685	233.9685	53.92	53.92	53.92			54	12.9	1.1	85	5	86.8	8.2	29.13	29.01
12	101400	101633.9685	233.9685	50.00	50.00	50.00			50	12.8	1.1	85	5	86.8	8.2	29.13	29.01
Mean	60880	61021	234.0	51.6	51.6	51.6	#DIV/0!	#DIV/0!	51.6	12.9	1.1	85.0	5.0	86.8	8.2	29.13	29.01

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

Mean density	0.745 kg/m3

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

Mean velocity	9.81 m/sec	
Standard uncertainty of velocity	0.44 m/sec	4.5 % of value
Expanded uncertainty in velocity	0.88 m/sec	9.0 % of value

	Circular duct		Rectangular duct	
Flow rate	60732	m³/hour	0	m3/hour
Volume flow rate expanded uncertainty	5560	m³/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 1H Uncertainty Calculations

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

v1.0 May-20

		Cal gas conc	15.13 % vol
Measured concentration	12.80 % 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	0.0	% range		≤0.2 % vol
Deviation from linearity(lack of fit)	-0.5	% range		≤0.3 % vol
Zero drift	0.5	% of span value		≤±5% span value
Span drift	0.7	% of span value		≤±5% span value
Influence of sample gas flow	0.1	% vol/10l/h		≤0.2 % vol
Influence of atmospheric pressure	0.2	% vol/3kPa		≤0.2 % vol
Influence of ambient temperature	0.2	% vol/20K		≤0.5 % vol
Cross sensitivity	0.2	% vol		≤0.4 % vol
Influence of voltage	0.1	% vol/10V		≤0.2 % vol
Influence from vibration	0.0	% vol		≤0.2 % vol
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

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

Performance characteristic			Uncertainty	Value of uncertainty quantity			% vol
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.01
Lack of fit			u_{flt}				-0.07
Zero drift			u_{0dr}				0.05
Span drift			u_{sdr}				0.06
Influence of sample gas flow			u_{spres}				0.000
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				0.029
Cross sensitivity			u_{interf}				0.11
Influence of voltage			u_{volt}				0.014
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.06

Measurement uncertainty				
Combined uncertainty			0.17	% vol
Expanded uncertainty	k =	2	0.34	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.34 % vol**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.62 % value**	

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

v1.0 May-20

Emission Limit Value	N/A	mg/m³ (Corrected)	Cal gas conc.	194.19	mg.m³
Measured concentration	208.33	mg/m3 (101.3kPa, 273K)	Range	250.09	mg/m³
Measured concentration	457.12	mg/m³ (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	12.80	0.0	101.3	273.0
	Uncert	0.34	0.0	0.0	0.0
Factors		2.19	1.00	1.00	1.00
Uncertainty in factor		0.09	0.00	0.00	0.00
Correction Factor (no O_2 factor)		1.00		0.00	
Correction Factor (inl. O_2 factor)		2.19	uf	0.09	

Performance characteristics	Value			specification
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.3	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	2.1	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	-0.3	% full scale/10l		≤±2% range
Influence of atmospheric pressure	0.1	% full scale /3kPa		≤±2% range
Influence of ambient temperature	1.5	% full scale/20K		≤±5% range
Cross sensitivity	0.1	% full scale		≤4% range
Influence of voltage	0.3	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

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

Performance characteristic			Uncertainty	Value of uncertainty quantity			mg/m3
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.72
Standard deviation of reproducibility			u_{rp}				0.00
Lack of fit			u_{fit}				3.06
Zero drift			u_{0dr}				0.00
Span drift			u_{sdr}				0.00
Influence of sample gas flow			u_{spres}				0.00
Influence of atmospheric pressure			u_{apres}				0.02
Influence of ambient temperature			u_{temp}				0.57
Cross sensitivity			u_{interf}				0.14
Influence of voltage			u_{volt}				0.24
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				1.04
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}				18.68

Measurement uncertainty				
Combined uncertainty			3.37	mg/m³
Expanded uncertainty	k =	2	6.75	mg/m³
Uncertainty corrected to std conditions (no O_2 factor)			6.75	mg/m³
Uncertainty corrected to std conditions (including O_2 factor)			**40.18**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**40.18**	**mg.m³**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**8.79**	**% value**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A**	**% ELV**

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

v1.0 May-20

Emission Limit Value	107	mg/m³ (Corrected)	Cal gas conc.	163.3	mg.m⁻³
Measured concentration	21.79	mg/m3 (101.3kPa, 273K)	Range	205.4	mg/m³
Measured concentration	47.82	mg/m³ (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	12.80	0.0	101.3	273.0
	Uncert	0.34	0.0	0.0	0.0
Factors		2.19	1.00	1.00	1.00
Uncertainty in factor		0.09	0.00	0.00	0.00
Correction Factor (no O_2 factor)		1.00		0.00	
Correction Factor (inl. O_2 factor)		2.19	uf	0.09	

Performance characteristics	Value			specification
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	-1.5	% of range		≤±2 % range
Zero drift	0.4	% of span value		≤±5% span value
Span drift	1.4	% of span value		≤±5% span value
Influence of sample gas flow	0.4	% full scale/10l		≤±2% range
Influence of atmospheric pressure	-0.2	% full scale /3kPa		≤±2% range
Influence of ambient temperature	-2.4	% full scale/20K		≤±5% range
Cross sensitivity	0.5	% full scale		≤4% range
Influence of voltage	-0.1	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.2	%		≥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}		0.09
Standard deviation of repeatability at span level		u_{rs}		0.00
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		-1.81
Zero drift		u_{0dr}		0.36
Span drift		u_{sdr}		1.30
Influence of sample gas flow		u_{spres}		0.00
Influence of atmospheric pressure		u_{apres}		-0.03
Influence of ambient temperature		u_{temp}		-0.76
Cross sensitivity		u_{interf}		0.59
Influence of voltage		u_{volt}		-0.06
Influence from vibration		u_{vib}		0.00
Converter efficiency		u_{conv}		0.60
Uncertainty of calibration gas		u_{cal}		0.11
Uncertainty in std conditions correction factor (no O_2 factor)		u_f		0.00
Uncertainty in std conditions correction factor (including O_2 factor)		u_{of}		1.95

Measurement uncertainty				
Combined uncertainty			2.54	mg/m³
Expanded uncertainty	k =	2	5.07	mg/m³
Uncertainty corrected to std conditions (no O_2 factor)			5.07	mg/m³
Uncertainty corrected to std conditions (including O_2 factor)			**11.80**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**11.80 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**24.67 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**4.74 % 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/m³
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	99110	99369.965	259.965	40.19	40.19	40.19			40	14.8	1.5	163	4.4	82.8	12.8	29.22	29.05
2	99110	99369.965	259.965	47.05	47.05	47.05			47	14.7	1.5	163	4.4	82.8	12.8	29.22	29.05
3	99110	99369.965	259.965	48.04	48.04	48.04			48	14.7	1.5	163	4.4	82.8	12.8	29.22	29.05
4	99110	99369.965	259.965	38.23	38.23	38.23			38	14.7	1.5	163	4.4	82.8	12.8	29.22	29.05
5	99110	99369.965	259.965	49.02	49.02	49.02			49	14.8	1.5	163	4.4	82.8	12.8	29.22	29.05
6	99110	99369.965	259.965	51.96	51.96	51.96			52	15	1.5	163	4.4	82.8	12.8	29.22	29.05
7	99110	99369.965	259.965	37.25	37.25	37.25			37	14.6	1.5	163	4.4	82.8	12.8	29.22	29.05
8	99110	99369.965	259.965	33.33	33.33	33.33			33	14.5	1.5	163	4.4	82.8	12.8	29.22	29.05
9	99110	99369.965	259.965	44.11	44.11	44.11			44	14.5	1.5	163	4.4	82.8	12.8	29.22	29.05
10	99110	99369.965	259.965	36.27	36.27	36.27			36	14.6	1.5	163	4.4	82.8	12.8	29.22	29.05
11	99110	99369.965	259.965	54.90	54.90	54.90			55	14.6	1.5	163	4.4	82.8	12.8	29.22	29.05
12	99110	99369.965	259.965	56.86	56.86	56.86			57	14.7	1.5	163	4.4	82.8	12.8	29.22	29.05
Mean	59506	59662	260.0	44.8	44.8	44.8	#DIV/0!	#DIV/0!	44.8	14.7	1.5	163.0	4.4	82.8	12.8	29.22	29.05

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

Mean density	0.725 kg/m3

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

Mean velocity	9.23 m/sec	
Standard uncertainty of velocity	0.42 m/sec	4.5 % of value
Expanded uncertainty in velocity	0.83 m/sec	9.0 % of value

	Circular duct		Rectangular duct	
Flow rate	57150	m³/hour	0	m3/hour
Volume flow rate expanded uncertainty	5276	m³/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 2E Uncertainty Calculations

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

v1.0 May-20

		Cal gas conc	15.13 % vol
Measured concentration	12.26 % vol	Full Scale	25.00 % vol

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

	ranges min	max	value at calib	
flow	0.30	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
temp	282	285	285	K
Voltage	105	115	110	V

Performance characteristic			Uncertainty	Value of uncertainty quantity			% vol
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.01
Lack of fit			u_{flt}				-0.07
Zero drift			u_{0dr}				0.01
Span drift			u_{sdr}				0.05
Influence of sample gas flow			u_{spres}				0.000
Influence of atmospheric pressure			u_{apres}				0.020
Influence of ambient temperature			u_{temp}				0.016
Cross sensitivity			u_{interf}				0.11
Influence of voltage			u_{volt}				0.014
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				0.06

Measurement uncertainty				
Combined uncertainty			0.16	% vol
Expanded uncertainty	k =	2	0.31	% vol
Expanded uncertainty	**expressed with a level of confidence of 95%**		**0.31 % vol**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**2.56 % value**	

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

v1.0 May-20

Emission Limit Value	N/A	mg/m³ (Corrected)	Cal gas conc.	194.19	mg.m⁻³
Measured concentration	218.04	mg/m3 (101.3kPa, 273K)	Range	250.09	mg/m³
Measured concentration	449.25	mg/m³ (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	12.26	0.0	101.3	273.0
	Uncert	0.31	0.0	0.0	0.0
Factors		2.06	1.00	1.00	1.00
Uncertainty in factor		0.07	0.00	0.00	0.00
Correction Factor (no O_2 factor)		1.00		0.00	
Correction Factor (inl. O_2 factor)		2.06	uf	0.07	

Performance characteristics	Value			specification
Standard deviation of repeatability at zero	0.2	% of range		≤±1% range
Standard deviation of repeatability at span level	0.3	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	2.1	% of range		≤±2 % range
Zero drift	0.0	% of span value		≤±5% span value
Span drift	0.0	% of span value		≤±5% span value
Influence of sample gas flow	-0.3	% full scale/10l		≤±2% range
Influence of atmospheric pressure	0.1	% full scale /3kPa		≤±2% range
Influence of ambient temperature	1.5	% full scale/20K		≤±5% range
Cross sensitivity	0.1	% full scale		≤4% range
Influence of voltage	0.3	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Uncertainty of calibration gas	1.0	% value		≤± 2% of value

	ranges min	max	value at calib	
Flow	0.3	0.5	0.4	l/min
pressure	101.0	102	101.4	kPa
Temp	282	285	285	K
Voltage	105	115	110	V

Performance characteristic			Uncertainty	Value of uncertainty quantity			mg/m3
Standard deviation of repeatability at zero			u_{r0}				0.00
Standard deviation of repeatability at span level			u_{rs}				0.72
Standard deviation of reproducibility			u_{rp}				0.00
Lack of fit			u_{fit}				3.06
Zero drift			u_{0dr}				0.00
Span drift			u_{sdr}				0.00
Influence of sample gas flow			u_{spres}				0.00
Influence of atmospheric pressure			u_{apres}				0.02
Influence of ambient temperature			u_{temp}				0.32
Cross sensitivity			u_{interf}				0.14
Influence of voltage			u_{volt}				0.24
Influence from vibration			u_{vib}				0.00
Uncertainty of calibration gas			u_{cal}				1.09
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}				16.12

Measurement uncertainty				
Combined uncertainty			3.36	mg/m³
Expanded uncertainty	k =	2	6.71	mg/m³
Uncertainty corrected to std conditions (no O_2 factor)			6.71	mg/m³
Uncertainty corrected to std conditions (including O_2 factor)			**35.07**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**35.07 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**7.81 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**N/A % ELV**	

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

v1.0 May-20

Emission Limit Value	107	mg/m³ (Corrected)	Cal gas conc.	163.3	mg.m⁻³
Measured concentration	24.90	mg/m3 (101.3kPa, 273K)	Range	205.4	mg/m³
Measured concentration	51.31	mg/m³ (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	12.26	0.0	101.3	273.0
	Uncert	0.31	0.0	0.0	0.0
Factors		2.06	1.00	1.00	1.00
Uncertainty in factor		0.07	0.00	0.00	0.00
Correction Factor (no O_2 factor)		1.00		0.00	
Correction Factor (inl. O_2 factor)		2.06	uf	0.07	

Performance characteristics	Value			specification
Standard deviation of repeatability at zero	0.0	% of range		≤±1% range
Standard deviation of repeatability at span level	0.0	% of range		≤±2% range
Standard deviation of reproducibility	0.0	% full scale		≤±3.3% range
Deviation from linearity(lack of fit)	-1.5	% of range		≤±2 % range
Zero drift	0.6	% of span value		≤±5% span value
Span drift	0.4	% of span value		≤±5% span value
Influence of sample gas flow	0.4	% full scale/10l		≤±2% range
Influence of atmospheric pressure	-0.2	% full scale /3kPa		≤±2% range
Influence of ambient temperature	-2.4	% full scale/20K		≤±5% range
Cross sensitivity	0.5	% full scale		≤4% range
Influence of voltage	-0.1	% full scale/10V		≤±2% range/10V
Influence from vibration	0.0	% full scale		≤±2% range
Converter efficiency	95.2	%		≥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	282	285	285	K
Voltage	105	115	110	V

Performance characteristic		Uncertainty	Value of uncertainty quantity	mg/m3
Standard deviation of repeatability at zero		u_{r0}		0.09
Standard deviation of repeatability at span level		u_{rs}		0.00
Standard deviation of reproducibility		u_{rp}		0.00
Lack of fit		u_{flt}		-1.81
Zero drift		u_{0dr}		0.59
Span drift		u_{sdr}		0.36
Influence of sample gas flow		u_{spres}		0.00
Influence of atmospheric pressure		u_{apres}		-0.03
Influence of ambient temperature		u_{temp}		-0.43
Cross sensitivity		u_{interf}		0.59
Influence of voltage		u_{volt}		-0.06
Influence from vibration		u_{vib}		0.00
Converter efficiency		u_{conv}		0.68
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}		1.84

Measurement uncertainty				
Combined uncertainty			2.19	mg/m³
Expanded uncertainty	k =	2	4.38	mg/m³
Uncertainty corrected to std conditions (no O_2 factor)			4.38	mg/m³
Uncertainty corrected to std conditions (including O_2 factor)			**9.75**	**mg/m3**
Expanded uncertainty	**expressed with a level of confidence of 95%**		**9.75 mg.m⁻³**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**19.01 % value**	
Expanded uncertainty	**expressed with a level of confidence of 95%**		**4.10 % 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/m³
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	101240	101475.44	235.44	41.17	41.17	41.17			41	14.8	1.4	177	4.4	83.3	12.3	29.20	29.04
2	101240	101475.44	235.44	44.11	44.11	44.11			44	14.6	1.4	177	4.4	83.3	12.3	29.20	29.04
3	101240	101475.44	235.44	42.15	42.15	42.15			42	14.4	1.4	177	4.4	83.3	12.3	29.20	29.04
4	101240	101475.44	235.44	39.21	39.21	39.21			39	14.8	1.4	177	4.4	83.3	12.3	29.20	29.04
5	101240	101475.44	235.44	36.27	36.27	36.27			36	14.6	1.4	177	4.4	83.3	12.3	29.20	29.04
6	101240	101475.44	235.44	35.29	35.29	35.29			35	14.6	1.4	177	4.4	83.3	12.3	29.20	29.04
7	101240	101475.44	235.44	27.45	27.45	27.45			27	14.8	1.4	177	4.4	83.3	12.3	29.20	29.04
8	101240	101475.44	235.44	34.31	34.31	34.31			34	14.5	1.4	177	4.4	83.3	12.3	29.20	29.04
9	101240	101475.44	235.44	35.29	35.29	35.29			35	14.6	1.4	177	4.4	83.3	12.3	29.20	29.04
10	101240	101475.44	235.44	39.21	39.21	39.21			39	14.8	1.4	177	4.4	83.3	12.3	29.20	29.04
11	101240	101475.44	235.44	41.17	41.17	41.17			41	14.8	1.4	177	4.4	83.3	12.3	29.20	29.04
12	101240	101475.44	235.44	40.19	40.19	40.19			40	15	1.4	177	4.4	83.3	12.3	29.20	29.04
Mean	60784	60926	235.4	38.0	38.0	38.0	#DIV/0!	#DIV/0!	38.0	14.7	1.4	177.0	4.4	83.3	12.5	29.20	29.04

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

Mean density	0.740 kg/m3

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

Mean velocity	8.43 m/sec	
Standard uncertainty of velocity	0.39 m/sec	4.6 % of value
Expanded uncertainty in velocity	0.77 m/sec	9.2 % of value

	Circular duct	Rectangular duct	
Flow rate	52193 m^3/hour	0	m3/hour
Volume flow rate expanded uncertainty	4876 m^3/hour	#DIV/0!	m3/hour
Volume flow rate expanded uncertainty	9.3 % of value	#DIV/0!	% of value

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

2.2.7 - Calculations Used in Reporting Results

Nozzle Selection

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

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

$$DH = K \times Dp$$

Where:-

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

D_n the nozzle diameter mm

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

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

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

C_p Pitot tube coefficient dependent on the Pitot tube type

T_m the meter temperature in °C

T_s the stack temperature in °C

P_s the stack pressure

P_m the meter pressure

M_d dry gas molecular weight

M_s apparent stack gas molecular weight

DH pressure drop across the orifice (mm water)

DP differential Pitot pressure (mm water)

From this the correct nozzle size can be determined.

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

Where the Constant = 0.6071 Metric

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

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

Where Km =Orifice meter coefficient

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

Where Const = 183.7 metric

Moisture Determination Calculations

These calculations are based at 273K and 101.325kPa

To calculate moisture the following equation is used:

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

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

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

Oxygen Concentration Correction C_{oxy} to Particulate concentration

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

Dry Molecular Weight of gases

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

Stack Molecular Weight of gases

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

Stack Gas Velocity

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

Mass Emission Rate M_R

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

IsoKinicity

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

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)