

STACK EMISSIONS MONITORING REPORT



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Celtic Recycling
29-31 Clearwater Road
Queensway Meadows
Newport
NP19 4ST

Permit Reference:

EPR Permit: EPR/YP3135TE

Release Point:

A1 Shredder

Sampling Date(s):

12th November 2021

SOCOTEC Job Number:	LSO 211129
Report Date:	17th December 2021
Version:	1
Report By:	Catherine Elsey
MCERTS Number:	MM 08 996
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
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Technical Endorsements:	1, 2, 3 & 4
Signature:	



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EXECUTIVE SUMMARY

MONITORING OBJECTIVES

Celtic Recycling operates a shredding papered covered copper process at Newport which is subject to EPR Permit EPR/YP3135TE, under the Environmental Permitting Regulations 2010.

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

The results of these tests shall be used to demonstrate compliance with a set of emission limit values for prescribed pollutants as specified in the Plant's EPR Permit, EPR/YP3135TE.

Plant

A1 Shredder

Operator

Celtic Recycling
29-31 Clearwater Road
Queensway Meadows
Newport
NP19 4ST

EPR Permit: EPR/YP3135TE

Stack Emissions Monitoring Test House

SOCOTEC - Cirencester Laboratory
Units C & D
Bankside Trade Park
Cirencester
GL7 1YT
UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.
MCERTS accredited results will only be claimed where both the sampling and analytical stages are UKAS accredited.
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EXECUTIVE SUMMARY

EMISSIONS SUMMARY					
Parameter	Units	Result	Calculated Uncertainty +/-	Emission Limit Value (ELV)	MCERTS accredited result
Total Particulate Matter	mg/m ³	1.16	0.64	10	✓
Particulate Emission Rate	g/hr	9.89	5.50	-	
Tar Mist	mg/m ³	0.13	0.27	-	✗
Tar Mist Emission Rate	g/hr	1.66	3.3	-	
Moisture	%	0.98	0.03	-	✓
Stack Gas Temperature	°C	25	-	-	✓
Stack Gas Velocity	m/s	16.7	0.41	-	
Gas Volumetric Flow Rate (Actual)	m ³ /hr	9586	493	-	
Gas Volumetric Flow Rate (STP, Wet)	m ³ /hr	8773	451	-	
Gas Volumetric Flow Rate (STP, Dry)	m ³ /hr	8688	447	-	
Gas Volumetric Flow Rate at Reference Conditions	m ³ /hr	8773	451	-	

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	12 November 2021	09:18 - 10:18	60 minutes
Tar Mist Run 1	12 November 2021	10:28 - 11:28	60 minutes
Preliminary Stack Traverse	12 November 2021	09:05	-

EXECUTIVE SUMMARY

PROCESS DETAILS

Parameter	Process Details
Description of process	Shredding papered covered copper
Continuous or batch	Batch
Product Details	Shredded Copper
Part of batch to be monitored (if applicable)	60 Minute period
Normal load, throughput or continuous rating	Normal
Fuel used during monitoring	None
Abatement	Bag Filter
Plume Appearance	None

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	0.32 mg/m ³	55.6%	6.4%
Moisture	SRM - BS EN 14790	AE 105	1015	Yes	0.01%	3.34%	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 preferred 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 - (Cirencester)	N/A	8 Weeks

ON-SITE TESTING							
Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	MCERTS Accredited Analysis	Laboratory	Data Archive Location	Archive Period
Moisture	Gravimetric	AE 105	1015	Yes	SOCOTEC - (Cirencester)	-	-

EXECUTIVE SUMMARY

SAMPLING LOCATION					
Sampling Plane Validation Criteria	Value	Units	Requirement	Compliant	Method
Lowest Differential Pressure	216	Pa	≥ 5 Pa	Yes	BS EN 15259
Lowest Gas Velocity	16.2	m/s	-	-	-
Highest Gas Velocity	17.0	m/s	-	-	-
Ratio of Gas Velocities	1.1	: 1	$< 3 : 1$	Yes	BS EN 15259
Mean Velocity	16.7	m/s	-	-	-
Maximum angle of flow with regard to duct axis	< 15	$^{\circ}$	$< 15^{\circ}$	Yes	BS EN 15259
No local negative flow	Yes	-	-	Yes	BS EN 15259

DUCT CHARACTERISTICS		
	Value	Units
Shape	Circular	-
Depth	0.45	m
Width	-	m
Area	0.16	m ²
Port Depth	90	mm

SAMPLING LINES & POINTS		
	Isokinetic	Non-Iso & Gases
Sample port size	3 inch flange	-
Number of lines used	1	-
Number of points / line	1	-
Duct orientation	Vertical	-
Filtration for TPM	Quartz	-

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

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	Yes
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 Line

Due to the fact there is only one sampling port - sampling was only conducted along the one sampling line. However, the number of sampling points along the one available line were doubled.

APPENDICES

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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

APPENDIX 3 - Measurement Uncertainty Budget Calculations

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	2
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	P1757	Horiba PG-250 Analyser	-	Laboratory Balance	P3225
Box Thermocouples	P1757	FT-IR Gasmet	-	Tape Measure	P2044
Meter In Thermocouple	P1757	FT-IR Oven Box	-	Stopwatch	P2240
Meter Out Thermocouple	P1757	Bernath 3006 FID	-	Protractor	-
Control Box Timer	-	Signal 3030 FID	-	Barometer	P1408
Oven Box	-	Servomex	-	Digital Micromanometer	P2053
Probe	-	JCT Heated Head Filter	-	Digital Temperature Meter	P1310
Probe Thermocouple	-	Thermo FID	-	Stack Thermocouple	P1800
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	-	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	P2768	Chiller (JCT/MAK 10)	-	1m Heated Line (3)	-
Last Impinger Arm	-	Heated Line Controller (1)	-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-	Heated Line Controller (2)	-	10m Heated Line (1)	-
Callipers	-	Site temperature Logger	-	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	-		-	20m Heated Line (1)	-
Inclinometer (Swirl Device)	P2594		-	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 +/- %
-	-	-	-	-	-

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
Catherine Elsey	MM 08 996	MCERTS Level 2	Nov-23	Dec-25	Dec-25	Feb-24	Mar-27	Nov-23
Amy Tanner	MM 21 1644	MCERTS Trainee	Sep-26	-	-	-	-	Sep-26

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER SUMMARY					
Parameter	Sampling Times	Concentration mg/m ³	Uncertainty mg/m ³	ELV mg/m ³	Emission Rate g/hr
Run 1	09:18 - 10:18 12 November 2021	1.2	0.64	10	10
Blank	-	0.52	-	-	-

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

Acetone Blank Value mg/l	Acceptable Value mg/l
0.3	10

FILTER INFORMATION

SAMPLES								
Test	Filter & Probe Rinse Number	Filter Start Weight	Filter End Weight	Mass Gained on Filter	Probe Rinse Start Weight	Probe Rinse End Weight	Mass Gained on Probe	Combined Total Mass Gained
		g	g	g	g	g	g	g
Run 1	316220	0.14490	0.14490	0.00000	73.66530	73.66710	0.00180	0.00180

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

BLANKS								
Test	Filter & Probe Number	Filter Start Weight	Filter End Weight	Mass Gained Filter	Probe Start Weight	Probe End Weight	Mass Gained Probe	Combined Total Mass Gained
		g	g	g	g	g	g	g
Run 1	316219	0.14120	0.14130	0.00010	66.67790	66.67860	0.00070	0.00080

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			Molecular weight of dry gas, M_d	
Barometric pressure, P _b	Kpa	100.9	CO ₂	% 0.01
Stack static pressure, P _{static}	pa	115	O ₂	% 20.95
P _s = P _b + P _{static}	Kpa	101.0	Total	% 20.96
			N ₂ (100 -Total)	% 79.04
			M _d = 0.44(%CO ₂)+0.32(%O ₂)+0.28(%N ₂)	28.84
Vol. of water vapour collected, V_{wstd}			Molecular weight of wet gas, M_s	
Moisture trap weight increase, V _{lc}	g	12.2	M _s = M _d (1 - B _{wo}) + 18(B _{wo})	g/gmol 28.73
V _{wstd} = (0.001246)(V _{lc})	m ³	0.0152012		
Volume of gas metered dry, V_{mstd}			Actual flow of stack gas, Q_a	
Volume of gas sample through gas meter, V _m		1.761	Area of stack, A _s	m ² 0.16
Gas meter correction factor, Y _d		0.926	Q _a = (60)(A _s)(V _s)	m ³ /min 155.0
Mean dry gas meter temperature, T _m		290		
Mean pressure drop across orifice, DH	mmH ₂ O	65.104	Total flow of stack gas, Q	
V _{mstd} = $\frac{(0.3592)(V_m)(P_b + (DH/13.6))(Y_d)}{T_m}$	m ³	1.541	Conversion factor (K/mm.Hg)	0.3592
			Q _{std} = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	Dry 141.1
Volume of gas metered wet, V_{mstw}			Q _{stdO2} = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	@O ₂ ref No O2 Ref
V _{mstw} = V _{mstd} + V _{wstd}	m ³	1.5562	Q _{stw} = $\frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet 142.45
Vol. of gas metered at O₂ Ref. Cond., V_{mstd@X%O2}			Percent isokinetic, %I	
Is the process burning hazardous waste? (If yes, no favourable oxygen correction)	No		Nozzle diameter, D _n	mm 6.07
% oxygen measured in gas stream, act%O ₂	21.0		Nozzle area, A _n	mm ² 28.94
% oxygen reference condition	21		Total sampling time, q	min 60
O ₂ Reference O ₂ Ref = 21.0 - act%O ₂	No O2 Ref		%I = $\frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	% 100.1
Factor 21.0 - ref%O ₂	No O2 Ref		Acceptable isokinetic range 95% to 115%	Yes
V _{mstd@X%oxygen} = (V _{mstd}) (O ₂ Ref)	m ³	No O2 Ref	Particulate Concentration, C	
Moisture content, B_{wo}			Mass collected on filter, M _f	g 0.00000
B _{wo} = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0098	Mass collected in probe, M _p	g 0.00180
		0.98	Total mass collected, M _n	g 0.00180
Moisture by FTIR		-	C _{wet} = $\frac{M_n}{V_{mstw}}$	mg/m ³ 1.157
Velocity of stack gas, V_s			C _{dry} = $\frac{M_n}{V_{mstd}}$	mg/m ³ 1.168
Velocity pressure coefficient, C _p		0.84	C _{dry@X%O2} = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³ No O2 Ref
Mean of velocity heads, DP _{avg}	Pa	220.42		
Mean stack gas temperature, T _s	K	296	Particulate Emission Rates, E	
Gas density (wet, ambient), p			E = [(C _{wet})(Q _{stw})(60)] / 1000	9.89
p=(M _s *P _s)/(8.314*T _s)	kg/m ³	1.179		
Stack Velocity, V _s $V_s = C_p \sqrt{\frac{\Delta DP_{avg}}{p}}$	m/s	16.24		

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 2				TAR MIST	
Absolute pressure of stack gas, P_s				Molecular weight of dry gas, M_d	
Barometric pressure, P _b	Kpa	100.9		CO ₂	% 0.01
Stack static pressure, P _{static}	pa	115		O ₂	% 20.95
P _s = P _b + P _{static}	Kpa	101.0		Total	% 20.96
				N ₂ (100 -Total)	% 79.04
Vol. of water vapour collected, V_{wstd}				M _d = 0.44(%CO ₂)+0.32(%O ₂)+0.28(%N ₂)	28.84
Moisture trap weight increase, V _{lc}	g	-		Molecular weight of wet gas, M_s	
V _{wstd} = (0.001246)(V _{lc})	m ³	-		M _s = M _d (1 - B _{wo}) + 18(B _{wo})	g/gmol 28.73
Volume of gas metered dry, V_{mstd}				Actual flow of stack gas, Q_a	
Volume of gas sample through gas meter, V _m		1.694		Area of stack, A _s	m ² 0.16
Gas meter correction factor, Y _d		0.926		Q _a = (60)(A _s)(V _s)	m ³ /min 150.7
Mean dry gas meter temperature, T _m		292		Total flow of stack gas, Q	
Mean pressure drop across orifice, DH	mmH ₂ O	62.111		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	1.472		Q _{std} = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s)}$	Dry 137.3
Volume of gas metered wet, V_{mstw}				Q _{stdO2} = $\frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s)}$	@O ₂ ref No O2 Ref
V _{mstw} = V _{mstd} + V _{wstd}	m ³	1.4868		Q _{stw} = $\frac{(Q_a)P_s(0.3592)}{(T_s)}$	Wet 138.66
Vol. of gas metered at O₂ Ref. Cond., V_{mstd@X%O2}				Percent isokinetic, %I	
Is the process burning hazardous waste? (If yes, no favourable oxygen correction)		No		Nozzle diameter, D _n	mm 6.07
% oxygen measured in gas stream, act%O ₂		21.0		Nozzle area, A _n	mm ² 28.94
% oxygen reference condition		21		Total sampling time, q	min 60
O ₂ Reference O ₂ Ref = 21.0 - act%O ₂		No O2 Ref		%I = $\frac{(4.6398E6)(T_s)(V_{mstd})}{(P_s)(V_s)(A_n)(q)(1-B_{wo})}$	% 98.2
Factor $\frac{21.0 - ref\%O_2}{21.0 - act\%O_2}$		No O2 Ref		Acceptable isokinetic range 95% to 115%	Yes
V _{mstd@X%oxygen} = (V _{mstd}) (O ₂ Ref)	m ³	No O2 Ref		Particulate Concentration, C	
Moisture content, B_{wo}				Mass collected on filter, M _f	g N/A
B _{wo} = $\frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0098		Mass collected in probe, M _p	g N/A
		0.98		Total mass collected, M _n	g N/A
Moisture by FTIR				C _{wet} = $\frac{M_n}{V_{mstw}}$	mg/m ³ N/A
Velocity of stack gas, V_s				C _{dry} = $\frac{M_n}{V_{mstd}}$	mg/m ³ N/A
Velocity pressure coefficient, C _p		0.84		C _{dry@X%O2} = $\frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m ³ No O2 Ref
Mean of velocity heads, DP _{avg}	Pa	208.50		Particulate Emission Rates, E	
Mean stack gas temperature, T _s	K	296		E = $\frac{[(C_{wet})(Q_{stw})(60)]}{1000}$	N/A
Gas density (wet, ambient), ρ					
ρ = (M _s *P _s)/(8.314*T _s)	kg/m ³	1.181			
Stack Velocity, V _s	$V_s = C_p \sqrt{\frac{\Delta DP_{avg}}{\rho}}$	m/s	15.79		

TAR FUME DATA - RUN 1		
Parameters	Units	Results
Mass Collected	mg	0.200
Concentration wet	mg/m ³	0.135
Concentration Dry	mg/m ³	0.136
Mass Emission	g/hr	1.664

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	27.19	0.20	-	-381	0.54	Yes
Run 2	26.16	0.23	-	-381	0.52	Yes

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

ISOKINETICITY		
Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	100.07	Yes
Run 2	98.21	Yes

Acceptable isokinetic range 95% to 115%

WEIGHING BALANCE UNCERTAINTY			
Run	Result mg/m ³	5% ELV mg/m ³	LOD < 5% ELV
Run 1	0.32	0.5	Yes
Run 2	0.34	0.5	Yes

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	0.52	10	1.0	Yes

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	25	180	160
Run 2	Quartz Fibre	47	23	180	160

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MOISTURE CALCULATIONS

Moisture Determination - Isokinetic							
Test Number	Sampling Time and Date	Start Weight	End Weight	Total gain	Concentration	LOD	Uncertainty
		kg	kg	kg	%	%	%
Run 1	09:18 - 10:18 12 November 2021	3.0089	3.0211	0.0122	1.0	0.01	3.3

Moisture Quality Assurance							
Test Number	Sampling Duration	Total Volume Sampled	Sampling Rate	Start Leak Rate	End Leak Rate	Acceptable Leak Rate	Leak Tests Acceptable?
	mins	l	l/min	l/min	l/min	l/min	
Run 1	60	1556	27.2	0.20	-	0.54	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics		
Stack Diameter / Depth, D	0.45	m
Stack Width, W	-	m
Stack Area, A	0.16	m ²
Average stack gas temperature	25	°C
Stack static pressure	0.218	kPa
Barometric Pressure	100.9	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	0.014286	0.000143	0.000280	0.014146	0.000141	0.000278
O ₂	32	1.427679	20.950000	0.209500	0.299099	20.745364	0.207454	0.296177
N ₂	28	1.249219	79.035714	0.790357	0.987329	78.263705	0.782637	0.977685
H ₂ O	18	0.803070	-	-	-	0.976785	0.009768	0.007844

Where: $p = M / 22.41$ $pi = r \times p$

Calculation of Stack Gas Densities		
Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2867	kg/m ³
Wet Density (STP), P_{STW}	1.2820	kg/m ³
Dry Density (Actual), P_{Actual}	1.1776	kg/m ³
Average Wet Density (Actual), $P_{ActualW}$	1.173	kg/m ³

Where:

P_{STD} = sum of component concentrations, kg/m³ (not including water vapour)

$P_{STW} = (P_{STD} + pi \text{ of H}_2\text{O}) / (1 + (pi \text{ of H}_2\text{O} / 0.8036))$

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

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

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	12 November 2021
Time of Survey	09:05
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 ₂ O (average of 3 readings)	Temp °C	Velocity m/s	Volumetric Flow Rate (actual) m ³ /s	O ₂ % Vol	Angle of Swirl °
1	0.05	218.9	22.3	24	16.2	2.6	-	<15
2	0.11	233.6	23.8	25	16.8	2.7	-	<15
3	0.34	241.7	24.7	25	17.0	2.7	-	<15
4	0.40	238.5	24.3	25	16.9	2.7	-	<15
Mean	-	233.2	23.8	25	16.7	2.7	-	-

PRELIMINARY STACK SURVEY QUALITY ASSURANCE CHECKLIST

PITOT LEAK CHECK								
Run	Pre Traverse Leak Rate				Post Traverse Leak Rate			
	Start Value mmH ₂ O	End Value mmH ₂ O	Difference %	Outcome	Start Value mmH ₂ O	End Value mmH ₂ O	Difference %	Outcome
Run 1	112	111	0.9	Pass	114	112	1.8	Pass

To complete a compliant pitot leak check a pressure of over 80 mmH₂O (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	112	111.5	0.5	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	219	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	16.2	m/s	-	-
Highest Gas Velocity	17.0	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, $V = K_{pt} \times (1-e) \times \sqrt{2 \times DP_{pt} / P_{ActualW}}$		
Where: K_{pt} = Pitot tube calibration coefficient (1-e) = Compressibility correction factor, assumed at a constant 0.998		
Average Stack Gas Velocity, V_a	16.7	m/s

Calculation of Stack Gas Volumetric Flowrate, Q			
Duct gas flow conditions	Actual	Reference	Units
Temperature	25	0	°C
Total Pressure	101.118	101.3	kPa
Oxygen	21.0	21	%
Moisture	0.98	0.98	%
Pitot tube calibration coefficient, K_{pt}	0.84		

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (V_a)	16.74	m/s
Stack Area (A)	0.16	m ²
Gas Volumetric Flowrate (Actual), Q_{Actual}	9586	m ³ /hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	8773	m ³ /hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	8688	m ³ /hr
Gas Volumetric Flowrate (REF), Q_{Ref}	8773	m ³ /hr

Where:

$$Q_{Actual} = V_a \times A \times 3600$$

$$Q_{STP} = Q_{Actual} \times (T_s / T_a) \times (P_a / P_s) \times 3600$$

$$Q_{STP,Dry} = Q_{STP} / (100 - (100 / Ma)) \times 3600$$

$$Q_{Ref} = Q_{STP} \times ((100 - Ma) / (100 - Ms)) \times ((21 - O_{2a}) / (21 - O_{2s}))$$

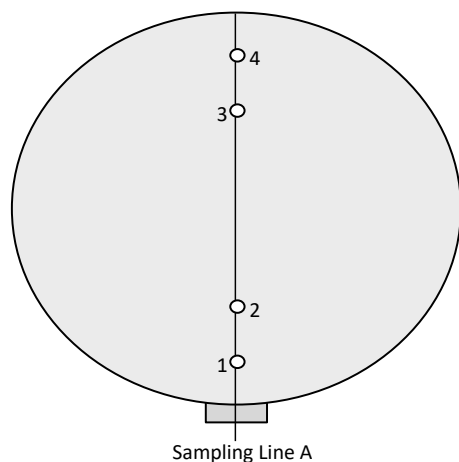
Nomenclature:

T_s = Absolute Temperature, Standard Conditions, 273 K
 P_s = Absolute Pressure, Standard Conditions, 101.3 kPa
 T_a = Absolute Temperature, Actual Conditions, K
 P_a = 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	0.45	m
Stack Width	-	m
Area	0.16	m ²



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

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

Isokinetic Sampling			
Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	11.1	0.05	< 15
2	25.0	0.11	< 15
3	75.0	0.34	< 15
4	88.9	0.40	< 15
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

SAMPLING LOCATION



APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume m ³	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	0.001	2.0	0.50	1.0	N/A	0.5000	-	-
as a %	0.06	0.68	0.50	1.0	N/A	3.21285	0.74	0.008
compliant?	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Run 2	0.002973531	2.0	0.50	1.0	N/A	0.500	-	-
as a %	0.20	0.69	0.50	1.0	N/A	3.213	0.88	0.008
compliant?	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes

Run	Volume (STP) m ³	Mass of particulate mg	O ₂ Correction -	Leak mg/m ³	Uncollected Mass mg	Combined uncertainty
Run 1	1.41	1.8000	1.0	0.005	0.0005	-
MU as mg/m ³	0.02	0.3213	-	0.005	0.0003	0.32
MU as %	1.31	27.7778	-	0.425	0.0257	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.64	mg/m³	55.62	% Result	6.43	% ELV
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(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 - MOISTURE

Run	Sampled Volume m ³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Leak %
MU required	≤ 2%	≤ 2%	≤ 1%	≤ 1%	≤ 10%	≤ 2%
Run 1	0.001	2.0	0.50	1.0	N/A	-
as a %	0.06	0.68	0.50	1.0	N/A	0.74
compliant?	Yes	Yes	Yes	Yes	N/A	Yes

Run	Volume (STP) m ³	Mass Gained mg	O ₂ Correction -	Leak mg/m ³	Uncollected Mass mg	Combined uncertainty
Run 1	1.41	12200	1.0	33.62	58	-
MU as % v/v	0.01	0.01	-	0.00	0.005	0.02
MU as %	1.31	0.82	-	0.42	0.47	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	0.03	% v/v	3.34	%
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APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE

Measured Velocity at Actual Conditions	16.7	m/s
Measured Volumetric Flow rate at Actual Conditions	9586	m ³ /hr

Performance Characteristics & Source of Value	Units	Values	Requirement	Compliant
Uncertainty of Local Gas Velocity Determination	-	0.010		
Uncertainty of pitot tube coefficient	-	1.84		
Uncertainty of mean local dynamic pressures	-	1.84		
Factor loading, function of the number of measurements.	3 readings	0.591	minimum 3	Yes
Range of measurement device	pa	1000		
Resolution	pa	1.00		
Calibration uncertainty	pa	35.55	<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	1.52	<1% of value	Yes
Uncertainty of absolute pressure in the duct	pa	516		
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	-	0.0002		

Measurement Uncertainty - Velocity	m/s
Combined uncertainty	0.21
Expanded uncertainty at a 95% Confidence Interval	0.41

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	m ³ /hr
Combined uncertainty	251
Expanded uncertainty at a 95% Confidence Interval	493

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