STACK EMISSIONS MONITORING REPORT

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Your contact at SOCOTEC LTD
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Operator & Address:
Camira Fabrics Holmfirth Dyers Ribbledon Dye Works Dunford Road Holmfirth West Yorkshire HD9 2DP

Permit Reference:
N/A - Investigative Test

Release Point:
Tenter Abatement System - Pre Set Process

Sampling Date(s):
22nd October 2019

SOCOTEC Job Number:	LNO 15340
Report Date:	29th November 2019
Version:	1
Report By:	Keith Bird
MCERTS Number:	MM 07 825
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Scott Wilson
MCERTS Number:	MM 03 327
Business Title:	MCERTS Level 2 - FTIR Manager
Technical Endorsements:	1, 2, 3 & 4
Signature:	

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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Camira Fabrics operates a fabric dyeing process at Holmfirth Dyers

SOCOTEC LTD were commissioned by Camira Fabrics to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under trial operating conditions.

Plant

Tenter Abatement System - Pre Set Process

Operator

Camira Fabrics
Holmfirth Dyers
Ribbledon Dye Works
Dunford Road
Holmfirth
West Yorkshire
HD9 2DP

No Permit Applicable: Investigative

Stack Emissions Monitoring Test House

SOCOTEC - Stockport Laboratory
Unit 5 Crown Industrial Estate
Kenwood Road
Stockport
SK5 6PH
UKAS and MCERTS Accreditation Number: 1015

EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	**Units**	**Result**	**Calculated Uncertainty +/-**	**Emission Limit Value (ELV)**	**MCERTS accredited result**
Total Particulate Matter	mg/m³	7.3	0.63	-	✓
Particulate Emission Rate	g/hr	165	14	-	
Hydrogen Chloride	mg/m³	0.76	0.08	-	✓
Hydrogen Chloride Emission Rate	g/hr	17	1.9	-	
Formaldehyde	mg/m³	1.9	0.21	-	✓
Formaldehyde Emission Rate	g/hr	44	4.7	-	
Ammonia	mg/m³	0.42	0.30	-	✓
Ammonia Emission Rate	g/hr	8.9	6.4	-	
Oil Mist	mg/m³	0.05	0.06	-	×
Oil Mist Emission Rate	g/hr	1.2	1.3	-	
Formic Acid	mg/m³	***0.27***	0.31	-	×
Formic Acid Emission Rate	g/hr	***5.6***	6.5	-	
Acetic Acid	mg/m³	***0.27***	0.31	-	×
Acetic Acid Emission Rate	g/hr	***5.6***	6.5	-	
VOC Screening	mg/m³	2.2	0.26	-	×
VOC Screening Emission Rate	g/hr	46	5.4	-	
Total Volatile Organic Compounds	mg/m³	16	1.3	-	✓
Total Volatile Organic Compounds Emission Rate	g/hr	336	28	-	
Oxides of Nitrogen (as NO_2)	mg/m³	4.0	3.3	-	✓
Oxides of Nitrogen (as NO_2) Emission Rate	g/hr	85	70	-	
Sulphur Dioxide	mg/m³	9.6	1.8	-	✓
Sulphur Dioxide Emission Rate	g/hr	203	38	-	
Carbon Monoxide	mg/m³	37	3.1	-	✓
Carbon Monoxide Emission Rate	g/hr	775	65	-	
Carbon Dioxide	% v/v	0.58	0.003	-	✓
Oxygen	% v/v	20.4	0.352	-	✓
Moisture	%	3.7	0.11	-	✓
Stack Gas Temperature	°C	43	-	-	✓
Stack Gas Velocity	m/s	10.9	0.26	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	24890	1275	-	
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	21089	1080	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	20300	1040	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	21089	1080	-	

ND = None Detected,
Results at or below the limit of detection are highlighted by bold italic text.
The above volumetric flow rate is calculated using data from the preliminary survey. Mass emissions for non isokinetic tests are calculated using these values. For all isokinetic testing the mass emission is calculated using test specific flow data and not the above values.

Reference conditions are 273K, 101.3kPa without correction for water vapour

EXECUTIVE SUMMARY

MONITORING TIMES			
Parameter	**Sampling Date(s)**	**Sampling Times**	**Sampling Duration**
Total Particulate Matter Run 1	22 October 2010	10:38 - 11:10	32 minutes
Hydrogen Chloride Run 1	22 October 2019	10:38 - 11:10	32 minutes
Formaldehyde Run 1	22 October 2010	10:38 - 11:10	32 minutes
Ammonia Run 1	22 October 2019	11:25 - 11:55	30 minutes
Oil Mist Run 1	22 October 2019	10:38 - 11:10	32 minutes
Formic Acid Run 1	22 October 2019	11:16 - 11:46	30 minutes
Acetic Acid Run 1	22 October 2019	11:50 - 12:20	30 minutes
VOC Screening Run 1	22 October 2019	10:37 - 11:07	30 minutes
Total Volatile Organic Compounds Run 1	22 October 2019	10:20 - 12:20	120 minutes
Combustion Gases	22 October 2019	10:20 - 12:20	120 minutes
Preliminary Stack Traverse	22 October 2019	09:40	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Fabric dyeing
Continuous or batch	Batch
Product Details	Polyester - Pre Set - Unitech 1
Part of batch to be monitored (if applicable)	During normal running
Normal load, throughput or continuous rating	Normal Load
Fuel used during monitoring	N/A
Abatement	ESP
Plume Appearance	Not visible from sampling location

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard reference / alternative methods employed by SOCOTEC is determined, wherever possible by the hierarchy of method selection outlined in Environment Agency Technical Guidance Note (Monitoring) M2.

MONITORING METHODS							
Species	**Method** Standard Reference Method / Alternative Method	**SOCOTEC Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Limit of Detection (LOD)**	**Calculated MU +/- % Result**	**Calculated MU +/- % ELV**
Total Particulate Matter	SRM - BS EN 13284-1	AE 104	1015	Yes	0.3 mg/m³	8.6%	N/A - No ELV
Hydrogen Chloride	SRM - BS EN 1911	AE 111	1015	Yes	0.01 mg/m³	10.7%	N/A - No ELV
Formaldehyde	US EPA Method 316	AE114	1015	Yes	0.01 mg/m³	10.7%	N/A - No ELV
Ammonia	SRM - BS EN 14791	AE 115	1015	Yes	0.093 mg/m³	71.6%	N/A - No ELV
Oil Mist	MDHS 84	AE 0061	1015	No	0.01 mg/m³	103.6 %	N/A - No ELV
Formic Acid	SRM - PD CEN-TS 13649:2014	AE 118	1015	Yes	0.133 mg/m³	115.9%	N/A - No ELV
Acetic Acid	SRM - PD CEN-TS 13649:2014	AE 118	1015	Yes	0.133 mg/m³	115.9%	N/A - No ELV
VOC Screening	SRM - PD CEN-TS 13649:2014	AE 118	1015	Yes	0.067 mg/m³	11.8%	N/A - No ELV
Total Volatile Organic Compounds	SRM - BS EN 12619:2013	AE 102	1015	Yes	0.64 mg/m³	8.2%	N/A - No ELV
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	Yes	0.39 mg/m³	82.0%	N/A - No ELV
Sulphur Dioxide	AM - PD CEN/TS 17021:2017	AE 102	1015	Yes	0.77 mg/m³	18.5%	N/A - No ELV
Carbon Monoxide	SRM - BS EN 15058:2017	AE 102	1015	Yes	0.26 mg/m³	8.3%	N/A - No ELV
Carbon Dioxide	SRM - ISO 12039	AE 102	1015	Yes	0.003 %	0.6%	N/A - No ELV
Oxygen	AM - BS EN 14789:2017	AE 102	1015	Yes	0.01%	1.7%	N/A - No ELV
Moisture	SRM - BS EN 14790	AE 105	1015	Yes	0.02%	2.96%	N/A - No ELV
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	5 Pa	2.4%	N/A - No ELV
Volumetric Flow Rate	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	-	5.1%	N/A - No ELV

BS EN 14790 has been validated over a range of 4 - 40%. It is however the prefered method of the Environment Agency for concentrations below 4%

EXECUTIVE SUMMARY

Analytical Methods

The following tables list the analytical methods employed together with the custody details. Unless otherwise stated the samples are archived at the analysis lab location.

SAMPLING METHODS WITH SUBSEQUENT ANALYSIS							
Species	**Analytical Technique**	**Analytical Procedure**	**UKAS Lab Number**	**UKAS Accredited Lab Analysis**	**Analysis Lab**	**Analysis Report number**	**Archive Period**
Total Particulate Matter	Gravimetric	AE 106	1015	Yes	SOCOTEC (Stockport)	N/A	8 Weeks
Hydrogen Chloride	Ion Chromatography	C27(U)	0605	Yes	RPS	WK19-10263	8 Weeks
Formaldehyde	Ion Chromatography	M103(U)	0605	Yes	RPS	WK19-10263	8 Weeks
Ammonia	Ion Chromatography	ASC/SOP/108	1252	Yes	SOCOTEC (Bretby)	ASC/41699	8 Weeks
Oil Mist	Gravimetric	IHM	1252	No	SOCOTEC (Bretby)	ASC/41737	8 Weeks
Formic Acid	Ion Chromatography	C28(N)	0605	No	RPS	WK19-10662	8 Weeks
Acetic Acid	Ion Chromatography	C28(N)	0605	No	RPS	WK19-10662	8 Weeks
VOC Screening	GC-MS	IHM	1252	No	SOCOTEC (Bretby)	ASC/41700	8 Weeks

ON-SITE TESTING							
Species	**Analytical Technique**	**Analytical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Analysis**	**Laboratory**	**Data Archive Location**	**Archive Period**
Total Volatile Orangic Compounds	Flame Ionisation Detection	AE 102	1015	Yes	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Oxides of Nitrogen	Chemiluminescence	AE 102	1015	Yes	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Sulphur Dioxide	Non Dispersive Infra Red	AE 102	1015	Yes	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Carbon Monoxide	Non Dispersive Infra Red	AE 102	1015	Yes	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Carbon Dioxide	Non Dispersive Infra Red	AE 102	1015	Yes	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Oxygen	Zirconia Cell	AE 102	1015	Yes	SOCOTEC (Stockport)	SOCOTEC (Stockport)	5 years
Moisture	Gravimetric	AE 105	1015	Yes	SOCOTEC (Stockport)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	**Value**	**Units**	**Requirement**	**Compliant**	**Method**
Lowest Differential Pressure	78	Pa	>= 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	10.6	m/s	-	-	-
Highest Gas Velocity	11.1	m/s	-	-	-
Ratio of Gas Velocities	1.1	: 1	< 3 : 1	Yes	BS EN 15259
Mean Velocity	10.9	m/s	-	-	-
Maximum angle of flow with regard to duct axis	<15	°	< 15°	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259

DUCT CHARACTERISTICS		
	Value	**Units**
Shape	Circular	-
Depth	0.90	m
Width	-	m
Area	0.64	m^2
Port Depth	90	mm

SAMPLING LINES & POINTS		
	Isokinetic	**Non-Iso & Gases**
Sample port size	4 Inch BSP	1 Inch BSP
Number of lines used	1	1
Number of points / line	4	1
Duct orientation	Horizontal	Horizontal
Filtration for TPM	In Stack	-

SAMPLING PLATFORM	
General Platform Information	
Permanent / Temporary Platform / Ground level / Floor Level / Roof	Temporary
Inside / Outside	Inside

M1 Platform requirements	
Is there a sufficient working area so work can be performed in a compliant manner	Yes
Platform has 2 levels of handrails (approximately 0.5 m & 1.0 m high)	Yes
Platform has vertical base boards (approximately 0.25 m high)	Yes
Platform has removable chains / self closing gates at the top of ladders	N/A
Handrail / obstructions do not hamper insertion of sampling equipment	Yes
Depth of Platform = >Stack depth / diameter + wall and port thickness + 1.5m	Yes

Sampling Platform Improvement Recommendations (if applicable)

The sampling location meets all the requirements as specified in EA Guidance Note M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Sampling Points

The upper sample port was not used for the isokinetic tests due to the glassware being used. Therefore the number of sample points was doubled on the available line used.

APPENDICES

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APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

MONITORING SCHEDULE					
Species	**Method** Standard Reference Method / Alternative Method	**SOCOTEC Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Number of Samples**
Total Particulate Matter	SRM - BS EN 13284-1	AE 104	1015	Yes	1
Hydrogen Chloride	SRM - BS EN 1911	AE 111	1015	Yes	1
Formaldehyde	US EPA Method 316	AE114	1015	Yes	1
Ammonia	SRM - BS EN 14791	AE 115	1015	Yes	1
Oil Mist	MDHS 84	AE 0061	1015	No	1
Formic Acid	SRM - PD CEN-TS 13649:2014	AE 118	1015	Yes	1
Acetic Acid	SRM - PD CEN-TS 13649:2014	AE 118	1015	Yes	1
VOC Screening	SRM - PD CEN-TS 13649:2014	AE 118	1015	Yes	1
Total Volatile Organic Compounds	SRM - BS EN 12619:2013	AE 102	1015	Yes	1
Oxides of Nitrogen	SRM - BS EN 14792:2017	AE 102	1015	Yes	1
Sulphur Dioxide	AM - PD CEN/TS 17021:2017	AE 102	1015	Yes	1
Carbon Monoxide	SRM - BS EN 15058:2017	AE 102	1015	Yes	1
Carbon Dioxide	SRM - ISO 12039	AE 102	1015	Yes	1
Oxygen	AM - BS EN 14789:2017	AE 102	1015	Yes	1
Moisture	SRM - BS EN 14790	AE 105	1015	Yes	1
Velocity	SRM - BS EN ISO 16911-1	AE 154	1015	Yes	1

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

CALIBRATEABLE EQUIPMENT CHECKLIST

Extractive Sampling		Instrumental Analyser/s		Miscellaneous	
Equipment	**Equipment I.D.**	**Equipment**	**Equipment I.D.**	**Equipment**	**Equipment I.D.**
Control Box DGM	LNO 13-21	Horiba PG-250 Analyser	LNO 21-12	Laboratory Balance	LNO 00-12 / 00-13
Box Thermocouples	LNO 03-21	FT-IR Gasmet	-	Tape Measure	LNO 24-KB
Meter In Thermocouple	-	FT-IR Oven Box	-	Stopwatch	LNO 17-KB
Meter Out Thermocouple	-	Bernath 3006 FID	-	Protractor	-
Control Box Timer	LNO 17-21	Signal 3030 FID	-	Barometer	LNO 08-KB
Oven Box	LNO 09-12	Servomex	-	Digital Micromanometer	LNO 01-KB
Probe	LNO 11-26	JCT Heated Head Filter	-	Digital Temperature Meter	LNO 03-KB
Probe Thermocouple	LNO 10-26	Thermo FID	LNO 21-03	Stack Thermocouple	LNO 10-KB
Probe	-	Stackmaster	-	Mass Flow Controller	LNO 29-78
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	LNO 29-78
S-Pitot	LNO 06-KB	Anemometer	-	Mass Flow Controller	LNO 29-79
L-Pitot	-	Ecophysics NOx Analyser	-	MFC Display module	LNO 29-79
Site Balance	LNO 14-KB	Chiller (JCT/MAK 10)	LNO 21-39	1m Heated Line (3)	-
Last Impinger Arm	-	Heated Line Controller (1)	LNO 03-133	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	-	10m Heated Line (1)	-
Callipers	LNO 31-KB	Site temperature Logger	LNO 12-KB	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	LNO 03-41		-	20m Heated Line (1)	LNO 18-133
Inclinometer (Swirl Device)	LNO 23-KB		-	20m Heated Line (2)	-

NOTE: If the equipment I.D is represented by a dash (-), then this piece of equipment has not been used for this test.

CALIBRATION GASES

Gas (traceable to ISO 17025)	Cylinder I.D Number	Supplier	ppm	%	Analytical Tolerance +/- %
Propane	HPC 1082	BOC	80	-	2.0
Nitric Oxide	HPC 2077	BOC	84.8	-	2.0
Sulphur Dioxide	HPC 2061	BOC	158	-	2.0
Carbon Monoxide	HPC 2078	BOC	163	-	2.0
Carbon Dioxide	HPC 2092	BOC	-	8.15	2.0

STACK EMISSIONS MONITORING TEAM

MONITORING TEAM								
Personnel	**MCERTS Number**	**MCERTS**		**TE / H&S Qualifications and Expiry Date**				
		Level	**Expiry**	**TE1**	**TE2**	**TE3**	**TE4**	**H&S**
Keith Bird	MM 07 825	MCERTS Level 2	Sep-20	Dec-23	Dec-24	Sep-20	Sep-24	Feb-22
Pete Watson	MM 08 953	MCERTS Level 1	Apr-24	-	-	-	-	Ape-24

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER SUMMARY					
Parameter	**Sampling Times**	**Concentration mg/m³**	**Uncertainty mg/m³**	**ELV mg/m³**	**Emission Rate g/hr**
Run 1	10:38 - 11:10 22 October 2010	7.3	0.63	-	165
Blank	-	0.30	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

Acetone Blank Value mg/l	Acceptable Value mg/l
2.0	10

FILTER INFORMATION

SAMPLES								
Test	Filter & Probe Rinse Number	Filter Start Weight g	Filter End Weight g	Mass Gained on Filter g	Probe Rinse Start Weight g	Probe Rinse End Weight g	Mass Gained on Probe g	Combined Total Mass Gained g
Run 1	Q1090	0.14850	0.15328	0.00478	188.66560	188.66620	0.00060	0.00538

If total mass gained is less than the LOD then the LOD is reported

BLANKS								
Test	Filter & Probe Number	Filter Start Weight g	Filter End Weight g	Mass Gained Filter g	Probe Start Weight g	Probe End Weight g	Mass Gained Probe g	Combined Total Mass Gained g
Run 1	Q1089	0.14286	0.14271	-0.00015	188.65640	188.65630	-0.00010	0.00022

If total mass gained is less than the LOD then the LOD is reported

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 1 — TPM

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	Kpa	100.1
Stack static pressure, P_{static}	pa	-750
$P_s = P_b + P_{static}$	Kpa	99.4
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	22.1
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.0275366
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.771
Gas meter correction factor, Y_d		0.980
Mean dry gas meter temperature, T_m		290
Mean pressure drop across orifice, DH	mmH_2O	65.943
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m}$	m^3	0.708
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.7359
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No
% oxygen measured in gas stream, act%O_2		20.5
% oxygen reference condition		21
O_2 Reference Factor O_2 Ref $= \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0374
	%	3.74
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Velocity pressure coefficient, C_p		0.98
Mean of velocity heads, DP_{avg}	Pa	77.18
Mean stack gas temperature, T_s	K	317
Gas density $_{(wet, ambient)}$, p		
p=(Ms*Ps)/(8.314*Ts)	kg/m^3	1.082
Stack Velocity, Vs $V_s = Cp\sqrt{\frac{\Delta DPavg}{p}}$	m/s	11.71

Molecular weight of dry gas, M_d		
CO_2	%	2.00
O_2	%	20.50
Total	%	22.50
N_2 (100 -Total)	%	77.50
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.14
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.72
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.64
$Q_a = (60)(A_s)(V_s)$	m^3/min	446.9
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	Dry	362.9
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	@O_2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet	377.00
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	6.77
Nozzle area, A_n	mm^2	36.00
Total sampling time, q	min	32
$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	107.8
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00478
Mass collected in probe, M_p	g	0.00060
Total mass collected, M_n	g	0.00538
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	7.311
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	7.595
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		165.37

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER QUALITY ASSURANCE CHECKLIST

LEAK RATE						
Run	Mean Sampling Rate litre/min	Pre-sampling Leak Rate litre/min	Post-sampling Leak Rate litre/min	Maximum Vacuum mm Hg	Acceptable Leak Rate litre/min	Leak Tests Acceptable?
Run 1	23.6	0.20	-	9296.4	0.47	Yes

In BS EN 13284-1:2017 a post sampling leak check is not require.

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	107.8	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.30	No ELV	N/A - No ELV

The above is based on both the Filter and rinse uncertainty

BLANK VALUE				
Run	Overall Blank Value mg/m^3	Daily Emission Limit Value mg/m^3	Acceptable Blank Value mg/m^3	Overall Blank Acceptable mg/m^3
Blank 1	0.30	-	-	-

FILTERS					
Run	Filter Material	Filter Size mm	Max Filtration Temperature °C	Pre-use Filter Conditioning Temperature °C	Post-use Filter Conditioning Temperature °C
Run 1	Quartz Fibre	47	45	180	160

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

HYDROGEN CHLORIDE SUMMARY					
Test	**Sampling Times**	**Concentration mg/m³**	**LOD mg/m³**	**ELV mg/m³**	**Emission Rate g/hr**
Run 1	10:38 - 11:10 22 October 2019	0.76	0.01	-	17
Field Blank	-	0.01	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

HYDROGEN CHLORIDE QUALITY ASSURANCE CHECKLIST

Leak Test Results	Total Sample Volume @ ref Conditions m³	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	0.74	23.6	0.20	0.20	0.47	Yes

	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Temperature during storage / transit <25°C	Type of Absorbers	Absorption Solutions
Run 1	Quartz Fibre	47	160	N/A	Glass	HPLC Water

HYDROGEN CHLORIDE ABSORPTION EFFICIENCY

Parameter	**Total ug**	**IMP C ug**	**Absorption Efficiency %**	**Acceptable Absorption Efficiency %**	**Absorption Efficiency Acceptable ?**
Run 1	562.9	6.3	99	95	Yes

ND - None Detected

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS 1 — Hydrogen Chloride

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	kPa	100.1
Stack static pressure, P_{static}	Pa	-750
$P_s = P_b + (P_{static})$	kPa	99.35
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	-
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m	m^3	0.7710
Gas meter correction factor, Y_d		0.98
Mean dry gas meter temperature, T_m	K	289.50
Mean pressure drop across orifice, DH	mmH_2O	65.94
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m}$	m^3	0.71
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.7359
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No
% oxygen measured in gas stream, act%O_2		20.50
% oxygen reference condition		21
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0374
	%	3.74
Moisture by FTIR	%	-
Molecular weight of dry gas, M_d		
CO_2		2.00
O_2		20.50
Total		22.50
N_2 (100 -Total)		77.50
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.14
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.7

Velocity of stack gas, V_s		
Velocity pressure coefficient, C_p		0.98
Mean of velocity heads, DP_{avg}	Pa	77.18
Mean stack gas temperature, T_s	K	317.25
Gas density $_{(wet, ambient)}$, p		
p=(Ms*Ps)/(8.314*Ts)	kg/m^3	1.082
Stack Velocity, Vs $V_s = Cp\sqrt{\frac{\Delta DPavg}{p}}$	m/s	11.71
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.64
$Q_a = (60)(A_s)(V_s)$	m^3/min	447
Dry total flow of stack gas, Q_{std}		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	m^3/min	363
Wet total flow of stack gas, Q_{stw}		
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	m^3/min	377
Dry total flow of stack gas at X% O_2, Q_{stdO2}		
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	m^3/min	No O2 Ref
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	6.77
Nozzle area, A_n	mm^2	36.00
Total sampling time, q	min	32
$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	108
Acceptable isokinetic range 95% to 115%		Yes
Hydrogen Chloride Concentration, C		
Mass collected , M	ug	563
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	0.765
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	0.795
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	No O2 Ref
Hydrogen Chloride Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$	g/hr	17.30

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

FORMALDEHYDE SUMMARY					
Test	**Sampling Times**	**Concentration mg/m³**	**LOD mg/m³**	**ELV mg/m³**	**Emission Rate g/hr**
Run 1	10:38 - 11:10 22 October 2010	1.9	0.01	-	44
Field Blank	-	0.02	-	-	-

Please note figures in bold italic font are at the limit of detection
Reference conditions are 273K, 101.3kPa without correction for water vapour

FORMALDEHYDE QUALITY ASSURANCE CHECKLIST

Leak Test Results	Total Sample Volume @ ref Conditions m³	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	0.74	23.6	0.20	0.20	0.47	Yes

	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Temperature during storage / transit <25°C	Type of Absorbers	Absorption Solutions
Run 1	Quartz Fibre	47	160	Yes	Glass	HPLC Water

FORMALDEHYDE ABSORPTION EFFICIENCY

Parameter	**Total ug**	**IMP C ug**	**Absorption Efficiency %**	**Acceptable Absorption Efficiency %**	**Absorption Efficiency Acceptable ?**
Run 1	1431	243	83	95	N/A - No ELV

ND - None Detected

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS 1 — Formaldehyde

Absolute pressure of stack gas, P_s			**Velocity of stack gas, V_s**		
Barometric pressure, P_b	kPa	100.1	Velocity pressure coefficient, C_p		0.98
Stack static pressure, P_{static}	Pa	-750	Mean of velocity heads, DP_{avg}	Pa	77.18
$P_s = P_b + (P_{static})$	kPa	99.35	Mean stack gas temperature, T_s	K	317.25
			Gas density $_{(wet, ambient)}$, p		
Vol. of water vapour collected, V_{wstd}			p=(Ms*Ps)/(8.314*Ts)	kg/m^3	1.082
Moisture trap weight increase,Vlc	g	-	Stack Velocity, Vs $V_s = Cp\sqrt{\frac{\Delta DPavg}{p}}$		
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-		m/s	11.70
Volume of gas metered dry, V_{mstd}			**Actual flow of stack gas, Q_a**		
Volume of gas sample through gas meter, V_m	m^3	0.7710	Area of stack, A_s	m^2	0.64
Gas meter correction factor, Y_d		0.98	$Q_a = (60)(A_s)(V_s)$	m^3/min	447
Mean dry gas meter temperature, T_m	K	289.50	**Dry total flow of stack gas, Q_{std}**		
Mean pressure drop across orifice, DH	mmH_2O	65.94	Conversion factor (K/mm.Hg)		0.3592
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m}$	m^3	0.71	$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	m^3/min	363
Volume of gas metered wet, V_{mstw}			**Wet total flow of stack gas, Q_{stw}**		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.7359	$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	m^3/min	377
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$			**Dry total flow of stack gas at X% O_2, Q_{stdO2}**		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No	$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	m^3/min	No O2 Ref
% oxygen measured in gas stream, act%O_2		20.9			
% oxygen reference condition		21	**Percent isokinetic, %I**		
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		No O2 Ref	Nozzle diameter, D_n	mm	6.77
			Nozzle area, A_n	mm^2	36.00
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	No O2 Ref	Total sampling time, q	min	32
Moisture content, B_{wo}			$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	108
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0374			
	%	3.74	Acceptable isokinetic range 95% to 115%		Yes
Moisture by FTIR	%	-	**Hydrogen Chloride Concentration, C**		
Molecular weight of dry gas, M_d			Mass collected , M	ug	1431
CO_2		2.00	$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	1.945
O_2		20.9			
Total		22.90	$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	2.020
N_2 (100 -Total)		77.10	$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	No O2 Ref
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.16			
Molecular weight of wet gas, M_s			**Hydrogen Chloride Emission Rates, E**		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.7	$E = [(C_{wet})(Q_{stw})(60)] / 1000$	g/hr	43.97

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

AMMONIA SUMMARY					
Test	**Sampling Times**	**Concentration mg/m³**	**LOD mg/m³**	**ELV mg/m³**	**Emission Rate g/hr**
Run 1	11:25 - 11:55 22 October 2019	0.42	0.09	-	8.9
Field Blank	-	0.39	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

AMMONIA QUALITY ASSURANCE CHECKLIST

Leak Test Results	Total Sample Volume @ ref Conditions m³	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	0.06	2.0	0.03	0.03	0.04	Yes

	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Temperature during storage / transit <25°C	Type of Absorbers	Absorption Solutions
Run 1	Quartz Fibre	47	150	N/A	Glass	0.1M Sulphuric Acid

AMMONIA ABSORPTION EFFICIENCY

Parameter	**Total ug**	**IMP C ug**	**Absorption Efficiency %**	**Acceptable Absorption Efficiency %**	**Absorption Efficiency Acceptable ?**
Run 1	26.3	6.6	75	95	N/A - No ELV

ND - None Detected

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

OIL MIST SUMMARY					
Test	**Sampling Times**	**Concentration mg/m³**	**LOD mg/m³**	**ELV mg/m³**	**Emission Rate g/hr**
Run 1	10:38 - 11:10 22 October 2019	0.05	0.007	-	1.23
Field Blank	-	0.01	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

OIL MIST QUALITY ASSURANCE CHECKLIST

Leak Test Results	Total Sample Volume @ ref Conditions m³	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	0.7	23.6	0.20	0.20	0.47	Yes

	Filter Material	Filter Size mm	Max. Filtration Temp. °C	Temperature during storage / transit <25°C	Type of Absorbers	Absorption Solutions
Run 1	Quartz Fibre	47	160	#N/A	N/A	#N/A

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS 1 — Oil Mist

Absolute pressure of stack gas, P_s			**Velocity of stack gas, V_s**		
Barometric pressure, P_b	kPa	100.1	Velocity pressure coefficient, C_p		0.98
Stack static pressure, P_{static}	Pa	-750	Mean of velocity heads, DP_{avg}	Pa	77.18
$P_s = P_b + (P_{static})$	kPa	99.35	Mean stack gas temperature, T_s	K	317.25
			Gas density $_{(wet, ambient)}$, p		
Vol. of water vapour collected, V_{wstd}			p=(Ms*Ps)/(8.314*Ts)	kg/m^3	1.082
Moisture trap weight increase,Vlc	g	-	Stack Velocity, Vs $V_s = Cp\sqrt{\frac{\Delta DPavg}{p}}$		
$V_{wstd} = (0.001246)(V_{lc})$	m^3	-		m/s	11.70
Volume of gas metered dry, V_{mstd}			**Actual flow of stack gas, Q_a**		
Volume of gas sample through gas meter, V_m	m^3	0.7710	Area of stack, A_s	m^2	0.64
Gas meter correction factor, Y_d		0.98	$Q_a = (60)(A_s)(V_s)$	m^3/min	447
Mean dry gas meter temperature, T_m	K	289.50	**Dry total flow of stack gas, Q_{std}**		
Mean pressure drop across orifice, DH	mmH_2O	65.94	Conversion factor (K/mm.Hg)		0.3592
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(DH/13.6))(Y_d)}{T_m}$	m^3	0.71	$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	m^3/min	363
Volume of gas metered wet, V_{mstw}			**Wet total flow of stack gas, Q_{stw}**		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.7359	$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s)}$	m^3/min	377
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$			**Dry total flow of stack gas at X% O_2, Q_{stdO2}**		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No	$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	m^3/min	No O2 Ref
% oxygen measured in gas stream, act%O_2		20.9			
% oxygen reference condition		21	**Percent isokinetic, %I**		
O_2 Reference Factor $\frac{O2\ Ref = 21.0 - act\%O2}{21.0 - ref\%O2}$		No O2 Ref	Nozzle diameter, D_n	mm	6.77
			Nozzle area, A_n	mm^2	36.00
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	No O2 Ref	Total sampling time, q	min	32
Moisture content, B_{wo}			$\%I = \frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	%	108
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0374			
	%	3.74	Acceptable isokinetic range 95% to 115%		Yes
Moisture by FTIR	%	-	**Hydrogen Chloride Concentration, C**		
Molecular weight of dry gas, M_d			Mass collected , M	ug	40
CO_2		2.00	$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	0.054
O_2		20.9			
Total		22.90	$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	0.056
N_2 (100 -Total)		77.10			
			$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	No O2 Ref
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.16			
Molecular weight of wet gas, M_s			**Hydrogen Chloride Emission Rates, E**		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.7	$E = [(C_{wet})(Q_{stw})(60)] / 1000$	g/hr	1.23

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

FORMIC ACID SUMMARY					
Test	**Sampling Times**	**Concentration mg/m³**	**LOD mg/m³**	**ELV mg/m³**	**Emission Rate g/hr**
Run 1	11:16 - 11:46 22 October 2019	***0.27***	0.13	-	5.6
Field Blank	-	0.13	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

Please note figures in bold italic font are at the limit of detection

FORMIC ACID QUALITY ASSURANCE CHECKLIST

Leak Test Results	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	0.5	0.002	0.002	0.01	Yes

	Type of tube	Max. Tube Temperature °C	Max. Storage / Transit Temp.
Run 1	Treated Silica	18	Yes

Tube sampling temperature should be < 40°C

FORMIC ACID ADSORPTION EFFICIENCY

Parameter	**Total ug**	**Back ug**	**Adsorption Efficiency %**	**Acceptable Adsorption Efficiency %**	**Adsorption Efficiency Acceptable ?**
Run 1	ND	ND	100	95	Yes

N/A - As Formic Acid does not have an emission limit an adsorption efficiency is not required.

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ACETIC ACID SUMMARY					
Test	**Sampling Times**	**Concentration mg/m³**	**LOD mg/m³**	**ELV mg/m³**	**Emission Rate g/hr**
Run 1	11:50 - 12:20 22 October 2019	***0.27***	0.13	-	5.6
Field Blank	-	0.13	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

Please note figures in bold italic font are at the limit of detection

ACETIC ACID QUALITY ASSURANCE CHECKLIST

Leak Test Results	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	0.5	0.002	0.003	0.01	Yes

	Type of tube	Max. Tube Temperature °C	Temperature during storage / transit <25°C
Run 1	Treated Silica	18	Yes

Tube sampling temperature should be < 40°C

ACETIC ACID ADSORPTION EFFICIENCY

Parameter	**Total ug**	**Back ug**	**Adsorption Efficiency %**	**Acceptable Adsorption Efficiency %**	**Adsorption Efficiency Acceptable ?**
Run 1	ND	ND	100	95	Yes

N/A - As Acetic Acid does not have an emission limit an adsorption efficiency is not required.

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

VOC SCREENING SUMMARY					
Test	Sampling Times	Concentration mg/m³	LOD mg/m³	ELV mg/m³	Emission Rate g/hr
Run 1	10:37 - 11:07 22 October 2019	2.2	0.07	-	46
Field Blank	-	0.07	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

VOC SCREENING RESULTS							
Substance	LOD (ng)	Run 1 (ng)		Run 1 (mg/m^3)			Mass Emission (g/hr)
		Front	Back	Front	Back	Total	
2-methyl-Pentane	20	1900	20	0.63	0.01	0.64	13
3-methyl-Hexane	20	1600	20	0.53	0.01	0.54	11
3-methyl-Pentane	20	910	20	0.30	0.01	0.31	6.5
2,3-dimethyl-Pentane	20	610	20	0.20	0.01	0.21	4.4
Toluene	20	430	20	0.14	0.01	0.15	3.2
2,2-dimethyl-Butane	20	240	20	0.08	0.01	0.09	1.8
Tetrachloroethylene	20	240	20	0.08	0.01	0.09	1.8
Acetone	20	220	20	0.07	0.01	0.08	1.7
Acetic acid	20	90	20	0.03	0.01	0.04	0.8
1,4-Dioxane	20	60	20	0.02	0.01	0.03	0.6
Total	**200.00**	**6300.00**	**200.00**	**2.10**	**0.07**	**2.17**	**46**

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

VOC SCREENING RESULTS BLANK			
Substance	LOD (ng)	Blank (ng)	
		(ng)	mg/m^3
2-methyl-Pentane	20	20	0.007
3-methyl-Hexane	20	20	0.007
3-methyl-Pentane	20	20	0.007
2,3-dimethyl-Pentane	20	20	0.007
Toluene	20	20	0.007
2,2-dimethyl-Butane	20	20	0.007
Tetrachloroethylene	20	20	0.007
Acetone	20	20	0.007
Acetic acid	20	20	0.007
1,4-Dioxane	20	20	0.007
Total	**200**	**200**	**0.07**

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

VOC SCREENING QUALITY ASSURANCE

Leak Test Results	Mean Sampling Rate l/min	Pre sampling leak rate l/min	Post sampling leak rate l/min	Acceptable leak rate l/min	Leak Tests Acceptable?
Run 1	0.1	0.001	0.001	0.002	Yes

	Type of tube	Max. Tube Temperature °C	Temperature during storage / transit <25°C
Run 1	ATD	18	Yes

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL VOLATILE ORGANIC COMPOUNDS SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	ELV mg/m³	Emission Rate g/hr
Run 1	10:20 - 12:20 22 October 2019	16	0.40	-	336

Reference conditions are 273K, 101.3kPa without correction for water vapour

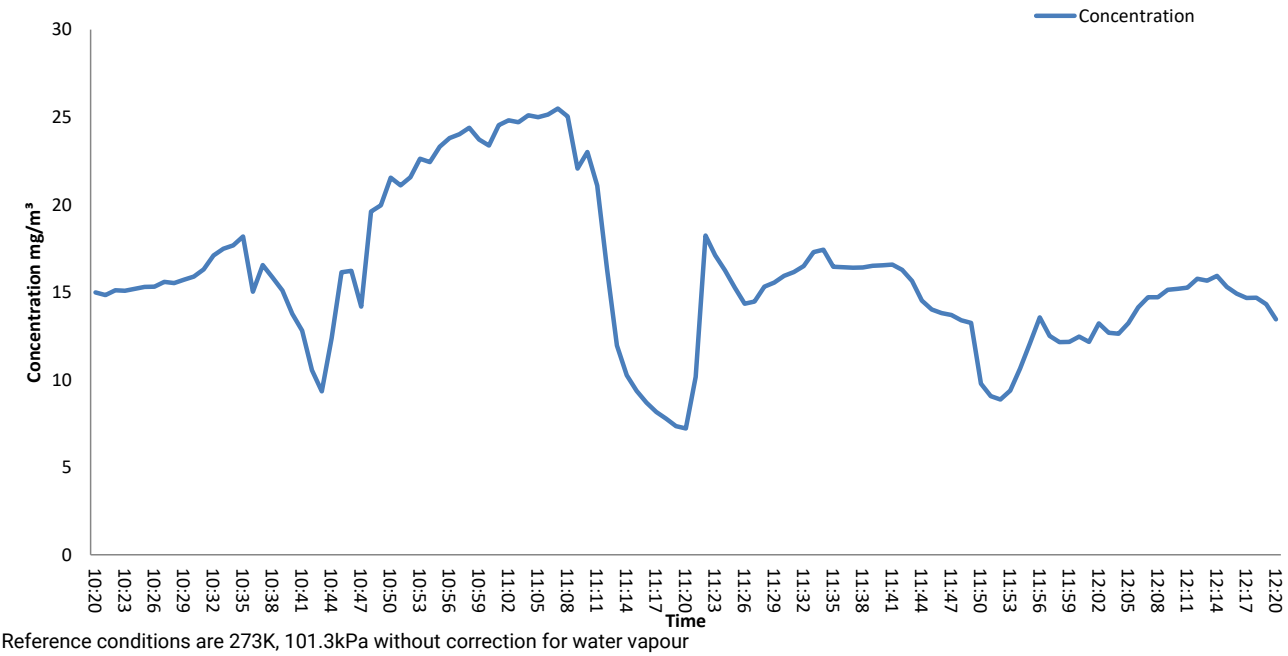
INSTRUMENTAL SPAN & ZERO CHECKS

PRE-SAMPLING CALIBRATION CHECKS								
Date	22 October 2019							
Start Time	09:55							
End Time	10:05							
Gas	Gas Conc (ppm)	Range	Instrument Zero Reading	Instrument Span Reading	Instrument Zero Reading	Zero Down line reading	Span down line reading	Leak Rate (%)
Propane	80.0	100	0.00	80.0	0.10	0.10	79.6	0.50

Zero and Span gas contained 10% Oxygen

POST-SAMPLING CALIBRATION CHECKS								
Date	22 October 2019							
Start Time	14:40							
End Time	14:45							
Gas	Mean Raw Value ppm	Zero down line reading	Span down line reading	Zero Drift (%)	Span Drift (%)	Corrected for Zero Drift	Corrected for Span Drift	Corrected Values ppm / %
Propane	9.91	0.20	80.0	0.00	0.12	×	×	N/A - not corrected

TOTAL VOLATILE ORGANIC COMPOUNDS EMISSIONS CHART



Reference conditions are 273K, 101.3kPa without correction for water vapour

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

COMBUSTION GASES SUMMARY

Test	Sampling Time and Date	Concentration mg/m³	LOD mg/m³	ELV mg/m³	Emission Rate g/hr
Oxides of Nitrogen	10:20 - 12:20 22 October 2019	4.0	0.39	-	85
Sulphur Dioxide	10:20 - 12:20 22 October 2019	9.6	0.77	-	203
Carbon Monoxide	10:20 - 12:20 22 October 2019	37	0.26	-	775

Test	Sampling Time and Date	Concentration %	LOD %
Carbon Dioxide	10:20 - 12:20 22 October 2019	0.58	0.003
Oxygen	10:20 - 12:20 22 October 2019	20.4	0.01

Reference conditions are 273K, 101.3kPa without correction for water vapour

PRE-SAMPLING CALIBRATION DATA

Date	22 October 2019
Start Time	10:05
End Time	10:20

Chiller Temperature (°C)	2.3
Requirement	< 4°C
Compliant	Yes

Gas	Range (ppm / %)	Zero Reading at analyser	Span Reading at analyser	Zero Check at analyser	Zero Check down line	Span Check down line	Response Time (Secs)	Leak Rate %
Nitric Oxide	200	0.00	84.8	0.10	0.20	83.6	60	1.42
Sulphur Dioxide	200	0.00	158.0	0.10	0.10	156.0	70	1.27
Carbon Monoxide	200	0.00	163.0	0.20	0.30	162.0	40	0.61
Carbon Dioxide	25	0.00	8.15	0.06	0.10	8.12	40	0.37
Oxygen	25	0.00	20.90	0.04	0.12	20.93	40	-0.14

POST-SAMPLING CALIBRATION DATA

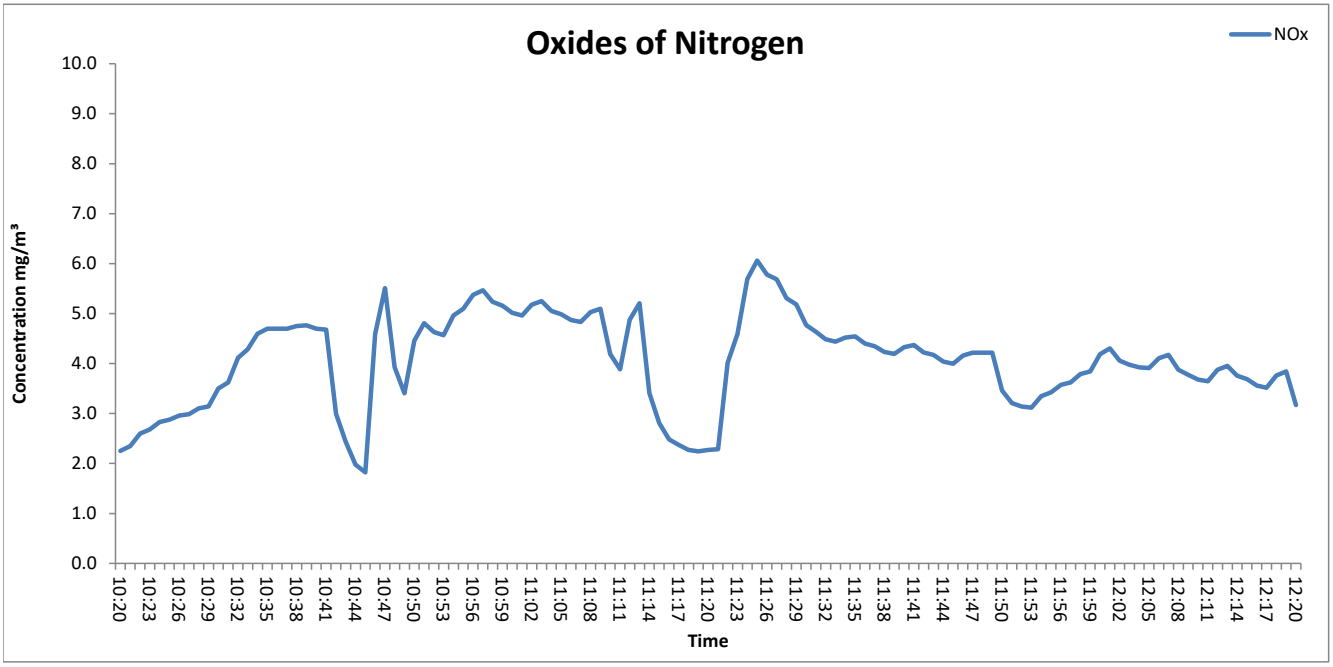
Date	22 October 2019
Start Time	14:35
End Time	14:45

Chiller Temperature (°C)	2.6
Requirement	< 4°C
Compliant	Yes

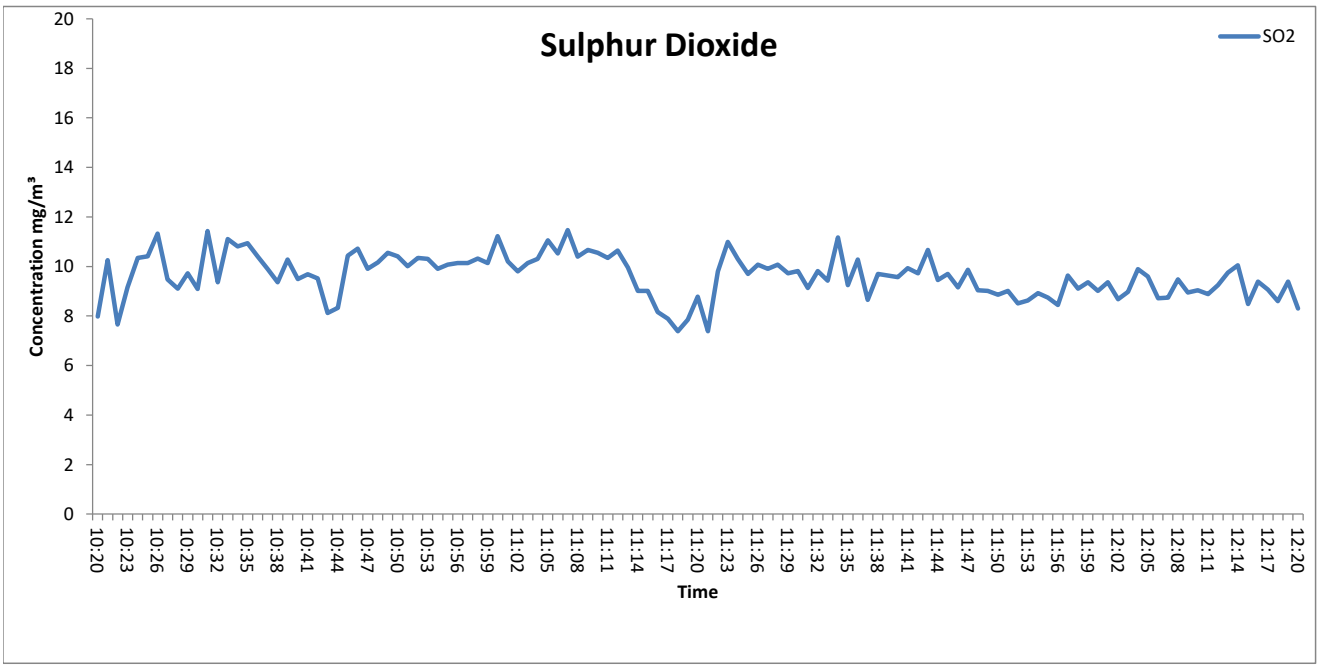
Gas	Zero Check at Analyser	Span Check at Analyser	Zero Drift (%)	Span Drift (%)	Corrected for Zero Drift	Corrected for Span Drift	Corrected Values ppm / %
Nitric Oxide	0.10	83.4	0.00	-1.65	×	×	N/A - not corrected
Sulphur Dioxide	0.10	157.9	0.00	-0.06	×	×	N/A - not corrected
Carbon Monoxide	0.20	162.3	0.00	-0.43	×	×	N/A - not corrected
Carbon Dioxide	0.06	8.11	0.00	-0.49	×	×	N/A - not corrected
Oxygen	0.08	20.93	0.19	-0.05	×	×	N/A - not corrected

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

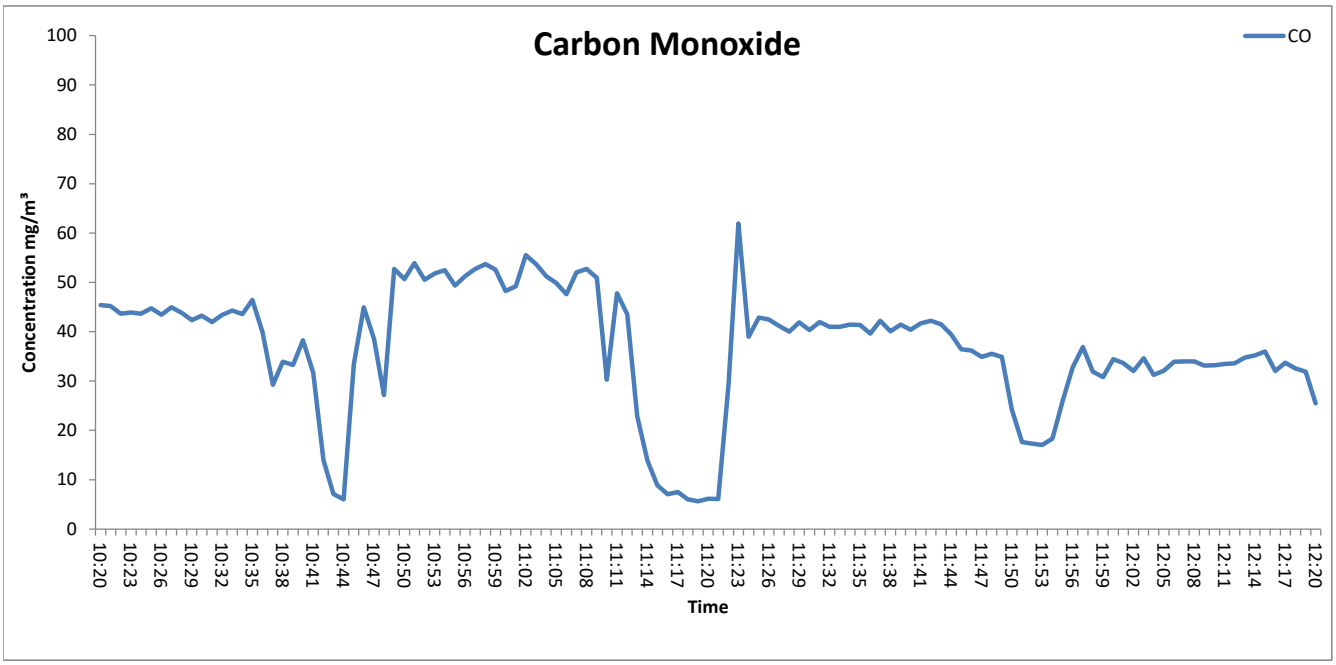
OXIDES OF NITROGEN (as NO_2) EMISSIONS CHART



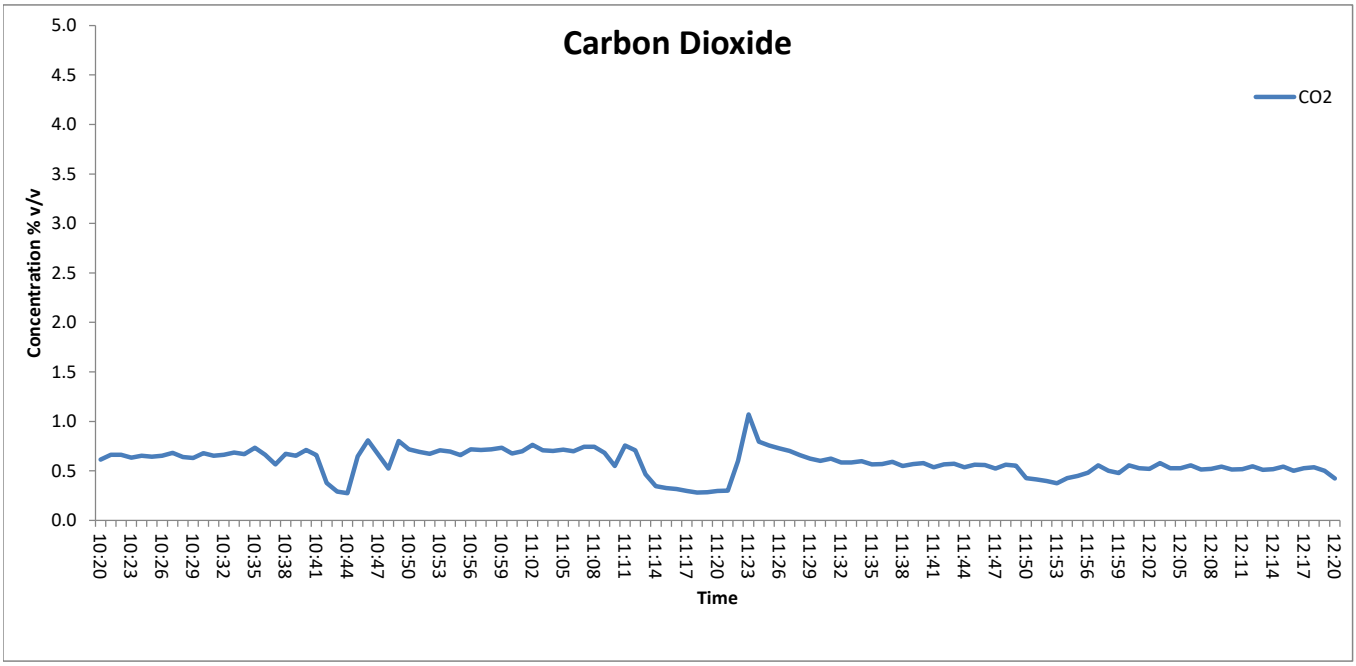
SULPHUR DIOXIDE EMISSIONS CHART



CARBON MONOXIDE EMISSIONS CHART

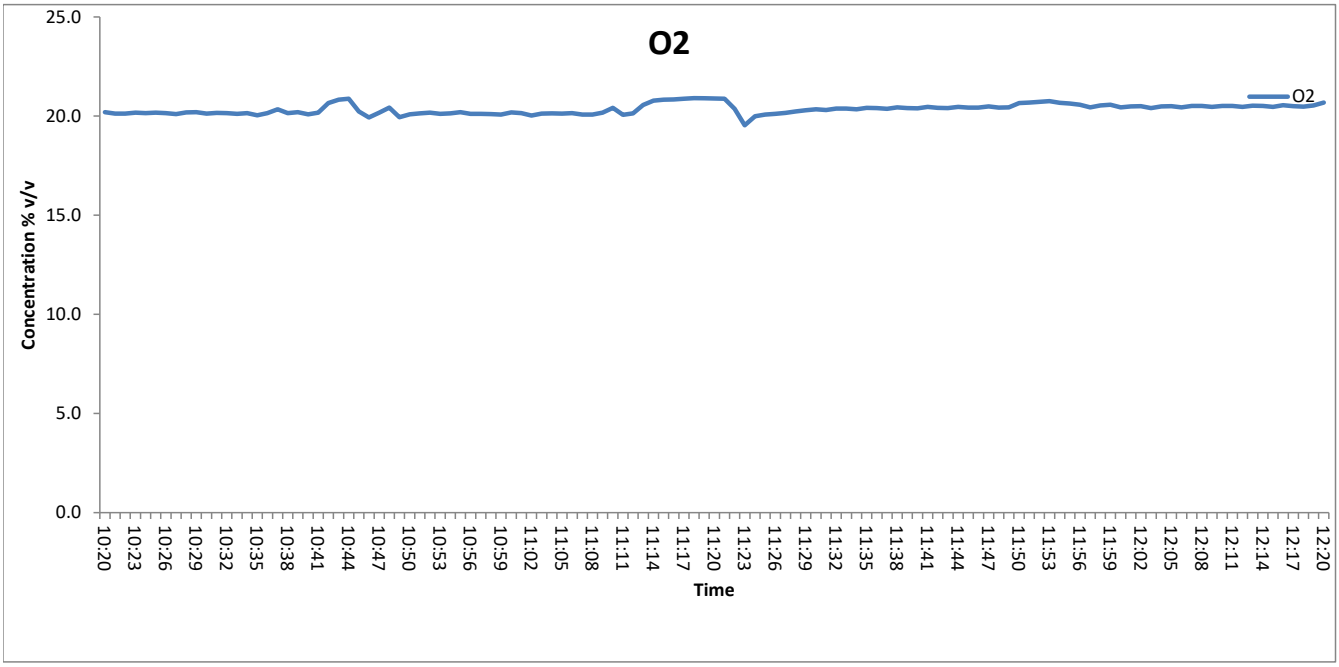


CARBON DIOXIDE EMISSIONS CHART



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

OXYGEN EMISSIONS CHART



APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MOISTURE CALCULATIONS

Moisture Determination - Isokinetic							
Test Number	Sampling Time and Date	Start Weight kg	End Weight kg	Total gain kg	Concentration %	LOD %	Uncertainty %
Run 1	10:38 - 11:10 22 October 2010	3.2323	3.2544	0.0221	3.7	0.02	3.0

Moisture Quality Assurance							
Test Number	Sampling Duration mins	Total Volume Sampled l	Sampling Rate l/min	Start Leak Rate l/min	End Leak Rate l/min	Acceptable Leak Rate l/min	Leak Tests Acceptable?
Run 1	32	736	23.6	0.20	-	0.47	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.90	m
Stack Width, W	-	m
Stack Area, A	0.64	m^2
Average stack gas temperature	43	^oC
Stack static pressure	-0.75	kPa
Barometric Pressure	100.1	kPa

Stack Gas Composition & Molecular Weights								
Component	Molar Mass M	Density kg/m^3 p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m^3 pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m^3 pi
CO_2	44	1.963059	0.580000	0.005800	0.011386	0.558297	0.005583	0.010960
O_2	32	1.427679	20.351756	0.203518	0.290558	19.590228	0.195902	0.279686
N_2	28	1.249219	79.068244	0.790682	0.987736	76.109644	0.761096	0.950776
H_2O	18	0.803070	-	-	-	3.741831	0.037418	0.030050

Where: p = M / 22.41 p*i* = r x p

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2897	kg/m^3
Wet Density (STP), P_{STW}	1.2715	kg/m^3
Dry Density (Actual), P_{Actual}	1.0927	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	1.077	kg/m^3

Where:

P_{STD} = sum of component concentrations, kg/m^3 (not including water vapour)

$P_{STW} = (P_{STD} + pi \text{ of } H_2O) / (1 + (pi \text{ of } H_2O / 0.8036))$

$P_{Actual} = P_{STD} \times (Ts / Ps) \times (Pa / Ta)$

$P_{ActualW} = P_{STW} \times (Ts / Ps) \times (Pa / Ta)$

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	22 October 2019
Time of Survey	09:40
Velocity Measurement Device:	S-Type Pitot

Sampling Line A								
Traverse Point	Distance into duct (m)	DP pt Pa (average of 3 readings)	DP pt mmH_2O (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
1	0.06	81.3	8.3	43	10.6	6.7	-	<15
2	0.23	90.5	9.2	43	11.1	7.1	-	<15
3	0.68	89.8	9.2	43	11.1	7.1	-	<15
4	0.84	82.6	8.4	43	10.7	6.8	-	<15
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	86.1	8.8	43	10.9	6.9	-	-

Sampling Line B								
Traverse Point	Distance into duct (m)	DP pt Pa (average of 3 readings)	DP pt mmH_2O (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m^3/s	O_2 % Vol	Angle of Swirl °
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-

PRELIMINARY STACK SURVEY QUALITY ASSURANCE CHECKLIST

PITOT LEAK CHECK								
Run	Pre Traverse Leak Rate				Post Traverse Leak Rate			
	Start Value mmH2O	End Value mmH2O	Difference %	Outcome	Start Value mmH2O	End Value mmH2O	Difference %	Outcome
Run 1	116	113	2.6	Pass	124	119	4.0	Pass

To complete a compliant pitot leak check a pressure of over 80 mmH_2O (or 800 Pa) is applied and the pressure drop monitored over 5 mins. A drop of less than 5% must be observed.

S-Type Pitot Stagnation Check				
Run	Stagnation (Pa)	Reference (Pa)	Difference (Pa)	Outcome (Permitted +/- 10 Pa)
Run 1	-750	-750	0.0	Pass

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY (CONTINUED)

Sampling Plane Validation Criteria				
EA Technical Guidance Note (Monitoring) M1	Result	Units	Requirement	Compliant
Lowest Differential Pressure	81	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	10.6	m/s	-	-
Highest Gas Velocity	11.1	m/s	-	-
Ratio of Gas Velocities	1.1	-	< 3 : 1	Yes
Maximum angle of flow with regard to duct axis	<15	°	< 15°	Yes
No local negative flow	Yes	-	-	Yes

Calculation of Stack Gas Velocity, V		
Velocity at Traverse Point, V = K_{pt} x (1-e) * Ö(2 * DP_{pt} / $P_{ActualW}$)		
Where:		
K_{pt} = Pitot tube calibration coefficient		
(1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, Va	**10.9**	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	43	0	°C
Total Pressure	99.35	101.3	kPa
Oxygen	20.5	21	%
Moisture	3.74	3.74	%
Pitot tube calibration coefficient, K_{pt}	0.86		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	10.87	m/s
Stack Area (A)	0.64	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	24890	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	21089	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	20300	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	21089	m^3/hr

Where:
Q_{Actual} = Va x A x 3600
Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600
$Q_{STP,Dry}$ = Q (STP) / (100 - (100 / Ma)) x 3600
Q_{Ref} = Q (STP) x ((100 - Ma) / (100 - Ms)) x ((21 - O_2a) / (21 - O_2s))

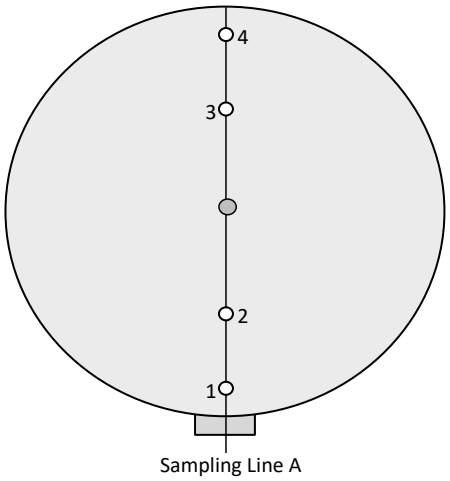
Nomenclature:
Ts = Absolute Temperature, Standard Conditions, 273 K
Ps = Absolute Pressure, Standard Conditions, 101.3 kPa
Ta = Absolute Temperature, Actual Conditions, K
Pa = Absolute Pressure, Actual Conditions, kPa
Ma = Water vapour, Actual Conditions, % Vol
Ms = Water vapour, Reference Conditions, % Vol
O_2a = Oxygen, Actual Conditions, % Vol
O_2s = Oxygen, Reference Conditions, % Vol

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK DIAGRAM

	Value	Units
Stack Depth	0.90	m
Stack Width	-	m
Area	0.64	m^2

Non-Isokinetic/Gases Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	50	0.45	m



Isokinetic sampling point
Isokinetic sampling points not used
Non Isokinetic/Gases sampling point

Isokinetic Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	6.7	0.06	< 15
2	25.0	0.23	< 15
3	75.0	0.68	< 15
4	93.3	0.84	< 15
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

SAMPLING LOCATION

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak	Uncollected Mass
	m^3	K	kPa	% by volume	% by volume	% by mass	%	mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.001	2.0	0.50	1.0	N/A	0.22	-	-
as a %	0.14	0.63	0.50	1.0	N/A	N/A	0.85	N/A
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**	**N/A**

Run	Volume (STP)	Mass of particulate	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.60	5.4	1.0	0.04	0.0001	-
MU as mg/m^3	0.09	0.30	-	0.04	0.0002	**0.32**
MU as %	1.3	4.1	-	0.49	0.0024	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.63**	**mg/m^3**	**8.6**	**% Result**	**N/A**	**% ELV**

(k is a coverage factor which gives a 95% confidence in the quoted figures)

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - ISOKINETIC HYDROGEN CHLORIDE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak
	m³	K	kPa	% by volume	% by volume	% by mass	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.74	289.5	93	1.0	-	0.81	-
as a %	0.14	0.69	0.54	1.0	-	-	0.85
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**

Run	Volume (STP)	Mass of Hydrogen Chloride	O2 Correction	Leak	Lab Uncertainty	Combined uncertainty
	m³	mg	-	mg/m³	mg	
Run 1	0.63	0.81	-	0.004	-	-
MU as mg/m^3	0.010	0.01	-	0.004	0.04	**0.04**
MU as %	1.3	1.9	-	0.49	4.8	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.08**	**mg/m³**	**10.75**	**% Result**	**-**	**% ELV**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - ISOKINETIC FORMALDEHYDE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak
	m^3	K	kPa	% by volume	% by volume	% by mass	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.74	290	92.6	1.0	-	2.5	-
as a %	0.14	0.69	0.54	1.0	-	-	0.85
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**

Run	Volume (STP)	Mass of Formaldehyde	O2 Correction	Leak	Lab Uncertainty	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.63	2.5	-	0.010	-	-
MU as mg/m^3	0.03	0.02	-	0.010	0.10	**0.10**
MU as %	1.3	1.3	-	0.49	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.21**	**mg/m^3**	**10.7**	**% Result**	**-**	**% ELV**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - NON-ISOKINETIC AMMONIA

Run	Sampled Volume m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.00004	2.0	0.50	1.0	0.10	0.02	-
as a %	0.06	0.69	0.50	1.0	-	N/A	1.4
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**

Run	Volume (STP) m³	Mass of Ammonia mg	O2 Correction -	Leak mg/m³	Lab Uncertainty mg	Combined uncertainty
Run 1	0.06	0.05	-	0.003	-	-
MU as mg/m^3	0.006	0.15	-	0.003	0.02	**0.15**
MU as %	1.3	35	-	0.81	5.8	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.30**	**mg/m³**	**71.60**	**% Result**	**-**	**% ELV**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - ISOKINETIC OIL MIST

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak
	m^3	K	kPa	% by volume	% by volume	% by mass	%
MU required	**<=2%**	**<2.5 k**	**<=1%**	**<=1%**	**<=5%**	**≤ 5% of ELV**	**<=2%**
Run 1	0.74	289.5	92.6	1.0	-	0.08	-
as a %	0.14	0.69	0.54	1.0	-	-	0.85
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**

Run	Volume (STP)	Mass of Oil Mist	O2 Correction	Leak	Lab Uncertainty	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.63	0.0800	-	0.0003	-	-
MU as mg/m^3	0.0007	0.0280	-	0.0003	0.003	**0.03**
MU as %	1.3	52	-	0.49	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.06**	**mg/m^3**	**103.60**	**% Result**	**-**	**% ELV**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - FORMIC ACID

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak	Uncollected Mass
	m^3	K	kPa	% by volume	% by volume	% by mass	%	mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.00001	2.0	0.50	1.0	N/A	0.002	-	-
as a %	0.07	0.69	0.50	1.0	N/A	N/A	0.40	N/A
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**	**N/A**

Run	Volume (STP)	Mass of Formic Acid	O2 Correction	Leak	Uncollected Mass	Lab Uncertainty	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	mg	
Run 1	0.01	0.004	1.0	0.001	0.001	-	-
MU as mg/m^3	0.00001	0.13	-	0.001	0.08	0.013	**0.15**
MU as %	0.004	50	-	0.23	29	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.309**	**mg/m^3**	**115.90**	**% Result**	**N/A**	**% ELV**

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - ACETIC ACID

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak	Uncollected Mass
	m³	K	kPa	% by volume	% by volume	% by mass	%	mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.00001	2.00	0.50	1.00	N/A	0.002	-	-
as a %	0.07	0.68	0.50	1.0	N/A	N/A	0.60	N/A
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**	**N/A**

Run	Volume (STP)	Mass of Acetic Acid	O2 Correction	Leak	Uncollected Mass	Lab Uncertainty	Combined uncertainty
	m³	mg	-	mg/m³	mg	mg	
Run 1	0.014	0.004	1.0	0.001	0.001	-	-
MU as mg/m^3	0.00001	0.13	-	0.001	0.08	0.01	**0.15**
MU as %	0.004	50	-	0.35	29	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.309**	**mg/m³**	**115.90**	**% Result**	**N/A**	**% ELV**

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VOC SCREENING

Standard Uncertainty

Run	Sampled Volume m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %	Uncollected Mass mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.0006	2.00	0.50	1.0	N/A	0.0002	-	-
as a %	2.0	0.69	0.50	1.0	N/A	N/A	1.0	-
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**N/A**	**Yes**	**N/A**

Run	Volume (STP) m³	Mass of Total VOC mg	O2 Correction -	Leak mg/m³	Uncollected Mass mg	Lab Uncertainty mg	Combined uncertainty
Run 1	0.003	0.01	1.000	0.013	0.00001	-	-
MU as mg/m^3	0.000001	0.07	-	0.013	0.004	0.11	**0.13**
MU as %	0.000036	3.1	-	0.577	0.178	5.0	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.256**	**mg/m³**	**11.80**	**% Result**	**N/A**	**% ELV**

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - MOISTURE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Leak
	m³	K	kPa	% by volume	% by volume	%
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**
Run 1	0.001	2.0	0.50	1.0	N/A	-
as a %	0.14	0.63	0.50	1.0	N/A	0.85
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP)	Mass Gained	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m³	mg	-	mg/m³	mg	
Run 1	0.60	22100	1.0	152.57	58	-
MU as % v/v	0.05	0.02	-	0.02	0.010	**0.06**
MU as %	1.29	0.45	-	0.49	0.26	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.12**	**% v/v**	**2.96**	**%**

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VOLATILE ORGANIC COMPOUNDS RUN 1

Measured Concentration	15.9	mg/m^3
Limit	-	mg/m^3
Calibration Gas Concentration	128	mg/m^3
Range	160	mg/m^3

Performance characteristics	Value	Units	specification	MU Met?
Response time	40	seconds	<180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.70	% of value	<2 % range	Yes
Zero drift	0.00	% full scale	<2% range / 24hr	Yes
Span drift	0.12	% full scale	<2% range / 24hr	Yes
volume or pressure flow dependence	0.02	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.80	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	0.01	% full scale/10K	<3% range / 10 K	Yes
dependence on voltage	0.10	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	0.50	% of value	< 2% of span gas value	Yes
Uncertainty of calibration gas	1.0	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	0.01
Standard deviation of repeatability at span level	urs	0.01
Lack of fit	ufit	0.65
Drift	u0dr	0.01
volume or pressure flow dependence	uspres	0.00
atmopsheric pressure dependence	uapres	0.04
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	0.14
losses in the line (leak)	uleak	0.05
Uncertainty of calibration gas	ucalib	0.09
Uncertainty in factor	uf	0.00

Measurement uncertainty Measured Concentration	15.93	mg/m^3
Combined uncertainty	0.67	mg/m^3
Expanded uncertainty	1.31	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**-**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**1.31**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**8.25**	**% value**

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXIDES OF NITROGEN

Limit value	-	mg/m^3
Concentration @ Ref conditions	4.0	mg/m^3
Cal gas conc	174	mg/m^3
Analyser Full Scale	410	mg/m^3

	Value	Units	specification	MU Met?
Response time	60	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.11	% full scale	<1 % range	Yes
Repeatability at span level	0.1	% full scale	<2 % range	Yes
Deviation from linearity	-0.40	% of value	<2 % range	Yes
Zero drift	0.00	% full scale	<2% range / 24hr	Yes
Span drift	-1.65	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.2	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.20	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	0.20	% full scale/10K	<3% range / 10 K	Yes
Combined interference	2.40	% range	<4% of Range	Yes
dependence on voltage	0.00	% full scale/10V	< 0.1%vol /10 volt	Yes
Influence of Vibration	N/A	% of upper limit of Cal range	<2%	-
losses in the line (leak)	0.00	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.004
lack of fit	U_{lof}	-0.231
short term zero drift	$U_{d,z}$	0.000
short term span drift	$U_{d,s}$	-0.953
influence of Ambient Temp at Zero	$U_{t,z}$	0.060
influence of Ambient Temp at Span	$U_{t,s}$	1.080
influence of sample gas pressure	U_p	0.000
influence of sample gas flow	U_{fit}	0.139
influence of supply voltage	U_v	0.004
Combined Interfence	U_i	0.004
Uncertainty of Cal gas	U_{adj}	0.848

Measurement uncertainty (Concentration Measured)	4.05	mg/m^3
Combined uncertainty	1.69	mg/m^3
Expanded at a 95% confidence interval	3.32	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**-**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**3.3**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**82.0**	**% value**

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - SULPHUR DIOXIDE

Limit value	-	mg/m^3
Concentration @ Ref conditions	9.6	mg/m^3
Cal gas conc	448.72	mg/m^3
Analyser Full Scale	572	mg/m^3

Performance characteristics	Value	Units	specification	MU Met?
Response time	70	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.70	% of value	<2 % range	Yes
Zero drift	0.00	% full scale	<2% range / 24hr	Yes
Span drift	-0.06	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.6	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.00	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	0.2	% full scale/10K	<3% range / 10 K	Yes
Cross-sensitivity	0.00	% range	<4% of Range	Yes
dependence on voltage	0.22	% full scale/10V	< 0.1%vol /10 volt	Yes
Influence of vibration	N/A	% of upper limit of Cal range	<2%	-

Uncertainty of calibration gas	% of value	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.008
lack of fit	U_{lof}	0.404
short term zero drift	$U_{d,z}$	0.144
short term span drift	$U_{d,s}$	0.087
influence of Ambient Temp at Zero	$U_{t,z}$	-0.019
influence of Ambient Temp at Span	$U_{t,s}$	0.060
influence of sample gas pressure	U_p	0.000
influence of sample gas flow	U_{fit}	0.416
influence of supply voltage	U_v	0.721
Combined Interfence	U_i	0.000
Uncertainty of Cal gas	U_{adj}	0.050

Measurement uncertainty (Concentration Measured)	10.0	mg/m^3
Combined uncertainty	0.9	mg/m^3
Expanded uncertainty	1.8	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**-**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**1.8**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**18.5**	**% value**

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - CARBON MONOXIDE

Limit value	-	mg/m^3
Concentration @ Ref conditions	36.8	mg/m^3
Cal gas conc	203.8	mg/m^3
Analyser Full Scale	250	mg/m^3

Performance characteristics	Value	Units	specification	MU Met?
Response time	40	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.1	% full scale	<1 % range	Yes
Repeatability at span level	0.2	% full scale	<2 % range	Yes
Deviation from linearity	0.61	% of value	<2 % range	Yes
Zero drift	0.00	% full scale	<2% range / 24hr	Yes
Span drift	-0.43	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.2	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.44	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence zero / span	1	% full scale/10K	<3% range / 10 K	Yes
Combined interference	0.03	% of Range	<4% of Range	Yes
dependence on voltage	-0.06	% full scale/10V	< 0.1%vol /10 volt	Yes
Influence of Vibration	N/A	% of upper limit of Cal range	<2%	N/A
losses in the line (leak)	0.01	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1.00	% of value	< 2% of value	Yes

N/A - Horiba's are not effected by Vibration

Performance characteristic	Uncertainty	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.003
lack of fit	U_{lof}	0.12
short term zero drift	$U_{d,z}$	0.35
short term span drift	$U_{d,s}$	0.00
influence of Ambient Temp zero	$U_{t,z}$	0.06
influence of Ambient Temp span	$U_{t,s}$	0.11
influence of sample gas pressure	U_p	0.00
influence of sample gas flow	U_{fit}	0.14
influence of supply voltage	U_v	-0.09
Combined Interfence	U_i	1.34
Uncertainty of Cal gas	U_{adj}	0.82

Measurement uncertainty (Concentration Measured)	38.2	mg/m^3
Combined uncertainty	1.6	mg/m^3
Expanded uncertainty	3.2	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**-**	**% ELV**
Expanded uncertainty expressed with a level of confidence of 95%	**3.2**	**mg/m^3**
Expanded uncertainty expressed with a level of confidence of 95%	**8.3**	**% value**

Developed for the STA by R Robinson, NPL

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - CARBON DIOXIDE

Limit value	-
Measured concentration	0.58
Calibration gas	8.15
Analyser Full Scale	25

Performance characteristics	Value	Units	specification	MU Met?
Response time	40	seconds	< 200 s	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.015	% by volume	<0.2 % range	Yes
Repeatability at span level	0.014	% by volume	<0.4 % range	Yes
Deviation from linearity	0.13	% vol	<0.3 % volume	Yes
Zero drift (during measurement period)	0	% vol at zero level	<2% of volume / 24hr	Yes
Span drift (during measurement period)	-0.04	% vol at span level	<2% volume/24hr	Yes
volume or pressure flow dependence	0.02	% of fs / 10l/h	<1% range	Yes
atmospheric pressure dependence	0.8	% of fs/kPa	< 1.5 % range	Yes
ambient temperature dependence	0.01	% by volume /10K	<0.3% volume 10 K	Yes
Combined interference	0.56	% range	<2% range	Yes
Dependence on voltage	0.1	% by volume /10V	< 0.1%vol /10 volt	Yes
Losses in the line (leak)	0.36809816	% of value	< 2% of value	Yes
Uncertainty of calibration gas	1	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	-
Standard deviation of repeatability at span level	urs	0.00128
Lack of fit	ufit	0.07506
Drift	u0dr	-0.00166
volume or pressure flow dependence	uspres	0.00003
atmospheric pressure dependence	uapres	0.01222
ambient temperature dependence	utemp	0.00050
Combined interference (from mcerts)	-	0.08083
dependence on voltage	uvolt	0.08622
losses in the line (leak)	uleak	0.00124
Uncertainty of calibration gas	ucalib	0.00338

Measurement uncertainty	0.58	%vol
Combined uncertainty	0.14	%vol
Expanded uncertainty	0.00	%

Expanded uncertainty expressed with a level of confidence of 95%	**0.55**	**% of value**

Expanded uncertainty expressed with a level of confidence of 95%	**94.25**	**% vol**

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXYGEN

Reference	N/A	%vol
Reported Concentration	20.35	%vol
Calibration gas	20.9	%vol
Analyser Full Scale	25	%vol

	Value	Units	specification	MU Met?
Response time	40	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	120	minutes	-	-
Number of readings in measurement	120	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.13	% of value	<2 % range	Yes
Zero drift	0.19	% full scale	<2% range / 24hr	Yes
Span drift	-0.05	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.03	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.05	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	-0.08	% full scale/10K	<3% range / 10 K	Yes
Combined interference	0.14	% range	<4% of Range	Yes
dependence on voltage	0.00	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	0.14	% of value	< 2% of value	Yes
Uncertainty of calibration gas	0.1	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
repeatability	$U_r = S_r$	0.0083
lack of fit	U_{lof}	0.0751
short term zero drift	$U_{d,z}$	0.1105
short term span drift	$U_{d,s}$	-0.0276
influence of Ambient Temp at Zero	$U_{t,z}$	-0.0009
influence of Ambient Temp at Span	$U_{t,s}$	0.0000
influence of sample gas pressure	U_p	0.0000
influence of sample gas flow	U_{fit}	0.0173
influence of supply voltage	U_v	0.0001
Combined Interfence	U_i	0.0485
Uncertainty of Cal gas	U_{adj}	0.1045

Measurement uncertainty (Concentration Measured)	20.35	%
Combined uncertainty	0.18	%
Expanded uncertainty	0.35	%

Expanded uncertainty expressed with a level of confidence of 95%	**0.4**	**%**
Expanded uncertainty expressed with a level of confidence of 95%	**1.73**	**% vol**

Developed for the STA by R Robinson, NPL

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	10.9	m/s
Measured Volumetric Flow rate at Actual Conditions	24890	m³/hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination				
Uncertainty of pitot tube coefficient	-	0.010		
Uncertainty of mean local dynamic pressures	-	0.80		
Factor loading, function of the number of measurements.	3 readings	0.591	minimum 3	Yes
Range of measurment device	pa	1000		
Resolution	pa	1.00		
Calibration uncertainty	pa	14.36	<1% of Value or 20 Pa whichever is greater	Yes
Drift	% range	0.10		
Linearity	% range	0.06	<2% of value	Yes
Uncertainty of gas density determination				
Uncertainty of molar mass determination	kg/mol	0.00003		
Uncertainty of temperature measurement	K	1.61	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	507		
Uncertainty associated with the estimate of density	-	0.007		
Uncertainty associated with the measurement of local velocity	-	0.0001		
Uncertainty associated with the measurement of mean velocity	-	0.0001		

Measurement Uncertainty - Velocity	m/s
Combined uncertainty	0.13
Expanded uncertainty at a 95% Confidence Interval	0.26

Note - The expanded uncertainty uses a coverage factor of k = 2.

Expanded Measurement Uncertainty of Velocity at a 95% Confidence Interval	%
Expressed as a % of the Measured Velocity	1.2
Expanded uncertainty at a 95% Confidence Interval	2.4

Measurement Uncertainty Volumetric Flow Rate	m³/hr
Combined uncertainty	650
Expanded uncertainty at a 95% Confidence Interval	1275

Note - The expanded uncertainty uses a coverage factor of k = 2.

Expanded Measurement Uncertainty of Volumetric Flow Rate at a 95% Confidence Interval	%
Expressed as a % of the Measured Volumetric Flow Rate	2.6
Expanded uncertainty at a 95% Confidence Interval	5.1

Reference – SOCOTEC Technical Procedure AE150 Estimation of Uncertainty of Measurement

END OF REPORT

Thank you for choosing SOCOTEC for your environmental monitoring needs. We hope our services have met your requirements and that you are fully satisfied with your experience of working with us, we really do value your custom and would welcome your feedback. We would appreciate it if you could take a moment to complete a short online questionnaire so that we can improve our operations and address any areas that have not met with your expectations, by clicking on the following

https://www.surveymonkey.co.uk/r/CAE_customer_feedback_weblink